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Price - ₹ 250.00
ISBN: 978-81-957954-2-0
9 788195 795420
IAPH

VOL 1

Editor: Dr. Nithar Ranjan Madhu & Dr. Biplab Kumar Behera

A Basic Overview of Environment and Sustainable Development

IAPH

A Basic Overview of
ENVIRONMENT & SUSTAINABLE DEVELOPMENT
VOL. 1

Edited by
Dr. Nithar Ranjan Madhu
Dr. Biplab Kumar Behera

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International Academic Publishing House (IAPH)

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Published by:
International Academic Publishing House (IAPH)
Kolkata, India

A Basic Overview of Environment and Sustainable Development Vol. 1
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First published: 22nd August, 2022

PUBLISHER
International Academic Publishing House (IAPH)

ADDRESS

Head Office:
Village & Post. Thakurnagar,
P.S. Gaighata
Dist. North 24 Parganas
West Bengal 743287
India
E-mail: iaphjournal@gmail.com

National Branch Office:
Sri Manoranjan Madhu
Sarada Sarani, Nibedita Park,
Post Office: Hridaypur,
Dist- North 24 Parganas,
Kolkata, Pin – 700127,
West Bengal, India
E-mail: iaphjournal@gmail.com

International Branch Office:
91 Victoria Road, Swindon
SN13BD, ENGLAND
E-mail: publisher@iaph.co.in

Type setting and Printed by:
International academic Publishing House (IAPH), Kolkata, India

ISBN: 978-81-957954-2-0

Price - ₹250.00 (Two hundred fifty only)

Preface

Students at the undergraduate & postgraduate levels and Research Scholars will be given this edited book with the expectation that it will supply them with a correct and easy grasp of the fundamental overview of the environment and sustainable development.

Our understanding of the environment and sustainable development has significantly advanced as a result of the vast amount of work that scientists in these domains have done. This book aims to introduce new boundaries in terms of a fundamental overview of the environment and sustainable development as practical approaches for addressing environmental issues.

The process of attaining human development goals while maintaining the capacity of natural systems to continue providing the natural resources and ecosystem services upon which the economy and society depend is referred to as sustainable development. The idea of 'needs,' in particular, the essential needs of the world's poor, to which overriding priority should be given, and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs are both contained within it. It is important to note that the concept of 'needs,' in particular, the essential needs of the world's poor, to which overriding priority should be given.

The chapters cover various topics relating to sustainable development and human interaction with the natural environment. In light of recent work and the most recent information that is obtainable from various sources, a concise and exhaustive synopsis has been developed as a result.

The authors would like to take this opportunity to extend their gratitude to their coworkers at various institutions and universities located all over the country. These individuals have greatly assisted them by providing them with priceless advice while they were putting together this Endeavor. Finally, my deepest gratitude goes out to each of the contributors to this book; without their assistance, the publication of this volume would not be possible.

It would be very appreciated if you could offer some suggestions to improve the book.

Dr. Nithar Ranjan Madhu
&
Dr. Biplab Kumar Behera

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OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.001

Chapter- 1

Application of biofertilizers in polyculture: a way towards sustainability

Biplab Bhowmik*, Bipasa Dey and Riya Mondal

Keywords: Biofertilizers, Polyculture, Sustainable Agriculture.

Abstract:

The rate of population growth in the world is worrying. This sharp rise has led to increased demand for food resources, creating immense pressure in the agricultural sector. In order to increase crop yields, farmers rely on using fertilizers. Chemical based fertilizers, which are mostly utilize, negatively impact the environment. The production of crops using those chemical fertilizers are generally not fit for human consumption. Moreover, they cause harmful effects to other living beings. To reduce the harmful effects caused by chemical fertilizers, several alternatives are being preferred. Biofertilizers may prove to be decent alternative for the chemical based fertilizers since they promote growth of the plant without causing any environmental issues. Biofertilizer is an organic substance, containing beneficial microorganisms that enhance the growth and yield of the plant by producing various growth stimulants and hormones without causing any potential damage to the environment. The main components of biofertilizers include *Azospirillum*, *Rhizobium*, *Azolla*, blue-green algae and *Azotobacter*, which promote plants' growth by various mechanisms like nitrogen fixation, iron sequestration and phosphorus solubilization. Therefore, biofertilizers are rapidly gaining importance in the agricultural sector. Along with monoculture; polyculture is also becoming popular nowadays. This technique involves the culture of different species in a single environment simultaneously. Crop-based polyculture is a common practice in recent days. Polyculture in the aquatic sector is gaining rapid importance since it enhances productivity of the pond and increases the biomass of the fish. Scientifically using biofertilizers in polyculture may improve manifold production and promote sustainable agricultural practices.

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

Introduction:

"A biofertilizer is a substance which contains living microorganisms which when applied to seeds, plants, or soil, colonises the rhizosphere or the interior of the plants and promotes plant growth by increasing the supply of nutrients to the host plant"(Malusa and Vassilev, 2014; Bardi and Malusà, 2012; Vessey, 2003; Kar et al., 2022). Biofertilizers are able to solubilize insoluble phosphates, fix nitrogen present in the atmosphere. They produce such chemicals which can encourage the rapid growth and development of the plant. Thus, they improve soil fertility and have the extensive potential for enhancing crop production. Biofertilizers also supply sufficient amounts of nutrients to the crops (Mazid and Khan, 2015; Kundu, 2022). By boosting the protein, vitamins, nitrogen and vital amino acids, biofertilizers can increase crop output by roughly 10% to 40% (Bharadwaj et al., 2014). Through the process of nitrogen fixation, mobilisation of fixed micronutrients and macronutrients and the transformation of insoluble form of phosphorus present in the soil into soluble form, biofertilizers can ensure soil sustainability and fertility in long terms. Additionally, it is also claimed that biofertilizers exhibit characteristics that promote proper growth of the plant and also increases its yield by the mechanisms that involve nitrogen fixation, phosphorus solubilization, phosphorus mobilisation, potassium solubilization, micronutrient solubilization, plant growth promotion, and preventing the loss of organic matter present in the soil (Jeyabal and Kuppuswamy, 2001; De and Dey, 2021). Phosphorus is solubilized and fixed by phosphorus-solubilizing bacteria (PSB) which are present in the soil, including *Bacillus megaterium*, fungi, Pseudomonas putida, and including *Penicillium* species and *Aspergillus* species (Bagchi, 2021, 2020).

Therefore, its use in agricultural purposes, declines the cost of manufacturing of phosphate-based fertilisers and promotes mobilisation of the insoluble fertilizer present in the soil (Chang and Yang, 2009). Under microaerobic conditions, the *Azospirillum* sp. present in the biofertilizer can aid in the fixation of 20–40 kilos of nitrogen. *Azospirillum amazonense*, *A. brasilense*, *A.lipoferum* and *A. trikense* are significant species (Steenhoudt and Vanderleyden, 2000). The use of *Azolla* sp. significantly increased rice output by 0.5 to 2000/hectare (Gupta, 2004). For fixing the proper amount of N2, *Rhizobium* is considered most effective; especially if this fixation is in the leguminous plants (Jehangir et al., 2017; Banerjee et al., 2021). As biofertilizers may be added to the soil manually, it can assist in increasing the yield of the crop. Certain agricultural practices, such as mono-cropping and a few nature based process can result in the decreased load of microbes in the crops' root zone (Itelima et al., 2018). To reduce the excess use of chemical fertilizers and their cost of production, strains of *Azotobacter chroococcum* were used in the fish ponds with less organic wastes and organic fertilizers. Two strains of Azotobacter (Mac-27, and PS-21) were inoculated, and the effects on pond water physicochemical properties, nutrient status, plankton productivity, and fish biomass were assessed. It was observed that these Azotobacter strains increased fish productivity in still-water ponds (Gordon and Jacobson, 1983; Gaind and Gaur, 1991).

A more sophisticated type of agriculture, polyculture, involves simultaneously cultivating multiple species. It is also known as integrated agriculture or multitrophic aquaculture (Bunting 2008). Aquatic polyculture alters productivity, decomposition, and nutrient cycling, which increases yield and thereby improves the pond environment. As a result, it is consistent with sustainable cultural approaches. In South East Asian nations like Thailand, Indonesia, Cambodia, Myanmar, and Vietnam, IAA farming practices for tilapia are heavily integrated with agriculture (Dey et al., 2001).

IAA, on a modest scale in Africa, Polyculture outperformed traditional cultural norms in terms of the economic appeal (Jamu, 2001). Polyculture using African catfish (*Clarias gariepinus*), Nile Tilapia (*Oreochromis niloticus*) and Chinese cabbage (*Brassica rapa*) showed greater yield (Wang and Lu, 2015). Vegetables and integrated aquaculture of *C. gariepinus* and *Oreochromis niloticus* increased productivity, income, yield, production of food and nutrients for the farmers working on small-scale (Pant et al., 2004). With biofertilizers, polyculture will enable the production of numerous food species in a small amount of land, enhancing food security (Adnan et al., 2018).

So, the sustainable method of agriculture could be attained by the right use of biofertilizers in polyculture practices. Higher income and employment prospects may result from it. Everyone from small-scale farmers to large-scale agricultural companies can use these scientific culture techniques to fulfil the increased requirement of vegetables, fish and other crops. If those ideas are applied on a broad scale with ideal conditions & suitable managerial abilities, large nations like India and others may benefit.

Components of Biofertilizers:

Biofertilizers include PGPR, *Azospirillum, Azotobacter*, N2 fixing bacteria, blue green algae and also endophytes, *Azolla* and mycorrhizae.

Endophytes:

Fungi and bacteria called endophytes thrive without hurting the plant tissue. Bacterial endophytes and fungal endophytes are the two types of endophytes (Ganley et al 2004). There have been reports of the bacteria *Azoarcus, Azospirillum, Pseudomonas, Gluconacetobacter, Achromobacter, Harpophora, Rhizoctonia/ Ceratobasidium* complex, *Periconia macrospora*, etc (Jumpponen, 2001). Endophytes can contribute to increase the plant growth and output. Their use promotes healthy nutrient cycling and can potentially reduce pathogen impacts.

Plant growth promoting *Rhizobacterium* (PGPR):

It is a bacterial group which is present in the rhizosphere. A narrow, enclosed area which surrounds the root of the plant and functions as home to a variety of microbes. (Ahemad and Khan, 2012). Plant root nodules contain internal PGPR, PGPR existing in the extracellular portion. PGPR is non-symbiotic bacterial species (Martinez-Viveros et al 2010). PGPR can boost the release of chemicals like ethylene, auxin, cytokinin and giberellin, and also function

in the up taking of micronutrients, potassium solubilization, and phosphorus solubization by plants (Klopper et al., 1992). Adding to this, plant development under stress may be enhanced by PGPR (Egamberdieva and Kucharova, 2004).

Mycorrhizae:

Plants and mycorrhizal fungi coexist in a symbiotic relationship. To take up nutrients, the fungi enter the plant roots. For minerals, primarily phosphorus, mycorrhizal fungi provide around 90% of terrestrial plants (Bhatt et al., 2019, Sharma and Bhatt, 2016). Mycelia networks connect different trees in lowland forests. These networks are used by the seedlings of the tree and the tree themselves, for the communication of various chemical messages. (Bhatt et al. 2019d; Sharma et al. 2016; Gangola et al., 2018a). Endomycorrhiza and ectomycorrhizal are two forms of mycorrhizae that have been identified. While endomycorrhizal is primarily found on crops, ectomycorrhiza is found in trees (Bhandari and Bhatt, 2020; Bhatt et al., 2020).

N_2 fixing bacteria

Because the nitrogen present in the atmosphere is unsuitable for plants, it must be transformed into ammonia. The nitrogenase enzyme, produced by microorganisms, is used in the BNF process to convert a significant amount of atmospheric nitrogen into ammonia. These microbes make up a large portion of the biofertilizer. The nitrogenase enzymes can transmit nitrogen into ammonia and then protein. Nitrogen or dinitrogen fixation is the name of this process. Among the nitrogen-fixing microbes found in biofertilizers are:

Azotobacter:

A. chroococcum, *A. nigricans*, *A. beijerinckii*, *A. paspali*, *A. vinelandii*, and *A. amerniacus*, all belong to the genus *Azotobacter*. A rhizospheric bacteria causes it. When chemicals are applied, the cysts of these bacteria do not burst or become dessicated. In general, non-leguminous plants employ azotobacter. Cereals benefit specifically from *A. Chroococcum.*

Rhizobium:

Leguminous plants and rhizobium bacteria work together symbiotically to fix nitrogen. *Rhizobium, Mesorhizobium, Sinorhizobium, Azorhizobiu*m, and *Bradyrhizobium* are some of the genera of rhizobia (Mutch and Young, 2004; Keet et al., 2017).

Blue- Green algae:

BGA are non-symbiotic, single-celled species that fix nitrogen of the paddy fields and can consist of branched or unbranched filaments.

Azospirillum:

Azospirillum belong to the family of gram-negative, motile, vibrioid bacteria which can grow in anaerobic, aerobic, and microaerophilic environments. It includes polyhydroxy butyrate granules and has peritrichous flagella. A wide range of plants can have Azospirillum

colonising both their roots and their uppermost parts, creating a symbiotic association (Cassan and Diaz–Zorita, 2016). *Azospirillum is used* in sorghum, wheat, pearl millet, barley corn and finger millet, (Verse Oglou and Menexes, 2010).

Azolla:

Azolla is a nutrient-rich plant that fixes nitrogen. The fern gains a protective leaf cavity from *Azolla*, which also fixes nitrogen. Due to its ability to grow in still water, quick growth capacity, and high nitrogen content, *Azolla* is most often used as a rice fertiliser (Singh et al., 1984, Prasanna et al., 2008).

Mode of action of biofertilizers:

✔ **Direct mechanism**

- Fixation of atmospheric nitrogen
- Solubilization of phosphorus
- Seuestering Iron

✔ **Indirect mechanism**

- Role in photosynthesis
- Role in amino acid synthesis
- Effect on bioremediation of metals
- Role in remediation of pesticides
- Effect on plant parasitic nematodes

Direct Mechanism:

Fixation of atmospheric nitrogen :

Azospirillum, Rhizobium, and *Azotobacter* are a few of the significant bacteria that play an important role in the fixation of nitrogen. An intricate enzyme structure known as nitrogenase is responsible for fixing nitrogen. Iron (Fe) acts as an enzyme cofactor for dinitrogenase reductase, while iron (Fe) and molybdenum (Mo) are cofactors for the enzyme dinitrogenase. The NIF genes, which are found in nitrogen-fixing, free living and symbiotic bacteria are involved in N2 fixation (Black et al., 2012). Among this genus, *Azospirillum lipoferum* and *A. brasilense* are very beneficial to the plants. Several other species in this genus include *Azospirillum brasilense*, *Azospirillum amazonense* and *Azospirillum halopraeferens*(Mishra et al., 2013).

Solubilization of phosphorus:

Rhizobium, Bacillus, Achromobacter, Agrobacterium, Flavobacterium, Micrococcus, Burkholderia, Acetobacter, and *Erwinia* are some of the bacteria that are capable of dissolving phosphate.They include both anaerobic and aerobic strain, among which the aerobic strain is mostly harboured by the submerged soil. However, the rhizosphere typically has more phosphate-solubilizing bacteria (PSB) than the soil which lacks in the rhizosphere layer (Youssef and Eissa, 2014). In addition to supplying the plants with solubilized phosphorus, PSB promotes growth of the plant by increasing the effectiveness of biological nitrogen fixation (BNF), which is accomplished with the aid of microbes that fix the N2 (Mohammadi and Sohrabi, 2012).

Sequestering Iron:

Iron mostly resides as Fe^{3+}. It generally remains in an aerobic environment and produces large quantities of hydroxides and oxyhydroxides which are insoluble in nature.Due to this nature of iron , most of it cannot be accessed by the plants and their bacteria. (Rajkumar et al., 2010). However, the siderophores produced by bacteria have a strong attraction to complex iron. As a result, siderophores serve as solubilizers for iron in organic or mineral compounds. To be effective, they need iron-limiting environments, though.

Indirect Mechanism:

Role in photosynthesis:

*Bradyrhizobium sp. (*IRBG 271*), Rhizobium* sp. (IRBG 74), and *R. leguminosarum* were infected with biofertilizers. This boosted the plant's rate of photosynthesis done by a single leaf when compared to the control that was not inoculated. When both the experiments were compared, the bacteria that contained the IRBG strain demonstrated the greatest increase in photosynthetic activity (14%) in the plant (Peng et al., 2002).

Role in the synthesis of amino acid:

The amino acid type is determined by the plant and its related microbes. This also includes the composition of root exudates that the plant releases. (Kang et al., 2010; Bardgett and van der Putten, 2014).

Effect on metal bioremediation:

Numerous studies conducted on the role played by PGPR in the bioremediation of metal toxicity have revealed that a wide range of bacteria are essential for the remediation of the toxicity brought on by the accumulation of heavy metals. *A chroococcum*, *B. megaterium, Pseudomonas* sp., *Pseudomonas putida* play an important role in the bioremediation of heavy metals (Dixit et al., 2015).

It is well recognised that heavy metals release harmful chemicals that stress plants. As a result, the hormone ethylene is created, which, in large concentrations, can prevent plant growth. 1-aminocyclopropane-1-carboxylate (ACC) deaminase, which is produced by PGPR, lowers the level of ethylene build up. Therefore, the production of ACC deaminase by PGPR offers host plants an efficient defence against the stress response brought on by toxicity produced by the heavy metals. The generation of siderophores is another efficient method used by PGPR to minimise these toxicities (Singh et al., 2015; Radzki et al., 2013).

Effect on pesticide remediation:

Since pesticides can easily enter live things' tissues and cause disease, their excessive and prolonged usage cause environmental hazard and pose risk to both the plants and people (Aktar et al., 2009; Kumar and Puri, 2012). Research on bacteria strains that can degrade pesticides is now being seen as a possible way to counteract the harmful effects of pesticides. Numerous studies on PGPR have focused on its important function in horticulture, forestry, and

environmental protection. Microorganisms can decrease pesticide toxicity, including *Serratia, Gordonia, Paenibacillus, Enterobacter, Bacillus, Azotobacter, Azospirillum, Pseudomonas,* and *Klebsiella* among others.

Effect on plant parasitic nematode

Plants of tomato were infected by *M. incognita*, then some biofertilizers containing microbial organisms were applied, including the N2 fixer, Paenibacillus *polymyxa* (four strains), the phosphate solubilizing bacteria, B. *megaterium*, and three strains of *Bacillus circulans*. It was discovered that all the applied microbial biofertilizers showed significant decline in the growth of the nematode population (El-Haddad et al., 2011).

Polyculture over monoculture:

Polyculture is the practice of raising many species (such as plants, fish species, integrated aquatic animals and plants, or aquatic animals) in the same area simultaneously. Since polyculture produces superior yields and minimises fertiliser wastage, it is preferable than monoculture. Monoculture provides a constant supply of plant hosts, which causes repeated outbreaks of pest assault (Altieri et al., 1983). Pesticides become hazardous in the environment when they are used continuously. Monocultures also take the place of the natural ecosystem's intrinsic controls and functions. Due to their genetic uniformity, the majority of these crops are susceptible to attacks from pests and diseases (Wade, 1972).

On the other hand, polyculture offers a wide spectrum of genetic variants within the species. With minimal levels of external inputs, the polyculture method offers advantages, including greater output per unit area, because a variety of species uses the nutrient available in the soil and water in a more appropriate manner (Wang and Lu, 2015). Polyculture practices also improve microclimate, water balance, equally distributed food production (self-sufficiency), lower production risk, and internal nutrient cycling.

Types of Polyculture:

The common types of polyculture include intercropping, cover cropping, strip cropping, permaculture, and integrated aquaculture.

1. **Intercropping:**

The process of Intercropping is defined as "The growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage" (Gomez & Gomez, 1983). It consists of the largest category of multiple cropping and shows the crops' interactions very efficiently. Intercropping is further divided into:

- **Mixed Intercropping:**

When more than two plants can be grown concurrently without any clear layout of a row, this is known as mixed intercropping (Andrews & Kassam, 1976). It brings up the possibility of

mixing inside rows. However, mixed intercrops may have distinct crop maturation periods and are often planted together (Willey, 1979a).

- **Row Intercropping:**

Cultivation of two or more crop plants in a single row together is known as row intercropping (Andrews & Kassam, 1976). Peas with canola, maize, soybeans, and numerous tree-based systems exhibit this intercropping pattern (Vandermeer, 1990).

- **Strip Intercropping:**

Plants are stripped in this type of cropping technique. The crops are situated far enough apart to allow for separate cultivation but close enough for them to interact with one another (Andrews & Kassam, 1976).

- **Relay Intercropping:**

It involves the plantation of the second crop after the first one before it reaches the reproductive stage (Andrews & Kassam, 1976).

2. **Cover Cropping:**

A crop plant is grown next to a plant that is not a crop in cover cropping. In addition to halting soil erosion, cover crops can promote surface water retention, physically squelch weed growth, and, in the case of legumes, supply nitrogen molecules.

3. **Permaculture:**

The polyculture of perennial plants, like legume grass and wildflower combinations, is known as permaculture. It can prevent soil erosion, control water use, and lessen the need for ploughing. It can also boost soil fertility by fixing nitrogen. As a result, it aids in maintaining soil nutrients.

4. **Integrated agriculture aquaculture (IAA):**

Aquaculture practices that combine crops and integrated agriculture are done thus to promote sustainable development.

Polyculture practices in the fishery sector

It involves the culture of several freshwaters, estuarine or marine fishes in a single aquatic environment. Fish polyculture is based on the total utilisation of spatial and trophic niche in a pond at different levels. It is done to obtain a maximum number of fish per unit area. Generally, fast growing compatible fish species with different feeding habits or fish of the same species but different size and weights are stocked together to obtain high production per hectare. In India, initial fish polyculture started with three species of carps namely- catla (*Catla catla*), mrigal (*Cirrhinus mrigala)* and *rohu (Labeo rohita.* Later on more fishes are added.

The fish polyculture provides many advantage over the fish monoculture since there is complete utilisation of spatio-trophic habitats of the pond, the fishes can be stocked according to the preference of the market demand, it prevents competition since each species has different feeding habits and therefore occupies different pond niche and this technique can contribute to the improved health of the pond.

Method:

Pond preparation:

It needs a certain depth of the water with a supply of biofertilizer combined and wastes from livestock for a few days that increase the productivity of culture. Different parameters of water, like pH, salinity, and dissolved oxygen, need to be checked regularly to control the system for a better culture.

Stock preparation:

Preparation of different species for stocking is a very important technique. The number of species according to the volume of the culture pond is necessary to assess. Also, the diseased specimen should be isolated and monitored properly.

Feed management:

In the culture pond, different species require special attention to manage their feeding material. Generally, in a sustainable manner, optimum doses of bio fertiliser, cattle manure and specific fish meal combinations can increase productivity. And the leftover feed contributes to primary productivity, which the herbivorous fish utilise.

Water quality analysis:

Analysis of water samples from the culture pond is necessary to improve production. Water parameters like- temperature, pH, salinity, dissolved oxygen, and alkalinity are important to check. In addition, water nutrient parameters like- Ammonia-N, nitrite-N, and phosphate-P are essential to perform in certain intervals. For chlorophyll-a parameters, certain centrifuge and spectrophotometric techniques are used monthly to assess the rate of primary productivity in the culture system. Using an optimum amount of biofertilizer in polyculture systems can increase cultured species' growth as the feed materials' nutrient load improves. It ultimately increases the growth of phytoplankton & zooplankton, thus helping to increase productivity sustainably.

Biofertilizers are widely used in many agricultural fields for various crops to sustainably promote plant growth without causing any harmful environmental effects. Biofertilizers are mostly used for soil or field treatment, seed treatment, and seedling root dipping.

Seed Treatment:

The most common way to apply biofertilizers is seed treatment, which was mentioned. 100 grams of fertiliser are applied for each 5 kg of seeds. The quantity of fertiliser needed to be applied in the agricultural fields per hectare is determined by the number of seeds that will be sown in a field. A water and biofertilizer mix in the ratio of 1:2 is then added to the seed container with the seeds before the applying. The mixture can be gently mixed with an adhesive, such as jaggery, acacia, gum etc., to ensure that the seeds are evenly coated with the biofertilizer. In order to avoid direct sunlight, the seeds are then spread out on a clean sheet or

piece of fabric, subjected to 30 minutes of drying and then sown. According to Kumar et al. (2017) and Garca-Fraile et al. (2015), this approach is typically recommended for crops including oilseeds, fodder and pulses.

Seedling Root Dip:

For this kind of treatment, a dilution consisting approximately 1-part biofertilizer and water in the ratio 1:10 parts water is advice. In general, the approach is advised only for transplanted crops. In the field, a bed is constructed, and water mixed with certain biofertilizers for rice is poured into it. After being submerged in this solution for 8 to 10 hours, seedlings are replanted. This method is advised for replanting crops at the seedling stage, such as cabbage, chilly, paddy, brinjal, potato, tomato etc. Garcia-Fraile et al. (2015) demonstrated the treatment of plants of ornamental value like dahlia, Jasmine, chrysanthemum, rose and marigold.

Soil or main field treatment:

A certain amount of compost or dried powdered farmyard manure (20 kg) is combined with the suggested biofertilizers (4 packets), and the mixture is allowed to sit overnight. The soil is then treated with this mixture either just before transplanting or when seeds are sown (Rana et al., 2013).

Cause of sustainability:

1) Chemical fertilisers, which are used in huge amounts to produce large crop yields, have devastating effects on the environment. Consuming the food grown with the help of chemical fertilisers can cause health issues. On the other side, biofertilizers promote the plant growth without causing any degradation to the environment.
2) Since the biofertilizer is generally made from organic waste, it is comparatively cost-effective.
3) Generally, in monoculture practices, the excess nutrients are left untreated. It causes an increase in phytoplankton, Ammonia concentration and changes the dynamics of dissolved oxygen in the aquatic body. But Polyculture adds secondary species that utilise these excess nutrients, which increase the main culture's yield by improving water quality and thus completely fits in a sustainable method of agriculture.
4) It is a mixed type of culture where a product utilised by different species in the culture system can mimic the natural conditions.
5) Polyculture improves production and economics for many small-scale farmers.
6) The effluent water can be used in various agricultural crops as fertiliser.
7) It increases the profit level by optimizing the use of available resources.
8) It is reported in polyculture that algal bloom and pH condition are more stable than monoculture systems.

Objective:

1) To promote sustainability by increasing the yield in polyculture by biofertilizers.
2) To increase the net productivity of aquaculture farms by utilizing by-products.
3) To improve the economic balance by managing wastes produced at poultry and cattle farms in a sustainable way.
4) To manage the aquatic bodies & their natural production in organic ways & minimize the utilization of chemical products that ultimately damage mother nature.

Challenges:

- Polyculture is an alternative culture technique that promotes sustainability along with greater yield and production varieties. Detailed knowledge of Polyculture techniques like the selection of species according to the environment, their stocking rates and other management strategies in different climatic locations, is required to establish it.
- Proper combinations of different types of species in an adequate density maximising the production. It needs greater precision.
- Proper assessment is required to optimise the balance of bio fertiliser in culture ponds, without that, the total system can collapse, causing greater loss.
- The farmers need high management skills and proper education to establish the method.
- It shows positive results in small-scale culture farms worldwide, but in the case of large-scale industries, it needs much more studies to implement.

Global market report of Biofertilizer:

International Report:

According to the International Plant Nutrition Institute, Brazil uses between 60 and 70 K tonnes of biofertilizers annually. Nearly 70% area of soyabean crop field of 30 million hectares in Uruguay, Bolivia, Argentina and Paraguay and in South America receive *Bradyrhizobium* sp. inoculation each year, and these countries are regarded as having a sizable soybean market. While *Pseudomonas* sp. and *Azospirillum brasilense* are suggested for wheat and maize with an expected production improvement of maize and wheat, 4%–9%, a yield difference of 7.5% was detected between inoculated and non-inoculated crops. Biofertilizer production is increasing in nations with advanced research and development and high-end technologies, such as Japan, Korea, and Taiwan (FFTC Report).

National Report:

Over 100,000 hectares of land in India are used for organic farming, supported by almost 100 different types of biofertilizers producers located all over the nation. Special attention is being paid to developing horticulture, oilseeds, and medicinal plants. The use of biofertilizers has enabled the cultivation of almost 167 million hectares of land. However, it was discovered that rhizobium was the most effective (GBMAIF Report).

Conclusion:

As polyculture techniques maximise the consumption of all nutrients and boost annual yield for small-scale farmers, several publications and evaluations from around the world demonstrate higher production and favourable results when compared to monoculture practises. Positive outcomes are also produced by economic metrics like net profit, rate of return, and cost-effectiveness. It can stabilise farmers' income, and since a diversity of produce enhances that, it ensures their ability to feed themselves as the pace of production rises. It demonstrates how these environmentally friendly methods advance aquaculture and agricultural technologies as a whole. Using the leftovers and waste from one component as fertiliser for another is a long-term lucrative and sustainable cultural system. The farmers' managerial abilities, insurance coverage, level of education, and support from the community and government all favourably correlate with this strategy. For large-scale polyculture systems using biofertilizers to be successful, farmers, industrialists, and researchers will need to be more knowledgeable and precise. In the end, it is a fantastic advancement in aquaculture technology that will enhance ecosystem sustainability for the benefit of both people and the environment.

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HOW TO CITE

Biplab Bhowmik, Bipasa Dey and Riya Mondal (2022). Application of Biofertilizers in Polyculture: A way towards sustainability. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 1-17. ISBN: 978-81-957954-2-0 doi: https://doi.org/10.52756/boesd.2022.e01.001

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.002

Chapter- 2

A review study on Medicinal plants and their conservation for sustainable development

Dr. Rupa Sanyal

Keywords: Medicinal plant, Traditional uses, Conservation, Sustainable development.

Abstract:

Plants are essential to human lifestyles and necessary for supporting life on earth. To meet different needs living, all humans are dependent on plants. The world's most valuable sources of herbal goods are medicinal plants, yet they are vanishing quickly. A plant's usage as a medicine, therapeutic agent, or active component of a medicinal preparation is inferred when it is given the designation "medicinal." Therefore, a collection of plants those are used for medicine and have unique qualities that make them suitable as medications and therapeutic agents may be referred to as medicinal plants. Around 21,000 plant species have the potential to be utilised as medicines, and 80% of the world's population relies on herbal plants for primary healthcare, according to the WHO. Medicinal plants will be helpful for treating common illnesses and injuries, endemic infectious diseases, food and nutrition, mental and oral health, as well as for maternal and child health care, as well as for important pharmaceuticals. Animals and humans both rely on different medicinal plants to treat various health problems. For instance, in Madagascar, pregnant lemurs eat tamarind and fig leaves and bark to boost milk production, eliminate parasites, and increase the likelihood of a healthy birth. The rising trend in the demand for herbal products, there is a possibility of an increasing tendency of indiscriminate and unrecorded removal of medicinal plants from forests. Therefore, medicinal plants need to be conserved in places of their natural occurrence. The meticulous preservation and maintenance of medicinal plant habitats through strategic management constitutes the practice of medicinal plant conservation because it provides raw materials for the development of therapeutic drugs.

Introduction:

The term "medicinal plants" refers to any plants that have curative qualities or beneficial pharmacological effects on the human or animal body (Banerjee et al., 2014; Acharya, 2016; Sanyal et al., 2018; Bhattacharjee, 2021, Acharya et al., 2021). Drugs used in traditional medical systems, modern pharmaceuticals, nutraceuticals, food supplements, folk remedies, pharmaceutical intermediates, and chemical entities used in synthetic drugs are all produced most frequently from medicinal plants (*Maiti* et al., 2010; Maiti et al., 2013; Kar et al., 2022).

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

They are also the most abundant bio-resource for these products. A considerable portion of the Indian population benefits from medicinal plants in terms of livelihood and health security in addition to serving as a key resource base for the traditional medicine and herbal industries. Some of the most prominent medicinal herbs include *Aloe vera, Bacopa monnieri, Emblica officinalis, Eclipta alba, Azadirachta indica, Ocimum sanctum, Mentha pipertia, Aegle marmelos, Cassia fistula, Mimusops elengi, Asparagus racemosus, Cinnamomum tamala*, and many others. For basic healthcare, up to 80% of people in developing nations rely only on herbal remedies, and over 25% of prescribed medications in industrialised nations come from wild plants (Hamilton, 2004; De and Dey, 2021). However, climate change, alien species, and the use of land for intensive farming and development pose severe threats to the genetic variety of plants. Because it provides a livelihood for millions of people globally, biodiversity needs to be protected. In 2011, Krishnan et al. The usage of medicinal plants is expanding quickly all over the world due to the rising demand for herbal medications, natural health products, and secondary metabolites of medicinal plants (Nalawade et al., 2003; Cole et al., 2007; Sarkar et al., 2016; Sarkar, 2017; Sanyal et al., 2016; Erfani, 2021; Kundu, 2022). Numerous recommendations have been made regarding their conservation, including the necessity for integrated conservation methods based on both in situ and ex-situ tactics, the development of systems for species inventorying and status monitoring, and more (Hamilton, 2004).

Secondary metabolites:

Many chemical compounds found in medicinal plants that have a particular physiological impact on the human body are what give them their therapeutic effectiveness. Plant plants' most important bioactive components are alkaloids, tannins, flavonoids, and phenolic chemicals (Dhandapani & Sabna, 2008). The phytochemical properties of some medicinal plants are given in the table below:

Sl no.	Common name	Botanical name	Phytochemical constituents	Reference
1	Kulekhara	*Hygrophila auriculata* Schumach.	Flavonoids (7-O-glucuronide), Alkaloids (asteracanthine & asteracanthicine), Triterpenes (luteolin-7-O-rutinoside), Aliphatic esters, Sterols, Minerals (Fe, Cu & Co), Essential oils.	Hussain et al., 2010
2	Anantamul	*Hemidesmus indicus* L.	Salicylaldehyde, Camphor, Pinocarveol, Bornel, 4-Terpenenol, Myrtenal,Dodecanoic acid, Hexadecanoic acid, Isobornyl acetate.	Nagarajan et al., 2001
3	Sarpagandha	*Ravolfia serpentine* L. Benth. ex Kurz	Alkaloids, Flavonoids, Phenols, Tannins, Ascorbic acid, Riboflavin, Thiamine, Niacin, Saponins, Minerals such as Ca, P, K, Mg, Na, Fe and Zn.	Harisaranraj et all., 2009

4	Tulsi	*Ocimum Sanctum* L.	Rosmarinic acid, Apigenin, Myretenal, Luteolin, β–sitosterol, Eugenol, Flavanoids, Orintin, Vicenin, Carnosic acid	Baliga et al., 2013
5	Mint	*Mentha spicata* L.	α-pinene, β-pinene, β-myrcene , DL-limonene , Trans-carveol, d-carvone, Piperitenone (Eucarvone), β-bourbonene, Cis-calamenene , α-copaene , α-cadinol, Essential oil	Alsaraf et al., 2021
6	Neem	*Azadirachta Indica* A.Juss	Tannins, Saponins, Flavonoids, Alkaloids, Glycosides, Reducing sugars, Polyphenols, Nimbidin, Nimbin, Nimbolide, Gedunin, Azadirachtin, Mahmoodin, Cyclic trisulphide	Eid et al., 2017

Figure 1. *Andrographis paniculata* (Burm.f.) Nees

Figure 2. *Ocimum Sanctum L.*

Figure 3. *Azadirachta Indica* A.Juss

***Figure 4. Curcuma longa* L.**

Uses of Medicinal plants:

Herbal medicines are also gaining favour among western populations because they have very few or no negative side effects (Rokaya et al., 2014). In the natural course of daily life, traditional plant knowledge and characteristics have always been passed down from generation

to generation. Around the world, traditional and conventional medical systems are known to use between 50,000 and 70,000 plant species (Schippmann et al., 2006).

Table 1. Some of the medicinal plants and their medicinal uses are in the table below:

Sl no.	Scientific name	Part used	Medicinal uses	Reference
1	*Hygrophila auriculata* Schumach.	Roots and seeds	Treatment of "rheumatism, tuberculosis, leucorrhoea, anaemia, bodily ache, constipation, skin illness, and as an aphrodisiac".	Sethiya et al., 2018
2	*Hemidesmus indicus* L.	Roots	Treatment of "scorpion stings, diabetes, urinary diseases, dyspnea, menorrhagia, oligospermia, anorexia, fever, abdominal colic and pain, dysentery, diarrhea, cough, rheumatism, snakebites, headache, inflammation, pyrosis, skin diseases, leprosy, sexually transmitted diseases and cancer."	Nandy et al., 2020
3	*Ravolfia serpentine* L. Benth. ex Kurz	Roots	Treatment for illnesses including but not limited to "venomous insect bites, high blood pressure, inability to sleep, mental issues, gastrointestinal disorders, epilepsy, fever, wounds, and schizophrenia".	Kaur, 2017

4	*Ocimum Sanctum* L.	Leaves, stem, flower, root, seeds	Treatment for "earaches, fever, colic pain, sore throat, asthma, hepatic diseases, malaria fever, as an antidote for snake bite and scorpion sting, flatulence, migraine headaches, influenza, fatigue, skin diseases, bronchitis, common cold,wounds, insomnia, arthritis, digestive disorders, headaches, coughs, night blindness, diarrhoea, and influenza."	Pandey & Madhuri, 2010
5	*Mentha spicata* L.	Leaves, flower, stem, bark, and seeds	Treatment of "diarrhoea, antidote, indigestion, intestinal weakness, abdominal pain, cold, influenza, sinusitis headache and flatulence".	Mahendran et al., 2021
6	*Azadirachta Indica* A.Juss	Leaves, bark, root	Treatment of "heat-rash, boils, wounds, jaundice, leprosy, skin disorders, stomach ulcers, chicken pox", etc.	Bhoumik et al., 2010
7	*Bacopa monnieri* (L.) Pennell	Stem & leaves	Enhances memory, treatment of anxiety Alzheimer's disease, attention deficit-hyperactivity disorder, etc.	Sanyal et al., 2022
8	*Catharanthus roseus* (L.) G.Don	Leaf, root, shoot and stem	Treatment of "fever, malaria, throat infections, chest complaints, diabetes, regulation of menstrual cycles."	Gajalakshmi et al., 2013
9	*Andrographis paniculata* (Burm.f.) Nees	Leaves	Treatment of "Pharyngolaryngitis, diarrhoea, dysentery, cough with thick sputum, carbuncle, sores, and snake bites".	Akbar., 2011

10	*Curcuma longa* L.	Roots	Treatment of "Alzheimer's disease, Eye inflammation, skin rash, colorectal cancer, prostate cancer, skin wounds, depression, diabetes, joint pain, etc."	Krup et al., 2013

Conservation strategies:

The rising trend in demand of herbal products, there is a possibility of an increasing tendency of indiscriminate and unrecorded removal of medicinal plants from forests and therefore the medicinal plants need to be conserved in places of their natural occurrence. IUCN updated the Red list in June 2015 and added 44 Indian medicinal plants in the list of which 18 were categorized as vulnerable, 16 as endangered and 10 as critically endangered. Some of the endangered species are *Lilium polyphyllum, Saaussurea coatus, Tribulus rajasthanensis* etc. As most of their pharmaceutical potential has not yet been explored, medicinal plants have a bright future and should be the subject of current and future research. There are basically four scientific and social actions to conserve medicinal plants:-

Legislation:

Laws already in place governing forestry cover the preservation of medicinal plants. The Forest Act of 1927, the Wildlife (Protection) Act of 1972 and the Wildlife (Protection) Amendment Act of 1991, the Forest (Conservation) Act of 1980, the Environment Protection Act of 1986, the National Forest Policy of 1988, and the National Biodiversity Act of 2002 are the laws developed by the Indian government for forest conservation that either directly or indirectly protect the wild herbal flora (Singh & Kushwaha, 2008).

In-situ conservation:

On-site conservation, also known as augmentation, refers to the preservation of genetic resources found in wild populations of certain plant or animal species, such as the genetic resources found in forests in wild populations of certain tree species. It is the process of preserving a threatened plant or animal species in its native environment by safeguarding the habitat from damage or pollution or defending the species against predators. Farmers, particularly those who use unorthodox farming methods, apply it to preserving agricultural biodiversity in agroecosystems.

It deals with the local preservation of the genetic diversity of the wild in its natural setting. In situ conservation aids in preserving the natural environment and habitat so that species can adapt and evolve in response to climatic changes. The method to keep endangered medicinal plants is through natural parks, wild nurseries, and biosphere reserves.

Figure 5. Indian biosphere reserves,
Source: Creative Commons Attribution-Share Alike 4.0

Ex-situ conservation:

Ex-situ conservation literally translates to "off-site conservation." It is the procedure for preserving a threatened plant or animal species outside of its natural habitat. For instance, a portion of the population may be relocated from a threatened habitat and kept in human care or in a wild region. Ex-situ conservation incorporates more modern, somewhat contentious laboratory techniques and some of the oldest and most well-known conservation techniques. When in-situ conservation is too challenging or impracticable, it may be utilised on some or all of the population. Ex situ conservation often overlaps with in situ conservation, but it also often effectively complements it, especially for overexploited and endangered species.

Slow-growing, scarce, and highly susceptible to replanting diseases, medicinal plants aim to cultivate and naturalise endangered species to ensure their survival and occasionally to produce large amounts of plant material used in the production of medicines, and it is frequently an immediate action taken to sustain medicinal plant resources. In addition to maintaining high potency when grown in gardens far from their natural habitats, many species of formerly wild medicinal plants can also have their reproductive components carefully chosen and saved in seed banks for future replanting. The technologies include in vitro preservation (using tissue culture and cryopreservation techniques to preserve germplasm), in vitro propagation (using molecular marker techniques), and others.

Cultivation practice:

The appropriate cultivation of medicinal plants can contribute to both the preservation of wild stocks and the resolution of the global health crisis. To promote the growth of medicinal plants, the Central Institute of Medicinal and Aromatic Plants (CIMAP) has developed a number of high-producing cultivars, agrotechnologies, and processing methods (Kumar &

Jnanesha, 2017). Cultivation encourages both socioeconomic advancement and the protection of plant species from extinction.

Research & development:

Through their useful economic applications in health and medical care, research and development activities aid in the enrichment of flora and fauna, environmental protection, and human assistance. Through its useful economic applications in health and medical care, research and development efforts benefit people by enhancing flora and fauna, protecting the environment, and benefiting from its benefits.

Conclusion:

The most significant plants in prehistoric times were those employed as medicines; many of these plants are being utilised today in the food, cosmetics, and pharmaceutical industries. They can be found all over the world and are widely scattered. Today, the cultivation of medicinal herbs is quite important commercially. Herbal plants are used for various medical purposes, including the topical treatment of burns and the ingestion of substances that help relieve constipation. Cosmetology also makes extensive use of them. These plants may also be used as food flavourings. There are many uses for medicinal plants, and each of the aforementioned sectors has experienced highly positive outcomes. Plants and the knowledge that goes with them are slowly vanishing due to deforestation, environmental degradation, habitat degradation, overexploitation, and acculturation happening worldwide. The conventional formulations and medicines used for the treatment of numerous ailments, including lifestyle disorders like diabetes, hypertension, and asthma, will no longer be available if there is no sustainable supply of these crude drugs.

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HOW TO CITE

Dr. Rupa Sanyal (2022). A review study on Medicinal plants and their conservation for sustainable development. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 18 -28. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.002

OPEN ACCESS
DOI: https://doi.org/10.52756/boesd.2022.e01.003
Chapter- 3

Human security in context of sustainable urban development in India

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Keywords: Human security, development, Swachh Bharat, Bruntland, Framework.

Abstract:

The conditions necessary for protecting vital values and experiencing a sense of safety from danger are established when security is present. It is consequently one of the essential difficulties. It generates some concerns in people's thinking because of the strain that population growth and migration have placed on India's major cities. Freedom from adversity and prosperity are essential components of human security. A basic and dynamic pull toward democracy and the opportunity to participate in social decision-making is exerted on people by the promise of human security.

The Brundtland framework for analysis and action made every effort to move in the context of human security and human development with sustainability, focusing on major goals, priorities, and action plans by placing a strong emphasis on people and strengthening the social pillar of sustainable development. India in 2020-2022 has taken a numbers of missions of Nirmal Bharat with brief emphasis on human security and development such as Swachh Bharat, Satat Bharat – Sanatan Bharat, Samagra Bharat - Saksham Bharat etc. So, the entire scenario tries to improve a great change in India's security and developmental paradigms.

Introduction:

The interrelationships between climate change, sustainable development, and human safety and well-being can be used to comprehensively analyse the potential consequences that extreme global warming could have on all aspects of human life and security. Currently, for various reasons, the destitute tropical parts of the world will be the ones most severely impacted by the effects of climate change. Studies on both sides of the global warming and climate change argument have been done in great numbers by academics, decision-makers, and scientists. The possible harm that global warming and climate change might do to human security and social and economic growth is also examined in this research (food, health, immigration etc.).

The topic that was just discussed is very debatable. Various scientific articles published by the United Nations, scientific societies, non-governmental organizations (NGOs), environmentalists, and decision-makers have expressed concern about it. However, through in-

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

depth conversation and study of the relevant literature, one can determine the connection between the many climate change and global warming models in use today and their ability to provide information on the subject of interrelationships (Maria et al., book chapter).

The different Parameters regarding Sustainability and security

Sustainable development

The World Conservation Strategy from 1980 and the Stockholm Conference on the Human Environment from 1972 are the two events that are credited with being the starting points for the idea of sustainable development (Mark, 1990). The Brundtland Commission, established in 1987, is considered the starting point of the contemporary field of sustainable development, which has subsequently altered earlier conversations about the environment and development. In 1992, at the United Nations Conference on Environment and Development held in Rio de Janeiro, early support was given for the idea of sustainable development as it was articulated in the report. The similar idea was created in 2002 at the Johannesburg World Summit on Sustainable Development in South Africa. The ability of "sustainability" to make "space" for genuine efforts to address the intricate, genuine, and ever-changing relationships that exist between civilizations and between the past, present, and future is the genius behind the concept of "sustainability" (World Commission on Environment and Development, 1987, p. 8).

However, a connection between these divergent viewpoints has grown over a wide area, indicating what needs to be built, and sustained, and how far into the future people are willing to look (Table 1). What should be maintained? The most frequent response to this query is "life support systems," emphasizing the importance of supporting human life. This response's initial version strongly emphasized the necessity for sustainable use.

Human security

Human security is defined as eliminating poverty and achieving an acceptable standard of living, protecting fundamental human rights, and non-physical factors influencing the issue's qualitative component. There are two qualitative and two quantitative dimensions to human security. The quantitative component is meeting physical necessities or providing the bare minimum level of security for people, including housing, food, education, and public health. The qualitative aspect of human security pertains to his human identity, which includes freedom to participate in social life, individual independence, and the right to control one's destiny [Tomas, 2004].

Human development

The process of increasing human options is known as human development, and it is accomplished by balancing three factors—economic wellbeing, the development of human resources, and the identification of fundamental social needs—under the umbrella of human

security. Some individuals think that human development involves equality in the form of equal access to opportunity. There is consistency in the form of accepting responsibility for the next generation, and suitable productivity for human resources. Enhancement is there, i.e., the people must reach a certain level of personal development in order to be able to choose their basic needs [Yadollahi, 2004].

The impact of human security on the Environment and Sustainable development

Impact of human security in SDG

The progress of human security should help to realize sustainable development, according to the UN General Assembly's resolution on the topic (66/290). An international agreement on sustainable development as a broad goal to save future generations from the negative effects of overusing natural resources is desperately needed. In fact, there appears to be a global consensus on the fundamental idea of sustainable development, which was first put forth by the Brundtland Report in 1987.

The Copenhagen Conference on Climate Change in 2009 and the Kyoto Protocol failed to have the desired impact on halting global warming. Even after the Rio+20 Conference on Sustainable Development in 2012, the SDG did not produce a significant outcome on sustainable development. In addition, the United Nations Framework Convention on Climate Change (UNFCCC) could not produce the desired impact on halting global (SDGs).

Impact of Population on Environment and Human Security

The result of migration and population growth, satellite towns are under more and more pressure. In addition to relieving pressure spots, the emergence of peri-urban development has become one of the main forces behind societal advancement. Urban space has changed as a result of these processes; nevertheless, due to a lack of suitable governance systems and knowledge, as well as insufficient planning, consultation, and accountability, urban areas have also turned into sites of inequality, insecurity, conflict, and environmental degradation (Kennet, human security).

In terms of people, security means that people don't fear exercising their legal freedoms and rights. When their rights are in jeopardy, which entails being or feeling comfortable and free from fear, anxiety, rage, doubt, etc., no force can threaten him or her [Tendler,1997]. Security creates the conditions necessary for safeguarding important values and feeling safe from threats. It is the most significant issue, and as a result, it raises some concerns in people's minds. Governments are security caretakers and operate on a consensual basis since security has complex features. Security is therefore seen as humanity's greatest enduring goal. In addition to the several definitions described above, there are various types of security, including:

The challenges of human security

With the help of spirituality, human security development improves in nature. The rate of human disorders, immoralities, wickedness, and depravity decreases during religious ceremonies and particular months of the year, such as Durga Puja, Janmashtami, Moharram, Ramadan, and Hajj, while human security improves in the opposite direction. When discussing human security, it's important to consider its social costs. Because ignoring human security will generate challenges for people and eventually a national catastrophe for nations. Regarding pathology and assessment, we shouldn't ignore human security.

Human security and sustainable development

Former UN General Petros Ghali, in 1994, stated that the previous commitments about land security with a new commitment concerning human security to be modified. He postulated that security through the gun, has been replaced by security through development [Yadollahi, 2009; Dejpasamd, 2002]. The concept of human security is a part of current discussions on global social justice and is linked to the activities of United Nations development plan [UN organizations]. There was emphasis on seven important categories in this article as follows: Economy, food, health, environment, individuals, society and politics. This plan, therefore, remind us that human security is a global concern because there are some dangers in the world that threaten humans equally, irrespective of wealth condition, but their effects may be different from each other in different places.

Expanding the Traditional Security Narrative: Merging Development and Security in Neighbouring Countries

After three years of consideration, NATO agreed to increase the size of its International Security Assistance Forces (ISAF) component and send it to Afghanistan. In March 2005, the US Senate approved a $82 billion emergency spending plan to fund military operations in Afghanistan and Iraq. This claim brought up the old "arms vs. butter" argument again and was supported by extensive studies on the poverty and instability in Afghanistan. The Afghanistan National Human Development Report argued that in a country where the GDP per capita was $200, the life expectancy was 44.5 years, and the literacy rate was 28.7%, the priority of the new government should be to provide "human security" as a public good for all. This was the first thorough analysis of the development situation in Afghanistan since the Taliban were overthrown in 2001.

Aim and focus on SDG by the Government sector

Then and therefore comes the question of Sustainable human development-

Sustainable Security and Development

TABLE 1. The field of sustainable development

What is to be sustained?		What is to be developed?
Life support systems. Resources, environment, ecosystem services *Natural environments*. Species, biodiversity, ecosystems, earth *Communities*. Traditions, values, ethnic groups, cultures, places	In what relation? Or, and, but, with . . . For how long? Years, decades, centuries, forever At what scale? Localities, states, regions, planet	*Economies*. Production, consumption,wealth, distribution *Societies*. Capacity building, organizations, institutions *People*. Longevity, education, capabilities, choices

A less anthropocentric perspective emphasizes preserving the environment due to its inherent worth and our resulting duties to preserve it. Maintaining species, biodiversity in general, ecosystems, or the Earth itself is necessary. These perspectives on what should be preserved frequently evoke ideas of "stewardship" and an implicit recognition of humans' dominance. More radical interpretations define "natural rights," according to which the environment and all life on it have an equal right to survive and be fed. The economy is frequently given precedence when development is discussed in terms of sustainability. Production growth is thought to open up job and consumption opportunities. Wealth gives the incentives and means for investing in additional output as well as the resources for maintaining and restoring the environment. Discussions concerning how growth and prosperity are distributed have taken centre stage, with strands covering everything from basic requirements and poverty alleviation to growth with equity. At different levels of governance, emphasis is placed on the creation of institutions and organizations for participation and deliberation, negotiation and dispute resolution, policy formulation and execution, etc. People have been yet another response to the question of "what is to be developed." This growth is centred on the quantity and quality of human life as it is broken down to the level of the individual.

What connections are there? The combined examination of what is to be developed and sustained characterizes virtually all concepts of sustainable development. For instance, the "three pillars" of sustainability—economic, environmental, and social—were frequently mentioned in the planning for the 2002 World Summit. These objectives were tied together and accorded equal weight. Given that the social pillar was underestimated at the 1992 Rio Conference on Environment and Development, the social dimension was, in fact, to receive priority emphasis. Many energy and environmental assessments were conducted over a century; among these were those of the Intergovernmental Panel on Climate Change. Both the far-off future and the long future are remote and unknown.

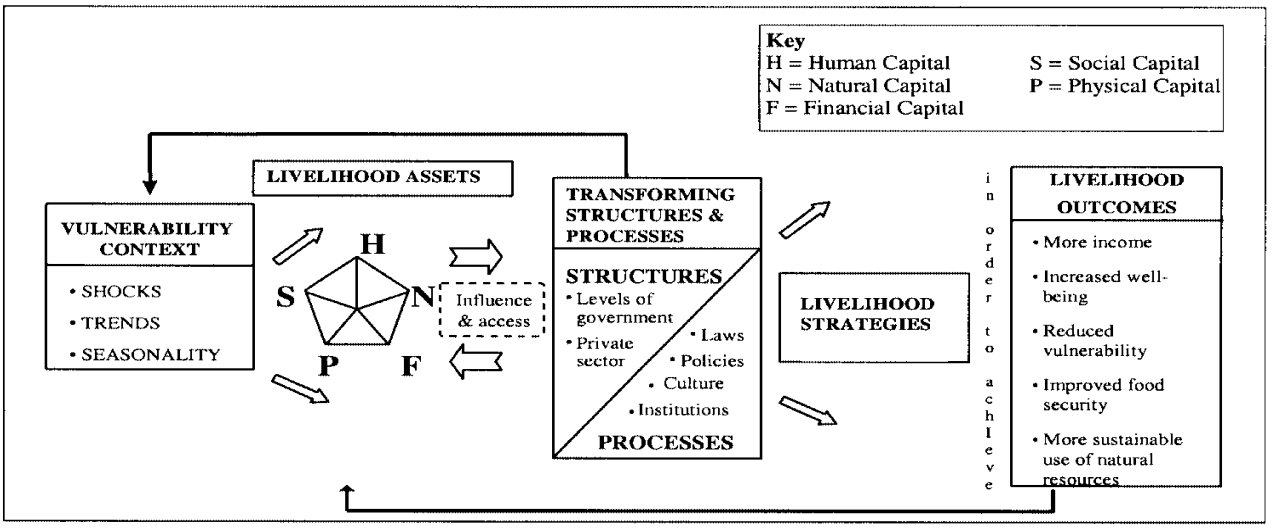

Figure 1. Sustainable livelihoods framework (Khagram et al., 2003).

Interlocking and mutually reinforcing institutional arrangements

The concept of state-building and -strengthening, as well as the development of government officials' human ability, is a component of a larger collection of potential action implications for enhancing governance at all levels, from the local to the global. Institutional arrangements that provide hospitable conditions for governmental and non-governmental 306 Sustainable Security and Development groups and persons likely need to be integrative, flexible, and legitimate (Kates and Clark, 2001). First, the more institutions integrate diverse spatial and temporal scales and the connections between human security and sustainable development, the more effective they are likely to be. Second, reasonably adaptable institutions appear to help people recognize, share, and use new and evolving knowledge and information that aim to advance practice. Third, institutions must be reasonably open to participation, and accountable to a range of stakeholders, notably the most vulnerable, poor, and disenfranchised, in order to be considered legitimate. Therefore, it is unlikely that radical changes in governance, like a new integrated "Right to Human Security" or extreme privatization initiatives, will be the most beneficial. On the other hand, a new "Right to a Healthy Environment" that strengthens the current right to water by increasing political, judicial, and administrative support for its priority could lead to changes in law and practise that include pro-poor pricing initiatives and increased taxation and penalties for water pollution (Jhonson et al., 2001). In addition, smart investments in public sector water management and provision capabilities may actually be more effective than wholesale water privatization, especially in environments with lax regulatory monitoring and frameworks (Perry t al., 1999; Hall et al., 2002).

The last consideration is the government's offer to make security and development more livable and sustainable. What is currently viewed as impossible may become feasible in the near future, likely in the medium term, and one day natural and unquestionable to the extent

that political advocacy networks and action learning coalitions are built among those concerned with making security and development more human and more sustainable.

The few drawbacks of management controlling sustainable development programs earlier:

The incorrect handling of SDGs has some causes. First, the word "sustainable development" has been used to refer to everything from agriculture and fisheries to entirely unrelated fields like insurance, making it more challenging to understand in a practical and beneficial way. In order to make a difference, the international community must create a new index or set of indicators for sustainable development that goes beyond gross domestic product. As a result, the following disadvantages of earlier settlements are discussed below:

1. The lack of agreement on a set of quantifiable indicators is one of the most frustrating issues with sustainable development. Due to disagreement over the inclusion of greenhouse gases, attempts to create a set of sustainable development indicators have failed. We must "measure what is measurable and make measurable what is not," as Galileo Galilei put it.

2. The economic, social, and environmental pillars of sustainable development are still analyzed separately. Institutional support hasn't been enough, till now. This is due to the fact that decision-makers, social activists, environmental scientists, and economists have frequently spoken over one another and indistinguishably from one another. A UN Sustainable Development Council that functions similarly to the Security Council does not exist. The UN Commission on Sustainable Development is unprepared for the job, and the Economic and Social Council (ECOSOC) is too ineffective and dysfunctional. Consensus on policies within countries is difficult. Different agencies and ministries independently focus on the food crisis, energy crisis, financial crisis, and climate catastrophe. The sustainable pattern of consumption has not been addressed, despite the fact that the sustainable pattern of production has. For instance, in recent past Japan experienced a very hot summer. Tens of thousands of people were hospitalized while hundreds of individuals perished. However, we do not know how to stop such hot summers from happening again. Another way to put it is that climate change is to blame for all disasters, including floods, tornadoes, forest fires, and droughts. And none of us seem to be doing anything about them, simply shrugging our shoulders. Isn't this also a concern of safety for people?

3. Developmental issues like poverty reduction have received too much attention from international initiatives. The international community has prioritized achieving the Millennium Development Goals (MDGs), which were primarily created to alleviate global poverty by the target year of 2015, pushing sustainable development to the back burner.

4. International negotiations on climate change and other environmental issues have not advanced due to a lack of strong support from science and technology. Such negotiations took a hit when the IPCC (Intergovernmental Panel on Climate Change) lost its credibility.

5. Fifth, negotiations on climate change and other issues have been hampered by the rift between wealthy and poor countries.

In June 2012, during the Rio+20 Conference, UN member states decided to start a process to create SDGs, or Sustainable Development Goals. They decided to form an international working group to create the SDGs. The SDGs must be "action-oriented, brief and simple to understand, ambitious, global in scope, and universally relevant to all countries." The SDGs, which will be a crucial component of the post-2015 development framework, will build on the accomplishments made under the MDGs. Another decision made at the Rio-plus-20 Conference was to create a high-level political forum for sustainable development **(**This summary was adapted from Human security and sustainable development, which was published on September 22, 2013 by Kiyotaka Akasaka, President of the Foreign Press Center in Japan and Former Under-Secretary-General of the United Nations.**)**

Sustainable Developmental Goals in India: Current Scenario

There are several current missions of union ministries in this respect, which are discussed below-

Progress Monitoring and SDG Localisation

The States and UTs play a pivotal role in the achievement of SDG targets at the national level with the State/UT Governments and supports them in a range of initiatives for SDG localisation, with help of NITI Aayog in this respect.

Private Sector Engagement and SDG Costing and Financing

Estimating the cost to achieve the SDGs and developing and implementing the tools to attract finance and investments are key requirements for the timely achievement of the ambitious targets under the framework. The initiatives of the SDG vertical in this area include costing exercise for key SDGs and an online platform to facilitate investments.

Multidimensional Poverty Measurement and Reduction

The SDG framework specifically targets ending poverty in all its forms, thereby raising the stakes on accelerated multidimensional poverty reduction. The Vertical steers the development of India’s national Multidimensional Poverty Index (MPI) and the reform action plan to reduce multidimensional poverty.

Overview of SDG plannings for SDG India Index and Dashboard

The SDG India Index and Dashboard, designed and developed by the Vertical, is the country’s official and principal tool for SDG progress monitoring at the national and sub-national levels. Two editions of the Index—2018 and 2019-20—rank the States/UTs on their achievements in various SDGs and associated targets.

The SDG Vertical has been assigned the responsibility of leveraging the monitoring mechanism of the global Multidimensional Poverty Index to drive policy reforms and develop an action plan. This is part of the Government of India’s decision to monitor the performance of

the country in 29 select global indices through an exercise known as the 'Global Indices for Reforms and Growth (GIRG)'. The SDG Vertical is working on designing and developing a national MPI based on the National Family Health Survey (NFHS) for bench-marking and ranking of State performance. Utilising the results of the global MPI to identify reform areas for policy action is a key part of the GIRG mandate. This feature of the MPI is being leveraged into a six-step action plan process for identifying reform areas.

India's ranking on SDGs (The data is collected from India's SDG report on NITI Ayog)

A. North-Eastern Region District SDG Index and Dashboard

The Ministry of Development of North Eastern Region (MoDoNER), UNDP, and SDG Vertical are collaborating on developing an NER District SDG Index and Dashboard, which will not only monitor progress but will also serve as a tool to trigger the action needed by the State Governments. The Index, along the lines of the SDG India Index, will be based on the State and District Indicator Frameworks of all eight NER States. This is an outcome of the SDG conclave of the eight North-Eastern States held in Guwahati in February 2020, organised by NITI Aayog and MoDoNER, in which the State Indicator Frameworks of all the eight North-Eastern States were launched.

B. SDG Cities Index

This is the rationale behind the SDG Vertical's project to institute an SDG monitoring mechanism at the city level. The project will involve annual progress monitoring of around 60 cities on a set of about 100 indicators.

HUMAN SECURITY: INDIAN SCENARIO

Human Security

There is little doubt that many of the security threats the world faces in the twenty-first century are related to problems like poverty, underdevelopment, inequality, environmental deterioration, climate change, pandemics, illegal immigration, people smuggling, drug trafficking, and conflicts resulting from failed states due to poor governance. Although these concerns are not new, they are becoming more transnational and interconnected in a time of expanding globalization. Furthermore, despite the fact that the system of nations that makes up the current international order may appear to be stable on the surface, these risks have a direct and profound impact on people's safety and well-being. As a result, the international community needs to reconsider what security is and how to best achieve it. The conventional national security idea must give way to a holistic, people-centric view of security as a better framework for reference and action in the modern world (Acharya et al., 2011).

As previously mentioned, India is a varied country with many different ethnic groups. In India, several ethnicity have consistently been able to maintain their identity, which is unusual.

This has frequently allowed for severe inequities; society has divisions based on caste, creed, class, religion, community, and other factors. Some groups frequently experience a sense of exclusion and believe they are society's victims. Even if it is true that there is still prejudice, it is noteworthy that these organizations have grown more assertive in raising their objections and sending elected officials to make their cases before the highest legislative bodies. Similar to this, numerous welfare programs are being introduced on the economic front to provide economic and social justice to the oppressed and disadvantaged members of society. Various groups are becoming more aware of their legal standing, making it simpler to demand the provision of human security. The state also ensures that each individual receives their fair share by putting in place various regulations and initiatives.

Political Security:

Since gaining its independence, India has taken great care to protect its territorial integrity. India's strategic location has left it open to challenges from various sources. The nation has faced various difficulties that have occasionally tested efforts to keep it united. Particularly, vulnerable are India's northern and northern-eastern regions, where terrorist and insurgent organizations have repeatedly tried to topple the government. There are various difficulties with this task: Parallel governments are run, especially in the Naxalite (Maoists) violence-prone areas, and difficulties are preventing the proliferation of small arms, drugs, and trafficking. Government officials rarely carry out their duties. Law and order enforcing agencies frequently encounter obstacles in the remote areas where the insurgent/militant groups operate. Since increased levels of development and the provision of fundamental requirements tend to reduce inequality, many experts advocate human development as a requirement for human security. The accessibility creates a sense of security that keeps crime rates from skyrocketing. Therefore, the decision-makers must consider the policies that guarantee everyone's welfare.

When a population is empowered and given possibilities for personal and human growth, wars can no longer be justified by economic or greedy motives. This is especially true within nations and is crucial at a time when intra-state conflicts predominate rather than conflicts between states (15). Wars put the country's economy under additional strain, increasing the losses and lowering the gains.

Human Security Relating to Food and Health:

One of the most important factors relating to human life is food security. The absence of this has terrible effects for individuals who are denied the bare necessities in society. Food security, hunger, and poverty are all interconnected issues. Starvation results from food deprivation, which then causes illness. It also results in a person's career and work capacity being harmed. Malnutrition lowers one's resistance to illness and has detrimental long-term effects on health. It makes people weak and unproductive and contributes to hunger, poverty, and disease. The availability of food is a crucial component of human development, and its lack results in

stunted human growth. Because food is a basic requirement for human survival and when the very question of survival is in danger, plans for meaningful progress retreat, the rejection of this renders the concept of development useless. Additionally, it raises doubts about the state's capacity when it fails to cater for the needs of its population. In a society, having access to food is crucial. There are attempts to pass legislation guaranteeing this fundamental right for everyone, but we must keep in mind that this is a huge undertaking that will require enormous willpower to accomplish. Millions of people in India are malnourished. Due to the high levels of aims to reduce hunger and poverty, the mission becomes even more crucial.

Security in terms of one's health is crucial for one's life and growth. In order to ensure that everyone in society is taken care of, the state and local communities must provide this assurance. Most communities in India have primary health care facilities, but they are not well-equipped to handle even minor illnesses. Public access to healthcare is generally quite poor, and the situation in rural areas is even more appalling. Because most residents of slums and other unsanitary situations cannot afford proper healthcare, urban regions also suffer. The private sector does not meet the requirements of the poor in terms of health because it is more commercial in character. Although it is stipulated that private hospitals must provide health care to the underprivileged, this programme has been implemented fairly slowly. Lack of awareness of common practices including maternal and child immunization, maternal healthcare, and infant mortality rates among the rural population has been a prevalent trend. Reforms in this area are required to ensure everyone's health.

Environmental Security:

Due to the extremely obvious environmental degradation, climate change, ozone layer thinning, and significant industrial pollution, environmental security has become increasingly important. Concerns over how development policies affect the environment are becoming more well known. It now has significance at the local, national, regional, and worldwide levels as more and more industrial, mining, and development projects receive approval from the governmental authorities for industrial/commercial objectives. Unfair use of natural resources has prompted numerous countries to cooperate globally and take action to slow down environmental destruction. Policy frameworks have been established to enable the states to comply with the many international conventions. Living in a clean environment and preserving our natural resources for future generations makes this a crucial aspect of human security. In order to protect future generations from escalating climatic changes and their detrimental impacts, some of the significant conventions, such as the one connected to climate change, need to be addressed and extensively debated. All nations should make a legally-binding promise to put it into practise honestly. India has its fair share of environmental legislation, but its judicial activism in this area is what really stands out. India's growth ambitions are expected to upset the country's ecological balance because it has one of the fastest-expanding economies in the

world. In light of its traditional knowledge and wisdom, which depends more on a delicate balance of the relationship between nature and man, it needs to work harder in this area.

Sustainability and Voluntary National Review 2020 (This part has been taken Govt manifestation on SDG development)

India, home to one-sixth of all humanity, holds the key to the success of the 2030 Agenda. India in its second VNR (voluntary national review) has made a paradigm shift to a "whole-of-society" approach with Government of India engaging sub-national and local governments, civil society organizations, local communities, people in vulnerable situations and the private sector. India's commitment to the SDGs (sustainable developmental growths) is reflected in its convergence with the national development agenda as reflected in the motto of Sabka Saath Sabka Vikaas (Collective Efforts for Inclusive Growth). Based on the evidence from the SDG India Index, which measures progress at the sub-national level, the country has developed a robust SDG localization model centered on adoption, implementation and monitoring at the State and district levels.

There are few agendas of India for human development with clear manifestations and motto-

Mission 1. Swachh Bharat - Swasth Bharat (Clean and Healthy India):

Through a nationwide initiative triggered by the Clean India Campaign and the National Nutrition Mission, India achieved 100% rural sanitation and sharp reduction in stunting and child and maternal mortality rates. Universal health coverage has been institutionalized through Ayushmaan Bharat, the world's largest health protection scheme which provides an annual cover of USD 7,000 to 100 million families.

Mission 2. Samagra Bharat - Saksham Bharat (Inclusive and Entrepreneurial India):

Financial inclusion through Jan Dhan-Aadhaar-Mobile (JAM), near universal access to bank accounts aided by the Jan Dhan Yojana (National Financial Inclusion Scheme); Aadhaar card (National unique identity number) for over 90% of the population; has propelled new avenues of credit, insurance, to over 200 million women to poor, accelerating their economic empowerment.

Mission 3. Satat Bharat – Sanatan Bharat (Sustainable India):

India's climate action strategies call for clean and efficient energy systems, disaster resilient infrastructure, and planned eco-restoration. India has electrified 100% of its villages, reduced 38 million tonnes of CO2 emissions annually through energy efficient appliances, provided clean cooking fuel to 80 million poor households, and set a target to install 450GW of renewable energy and aims to restore 26 million hectares of degraded land by 2030. Globally, India stands third in renewable power, fourth in wind power, and fifth in solar power. India launched the Coalition for Disaster Resilient Infrastructure and the International Solar Alliance to leverage global partnerships for climate action and disaster resilience.

Conclusion:

Nature and society are interdependent:

what happens when one affects the other in significant ways. This is not a normative statement, but rather an empirical finding about how the world works. Goals, policies, and activities based on this understanding are likely to be more successful that those that dis-embed people from nature. The interdependence of nature and society generate not only threats to both, but also opportunities for positive change. The potential for mutually destructive degradation and for mutually supportive nurture existence may be described in few aspects below-

1. Research and action that focus largely on threats posed by appropriately dis -aggregated nature and society to one another will miss important opportunities for joint improvement and mutual benefit.

2. Threats and opportunities (or risks) exist at all time and space scales, from the acute and local to the chronic and global. It is at intermediate regional spatial scales and decade time scales that some of the most critical contemporary threats arise, and some of the best opportunities for helpful initiatives exist. Popular efforts to establish agreement at the global level on 'the' most important challenges for human security are therefore likely to be much less effective than suitably contextualized efforts. Likewise, an exclusive focus on either immediate or very long term interactions is less likely to promote progress than a dynamic focus on intermediate temporal transitions.

3. Communities and people must be able to articulate their own aspirations, have the appropriate means to make their voices heard and to participate effectively in decision-making about their security and development.

Finally, there is a strong case to see nature as valuable in its own right, in addition to its instrumental value for human beings. Taking this last principle, and following the broader model of integration and linkages offered by sustainable development, perhaps it is 'sustainable security'. Sustainable security offers a more open space for deliberation, analysis, and action could help connect analysts and practitioners of human and environmental security in common purpose to expand the narrow and problematic field of state security.

(This part has been taken from Govt manifestation on SDG development)

In conclusion offer of government for making security and development more human and sustainable are the final thought. To the extent that political advocacy networks and action learning coalitions are built among those concerned with making security and development more human and more sustainable, what is considered impossible today may be possible in a short time, probable in the medium term, and one day natural and unquestioned.

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HOW TO CITE

Dr. Suranjana Haldar and Dr. Atish Haldar (2022). Human security in context of sustainable urban development in india. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 29-42. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.003

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.004

Chapter- 4

Toxicity of microplastics in humans: A search for sustainable alternatives

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Keywords: Microplastics, Toxicity, Humans, bioplastics.

Abstract:

Plastics have become ubiquitous in our daily lives and are a major source of microplastic pollution. Microplastics are plastic particles with a diameter of less than 5mm. It can now be found in all ecosystems, including virgin environments like Antarctica. The main form of microplastics entering the food web is through ingestion and eventually accumulation in a different body part. In this context, the objective of this chapter is to study the toxic effect microplastics have on major systems of humans and to find out existing sustainable alternatives to eliminate microplastics from the environment. The current research focused that microplastics reaching the respiratory, circulatory and gastrointestinal systems through the air, water and food. The toxicity of plastics depends on the particle's size, shape, texture, surface chemistry and charge, which governs its interactions with biological systems. Therefore, scientists partially substituted petrochemical-based polymers with development of bioplastics which are biodegradable in nature and can fight increased environmental and economic challenges. These bioplastics are made from cellulose, potato, corn starch and sugarcane. Though these raw materials are also major food resources, massive production of bioplastics from them may increase the possibility of food crisis.

Introduction:

Plastic means "malleable" or "flexible." Indeed, these synthetic materials can be molded into any form. Plastics are long chains of polymer molecules created from organic and inorganic raw materials, like carbon, silicon, hydrogen, oxygen, and chloride. They are versatile materials that are cheap, lightweight, strong, and durable (do Sul & Costa, 2014). Microplastics are officially defined as heterogeneously mixed plastics having less than five millimeters (0.2 inches) in diameter (Guo et al., 2020). They are loosely classified into two categories: primary

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

and secondary. Microfiber is a minute piece of plastic utilized in clothes and is thinner than a strand of hair. It passes through washing machine filters and sewage treatment plants and ends up in large water bodies like oceans. 'Nano-plastic' is a term for plastic particles within the submicron range <1 μm (Leslie et al., 2022). Primary microplastics are plastics that are manufactured as tiny particles for commercial use, such as in cosmetics, as well as microfibers shed from fabrics and textiles, such as fishing nets. They can also be released by spilling virgin plastic pellets with a millimetre range diameter.

Degradation is a chemical change that reduces the average molecular weight of a polymer (do Sul & Costa, 2014). Secondary microplastics are created when larger plastics eventually undergo some form of degradation and subsequent fragmentation and breakdown into smaller particles (e.g., water bottles). This breakdown is the result of exposure to environmental factors, such as the sun's radiation, known as photo-degradation and ocean waves, which is mechanical weathering (Chamas et al., 2020). The problem regarding microplastics is intertwined with other global issues like contributing to climate change through greenhouse gas emissions along the life cycle of plastics and microplastics (Garcia-Vazquez & Garcia-Ael, 2021). Microplastics may accelerate biodiversity decline, which is a global issue, because plastic particles cause harm to organisms across the trophic web, from plankton to top predators. Microplastics also pose a threat to human health, which is becoming a global concern. Though not well known yet, the prolonged ingestion of microplastics through diet is thought to enhance inflammatory responses and interrupt the gut microbiome (Eva Garcia-Vazquez, 2021). Microplastics entering the body through inhalation accumulate and are suspected of producing lung cancer. The accompanying toxic molecules which cause chemical and biochemical damage can affect the nervous system adversely (Garcia-Vazquez & Garcia-Ael, 2021).

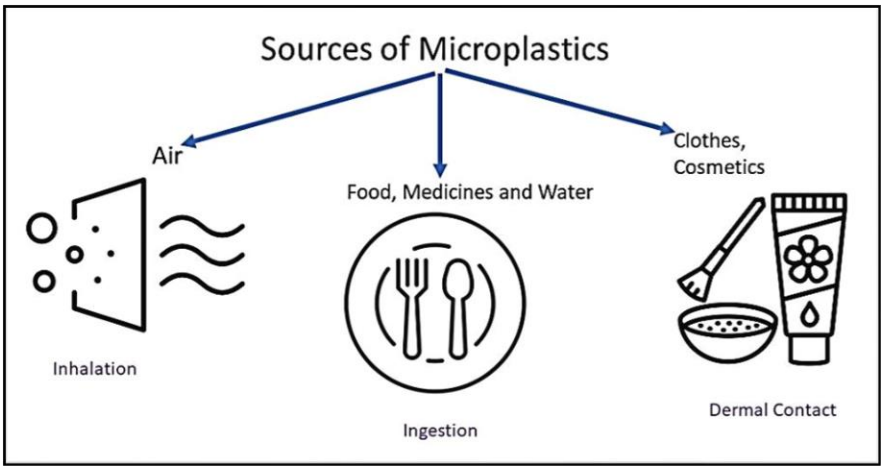

Figure 1. Different sources of Microplastics

Microplastics may come from landfills, sewage treatment plants, tire wear, paint failure, washing clothes and at-sea losses (Hale et al., 2020). Microplastics can be transported through the air (atmospheric) or water (riverine). In surface waters, microplastics weather, befoul,

aggregate, and sink, are ingested by organisms and redistributed by currents. Ocean sediments are likely the ultimate destination. Microfibers are continuously shed from the clothes or fabrics we use every day. Micro-beads from personal hygiene products like toothpaste and face scrubs make their way to the water bodies through sewage. Plastics, on degradation, release additives, concentrate environmental contaminants on their surface and work as substrates for biofilms, including exotic and pathogenic species (Hale et al., 2020).

Impact on human health:

Microplastics can be a risk to humans in three ways: physical, chemical and as a host for microorganisms to accumulate and breed on.

While there is no definite evidence currently linking microplastic consumption to human health, results from correlative studies in people exposed to high concentrations of microplastics, model animal and cell culture experiments, propose that effects of microplastics may include provoking the immune and stress responses and inducing reproductive and developmental toxicity.

Research on microplastics by the Food and Agriculture Organization of the United Nations (FAO) and the European Food Safety Authority (EFSA) concluded that large microplastics were likely to be excreted directly through faeces. In addition, the absorption of nano-plastics and chemicals found in plastics, including absorption into the organs, was limited.

Microfibers are consumed by organisms placed at the bottom of the food chain, such as plankton and mussels. It is predicted that microfibers accumulate up the food chain until it reaches humans - although this still needs to be researched.

Raman micro-spectroscopy has been recently applied to the image and identified three polypropylene particles between 5 and 10 µm in human placental tissue (Leslie et al., 2022). Microplastic particles were suggested to be reaching the placenta via inhalation or gastrointestinal translocation (Luís Fernando Amato-Lourenço, 2021). The effects of microplastics on essential human systems like the circulatory, respiratory, and gastrointestinal systems are elaborated in successive sections.

The circulatory system:

Environmental microcontaminant levels observed in venous blood samples are assumed to be representing the measurement of the entire bloodstream, including the microvascular system (Leslie et al., 2022). The distribution of plastic particles in blood differs depending on their sizes. Some tend to be localized in immune cells, while others may adhere to proteins, lipid particles, other plastic particles, or the vascular endothelium (Leslie et al., 2022). The fate of plastic particles depends on the mechanism of their elimination from the body, e.g., by renal filtration or biliary excretion or deposition in the liver, the spleen, or other organs (Leslie et al., 2022).

The plastic particles detected in the human bloodstream likely follow the uptake routes via mucosal contact (either ingestion or inhalation). Dermal uptake of fine particles is improbable

except if the skin is damaged. Airborne particles between 1 nm and 20 µm are respirable. Ultrafine (<0.1 µm) inhaled particles may become absorbed and accumulate in the lung, while most larger particles are expected to be coughed up and eventually swallowed and have a second chance of absorption via the gut epithelium (Leslie et al., 2022). Microplastics in the blood can cause inflammation, pulmonary hypertension, vascular occlusions, increased coagulability, and blood cell cytotoxicity. They may also reach the liver and kidney through circulation, which is responsible for metabolism and excretion. Continuous accumulation of microplastics in the renal cells after a certain threshold may lead to impaired renal function (Prata et al., 2020).

Respiratory system:

The human respiratory system is an exposure route to microplastics, and the lungs are a site of accumulation (Luís Fernando Amato-Lourenço, 2021). Due to the wide variety of sizes microplastics come in, they likely get inhaled by humans. Microplastics are detected in air and indoor and outdoor dust (Wibowo et al., 2021).

A study was conducted by Amato-Lourenço et al., (2021) by collecting pulmonary tissue samples (parenchymal tissue from the distal and proximal regions of the left lung) from 20 non-smoking adult individuals who underwent routine coroner autopsy at SaoPaulo City Death Verification Service of Sao Paulo University for the verification of cause of death. In thirteen out of twenty decedents, 31 synthetic polymer particles and fibres were observed, along with five natural polymer particles. Polypropylene was the most encountered polymer, followed by polyethene and cotton. Polypropylene and polyethene are in food packaging, automotive parts, sweets and snacks packaging, and currency notes. When used for apparel production, natural fibres are dyed and coated with flame retardants, reducing biodegradability (Amato-Lourenço et al., 2021).

The deposition of exogenous particulates in the lungs depends on size, charge, density, aerodynamic diameter, and flow rate. The number of fibres observed indoors is usually higher than in outdoor environments. Particles of sizes 1- 5 micrometres have the capability to reach the bronchial-alveolar regions (Amato-Lourenço et al., 2021). For fibres, this capability is regulated largely by the actual diameter, length, and density. Only fibres having a diameter smaller than 3 micrometres can reach the alveolar region. Pulmonary translocation to systemic circulation has been demonstrated for fine and ultrafine particles (Amato-Lourenço et al., 2021).

Gastrointestinal system:

The gastrointestinal tract is another possible site of microplastic entry in organisms (Amato-Lourenço et al., 2021). Human faeces were previously analysed with Fourier Transform Infrared spectroscopy (FTIR), providing evidence that microplastic particles can be excreted via the gastrointestinal tract (Leslie et al., 2022). Furthermore, human colectomy specimens

analysed using FTIR also detected plastic particles (Leslie et al., 2022). Usually, microplastics accumulate in the gastrointestinal system and larger plastic particles of about 20 µm accumulate across tissues.

Microplastic ingestion in invertebrates and fishes having harmful effects is demonstrated in laboratory experiments. Effects like physical damage and clogging of intestines, cracking of villi, endocrine disorders, immune responses and altered gene expression (Cao et al., 2021).

When exposed to polystyrene or polyvinyl chloride at certain concentrations, organisms like zooplanktons, crustaceans, and fishes show behavioural changes and decreased reproductive output (Cao et al., 2021).

Toxicity:

The toxicity of plastics depends on several factors, such as a particle's size, shape, texture, surface chemistry and charge, which governs its interactions with biological systems, including the formation of a protein corona on the particle surface. It is difficult to weigh the risks microplastics may pose for humans as each plastic is made up of a unique combination of chemicals. The same substance can have different effects depending on the concentration and how a person has been exposed to it (whether the plastic was consumed, inhaled, or injected). The rate at which the chemical is released is controlled by the interactions between the chemical and the plastic as well as its location in the body.

Studies show that microplastics may cause reduced energy intake and lead to negative energy balance due to increased energy consumption. They may also cause metabolic changes as secondary effects. In humans, microplastics may increase energy expenditure and decrease nutrient intake. Due to ethical constraints, studies on humans are limited, but the effects are thought to be similar as observed on fish and mice (Prata et al., 2020).

Microplastics have a chemically active, uneven surface with a large surface area which allows it to absorb a variety of toxic contaminants, such as organic compounds and heavy metals from the surroundings. Among the toxic contaminants absorbed by microplastics, heavy metals constitute most of the inorganic nature. Heavy metals interact with the nuclear proteins and DNA, causing damage to specific sites. After entering the environment once via natural or human activities, heavy metals keep accumulating through physical, chemical, and biological migrations (Cao et al., 2021). Microplastics act as vectors for heavy metals, transferring them along food webs and bringing potential hazards to organisms. It has been confirmed that microplastics have a high affinity for heavy metals in an aqueous medium in natural environments and rapidly adsorb heavy metals from nearby available metal sources. Adsorption of heavy metals on virgin microplastics without surface modification is negligible (Cao et al., 2021). The adsorption depends on multiple factors like types and characteristics of microplastics, chemical properties of the heavy metals and other environmental factors like soil pH, salinity, and background concentrations of pollutants (Cao et al., 2021). Additionally, microplastics' dose and particle size play a crucial role in metal absorption.

Two main sources of heavy metals in microplastics are found in the environment. Plastic manufacturing process where heavy metals like Cd and Zn are added to the polymers to improve their properties and performance act as the major source for heavy metals. Another important source is the surrounding environment, where microplastics can absorb heavy metals (Cao et al., 2021). Heavy metals like Cd occurs in association with zinc in nature. Kidneys trap the Cd ingested and eliminate it. Metallothionein, a body protein in the kidneys, effectively binds a small fraction of Cd and the rest in stored in the body, eventually accumulating. In excess ingestion of Cd, it replaces Zn at important enzymatic sites and causes metabolic disorders (Dey, 2022).

Sustainable alternatives:

Plastics have become ubiquitous in our day-to-day life. Plastics is the source of microplastics. The major source of plastics is fossil fuels like petroleum (Steinbuchel, 1992). Plastic manufacturing requires fossil fuels to exhaust the fossil carbon content and cannot be replenished. Also, non-biodegradability causes the accumulation of plastics to pollute the environment. There is an immediate need for sustainable alternatives to plastics to reduce the production of plastics, thus helping the problems it causes.

Scientist partially substituted petrochemical-based polymers with biodegradable ones due to the increasing environmental and economic challenges, forming Bioplastics. They can be made from different sources like cellulose, potato and corn starch, sugarcane and so on (Reddy et al., 2013). Thermoplastic starch is the most widely used bioplastic derived commonly from potatoes and maize. Pure starch can absorb humidity. It is mixed with plasticizers to make it more flexible. Its use in pharmaceutical products is remarkable. It is also used in the production of wrappers (Reddy et al., 2013). PLA or polylactides are bio-polyesters which closely resembles petrochemical-based plastics like polyethene and polypropylene. Lactic acid is the monomer precursor of PLA. It is produced from the fermentation of corn starch and sugarcane. The blends of PLA are used in making medical implants, packaging materials, bottles, cups and more. Poly-3-hydroxybutyrate (PHB) is a thin transparent film very similar to polypropylene, and is used in ropes, banknotes and packaging materials. It is usually made from sugarcane but new research shows water hyacinth can be an effective source of PHB. Polyhydroxy-alkanoate (PHA) are derived products of natural oils and sugars with the help of microbes. They are processed to form a variety of goods like packing materials, fibres, and water-resistant coating. Celluloid is one of the earliest thermoplastics used by humankind. It is a blend of camphor and cellulose nitrate (Steinbuchel, 1992), and is used to produce various articles like artificial textiles, car parts, buttons and many more (Reilly, 1991). Cellulose Xanthate is an inorganic ester of cellulose (Steinbuchel, 1992) where wood pulp (cellulose) is treated with a variety of chemicals in a series of processes and converted into spinnable filaments (Wilkes, 2001). It is used in making cellophane wraps and textile fibres such as rayon, etc. (Bajpai, 2018). Microbial cellulose produced by *Acetobacter xylinum* (Steinbuchel, 1992) closely resembles plant

cellulose and is being used for a wide range of products such as conductive membranes, temporary artificial skin, dietary fibres etc. (Mona et al., 2019). A high-fidelity equipment producer also uses it in Japan to manufacture headphone diaphragms (Steinbuchel, 1992). The above-discussed alternatives of plastics are summarized in table 1.

Table 1: Status of bioplastics and their application

Alternative	Abbreviation	Plastic it resembles	Source	Use	Reference
Thermoplastic starch	-	Polyethene	Potatoes, maize	Drug capsules, wrappers	(Reddy et al., 2013)
Polylactides	PLA	Polyethene, polypropylene	Corn starch, sugarcane	Medical implants, bottles	(Reddy et al., 2013)
Poly-3-hydroxybutyrate	PHB	Polypropylene	Sugarcane, water hyacinth	Ropes, bank notes, car parts	(Reddy et al., 2013)
Polyhydroxy-alkanoate	PHA	Polypropylene	Natural oils and sugar	Water-resistant coating, moulded goods	(Reddy et al., 2013)
Celluloid	-	Polyethene	Nitrocellulose + camphor	Photographic films, artificial textiles	(Steinbuchel, 1992); (Reilly, 1991)
Cellulose xanthate	-	Polyesters	Cellulose	Cellophane wrap, textile fibres like rayon	(Wilkes, 2001); (Bajpai, 2018)
Microbial Cellulose	-	Cellulose	*Acetobacter xylinum*	Temporary artificial skin, Headphone diaphragm	(Steinbuchel, 1992); (Mona et al, 2019)

Present day challenges:

Several types of raw materials are used to make bioplastics like plants, animals and microbial biomass. Scientists, engineers and business personnel are now dealing with some limitations in utilizing raw materials like the non-availability of high biomass, food crisis, and refinement of natural resources. Instead of all limitations, biodegradation and less human toxicity answer all challenges, no doubt.

Advantages:

Smaller Carbon Footprint:

The carbon footprint of a bioplastic is highly dependent on whether the plastic permanently stores the carbon extracted from the air by the growing plant. Plastic made from a biological source seizes the CO_2 captured by the plant in the photosynthesis process. Usually, bioplastic degrades into CO_2 and water in the natural environment with the influence of decomposers. But a permanent bioplastic, made to be similar to polyethene or other conventional plastics, stores the CO_2 forever. Even if the plastic is recycled many times, the CO_2 initially taken from the atmosphere remains sequestered (Arikan & Ozsoy, 2015).

Renewable resource:

Bioplastic is made from renewable resources like corn, sugarcane, soy and other plant sources, as opposed to common plastics, which are made from petroleum (Chen 2009).

Lower energy costs in manufacturing:

Bioplastic production uses less energy than conventional plastics. Generally, plastics are made from about 4% of the oil the world uses yearly. The manufacture of plastics becomes increasingly exposed to fluctuating prices of crude oil worldwide (Chen et al.,, 2021).

Eco-safety:

Bioplastic contains zero toxins and generates fewer greenhouse gasses (Chen et al., 2020). It helps reduce the global warming potential as bioplastics contribute clearly to the goal of mitigating GHG emissions with only 0.49 kg CO_2 being emitted from producing 1 kg of resin. This can be compared with the petrochemical counterparts, where 2 to 3 kg of CO_2 is produced from one plastic production unit (Chen, 2008).

Technical benefit

Bioplastics have improved printability, the ability to print a highly legible text or image on the plastic. Engineered bioplastics surfaces are smoother and printer-friendly than conventional plastics. It imparts less likelihood of imparting a different taste to the product contained in a plastic container. For example, milk will acquire a new taste in a styrene cup, but the bioplastic alternative has no such effect. Generally, bioplastics cannot tolerate much greater water vapour than common plastic can. As a result, bioplastic can not use to pack warm sandwiches, patties

etc. In the case of newly baked bread, a bioplastic container will offer a significant advantage in letting out excess vapour or steam. A bioplastic can feel softer and more tactile. For applications such as cosmetics packaging, this can be a major perceived consumer benefit. Furthermore, Bioplastics can be made clearer and more transparent (Jannah et al., 2019).

Disadvantages:

High costs:

It is considered that bioplastics cost two times more than conventional plastics. However, the amount of large-scale industrial production of bioplastics which will be more common in the future with the implementation of cost reduction, is expected.

Recycling issues:

Bioplastic material might actually contaminate the recycling process if not separated from conventional plastics. Infrared rays are used in plastic waste separation systems where bioplastics cannot be separated. These mixed plastics might be contaminated the system and bioplastics are not be recycled.

Reduction of raw materials:

Renewable resources are used to produce bioplastics which might reduce raw material reserves. Common starch food resources like potatoes, maize, etc., are valuable; utilising those food crops for bioplastic may initiate a food crisis (Lagaron & Lopez-Rubio, 2011).

Misunderstanding of terms:

The name bioplastics and related items are often misused by various companies to market their products. Usually “environmentally friendly”, “non-toxic”, and “degradable/totally degradable” like slogans are being used by manufacturers as a trick to sell the materials to the uninformed and overwhelmed consumers (Arikan and Ozsoy, 2015). All bioplastics are not compostable at home, like organic food waste. They usually require an industrial composting treatment that is unavailable at every composting site (Barker & Safford, 2009).

Lack of legislation:

Production of bioplastics is projected to increase to over 6.7 million tons by the year 2018, but still, now many countries have not used any law or legislation about their production, usage or waste management (Arikan and Ozsoy, 2015).

Current status of the bioplastics market in India:

Bioplastics play an important role in developing bioeconomy. Bioplastic is a growing market; it increases by about 20%~25% per year globally, and by 2020 it will increase to 25%~30% of the total plastic market. Developing countries like India's use of bioplastics will create new job opportunities. But Currently, the Bioplastics market in India is in an infant stage. Very few companies are operating in the bioplastic segment in India. Environmental awareness

programs, easy feedstock availability and government backing give major support to Bioplastics manufacturers in India. However, more initiative is needed for production, raw materials and technology development. The National Green Tribunal's state-level committee has set an August 31, 2019, deadline for the government to enforce the ban on plastic. Scientists across India were working on the development of bioplastics. A very recent development came from IIT-Guwahati, and the new bioplastic is under commercial production. Biogreen India's 1st Biotechnology Company for Bio-degradable Products. Truegreen, Plastobags, Ecolife, and Envigreen are already producing bioplastics in India. Many technological discoveries have boosted the Indian Bioplastics market and significant growth in the industry has been observed (Arikan and Ozsoy, 2015).

Conclusion:

Since the beginning of bulk plastic production in the 1940s, microplastic contamination of the environment has been a growing concern. Microplastics are in everyday products like face scrubs, toothpaste, and textiles. It is necessary to understand the role of microplastics and their contribution to human life to evaluate their potential contribution to the global disease burden. Although there are several studies conducted on the toxic effects of microplastics on model organisms like microorganisms, fishes and mice, there is very limited study on humans because of ethical and legal constraints. Plastic waste management is no doubt initiated lots of problems like increased greenhouse gas emissions, microplastic entering the human food chain, etc. Bio-plastics are considered a unique, sustainable alternative to plastic management. Thus, research and development in bio-plastics are much needed for better management of this problem. Policymakers, business houses and politicians have to play a crucial role in regularly using bioplastics.

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HOW TO CITE

Prokriti Saha, Riashree Mandal, Punarbasu Chaudhuri, Subarna Bhattacharyya (2022). Toxicity of microplastics in humans: A search for sustainable alternatives. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 43-54. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.004

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.005

Chapter- 5

Let's cut the ribbon of ribbon worm conservation with special reference to India: A review

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Keywords: Nemertea, Conservation status, Proboscis, Bio-active compounds.

Abstract:

Rhynchocoela, Nemertini, or Ribbon worms are non-segmented bilaterally symmetrical with long, soft and contractile bodies. The Indian subcontinent has only 8 species of Nemertea out of 1275 species worldwide to date. Due to their lack of direct impact on human society, they have been neglected thus far. There is now a clear understanding of Nemertea's importance in many fields, such as top predators in soft bottom communities, maintaining community structure, and serving as indicators. Now they are vanishing at an alarming rate. There are two species of Nemertea that have become extinct. In IUCN Red Data Book, there is no information about this phylum other than terrestrial Nemertea. An in-depth survey is needed to explore them, identify new species, monitor existing species and save them from extinction.

Introduction:

Nemerteans are bilaterally symmetrical acoelomates whose non-segmented body is covered with a ciliated epidermis. (Turbeville, 2002; Thollesson and Norenburg, 2003). They are often called Nemertea, Rhynchocoela, Nemertini, or ribbon worms. The presence of a long, eversible, muscular retractile proboscis lying in a fluid-filled body cavity known as rhynchocoel represents synapomorphy supporting monophyly of this phylum.The rhynchoel extends above the gut and is considered a true coelom. In anoplan nemerteans, the proboscis is either unarmed or provided with rhabdites. In enoplan species, the proboscis is armed by one (Monostilifera) or several (Polystilifera) needle-like stylets. The proboscis, although structurally independent of

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

the digestive system, is the key structure for capturing prey. Proboscis is also used against predators for defensive purposes.Marine nemerteans are distributed globally and settle in nearly each of marine ecosystems from shallow water to deep-sea bottom. Benthic species are slim and become flat dorsoventrally.They manifest the potential to stretch and contract their bodies considerably. They often are cryptic in habit and not frequently observed by non-specialists. Nevertheless, they have important effects as active predators, especially on molluscs, crustaceans and annelids (Roe, 1976; Thiel and Kruse, 2001; Caplins and Turbeville, 2012). The phylogenetic position of nemerteans among the metazoans is enigmatic and unsettled, although the evidence now points in the direction of attaching with protostome coelomates rather than having evolved from an acoelomate stock (Giribet et al., 2000). Recent studies support the hypothesis that phoronids (horseshoe worms) are their closest relatives within this group. Nemertean also seize the attention of different biological fields, such as regeneration (Coe, 1934; 1943), developmental biology (Martindale and Henry, 1995; Maslakova et al. 2004), genetics (Andrade et al. 2012; Chen et al. 2012), and pharmacology (Kem et al. 2006).

Distribution of Nemertea:

Nemertea is a worm with global distribution. They live in all marine ecosystem and Some Nemertea are found in fresh water ecosystem also.There are approximately 1275 species of Nemerteans distributed across 250 genera, most of which are found in marine environments (Kajihara et al. 2008). According to a recent study, Anopla accounts for approximately 38% of known genera and 44% of the named species, while Enopla accounts for approximately 62% and 56% respectively. The number of known freshwater nemerteans is very small; only 22 reported species represents less than 2% of the total number recorded. Only 13 terrestrial nemertea have been reported so far. In India, only 8 species of nemertea is found (Sreeraj, 2020). There are 2 species that bear stylets and others that do not have any (Paleonemertea-1, Heteronemertea-5, Hoplonemertea-2).

Order	Species	Distribution in India
Paleonemertea	*Balinonemertes australiensis* (Sundberg et al. 2003)	Tamil Nadu (Gulf of Mannar Biosphere Reserve).
Heteronemertea	*Gorgonorhynchus repens* (Dakin and Fordham, 1931)	Tamil Nadu (Gulf of Mannar Biosphere Reserve)
	Gorgonorhynchus sp. (Shrinivaasu, 2016.)	Tamil Nadu (Gulf of Mannar Biosphere Reserve).
	Cerebratulus gardineri (Punnett, 1903)	Lakshadweep (Minicoy Island)
	Evelineus mcintoshii (Langerhans, 1880)	Kerala (coast of Thiruvananthapuram)
	Baseodiscus hemprichii (Ehrenberg, 1831)	Lakshadweep (Minicoy Island), Tamil Nadu (Gulf of Mannar Biosphere Reserve), Gujarat (Gulf of Kachchh)
Hoplonemertea	*Prosadenoporus buergeri* (Punnett, 1903)	Lakshadweep (Minicoy Island)
	Dinonemertes investigatoris (Laidlaw, 1906)	Lakshadweep.

Role of Nemertea:

Modern society pays more attention to organisms based on their contribution to ecosystems and their direct benefits to society. Until the importance of any organism is recognized, it is neglected. While organisms of many phyla are rich in important knowledge and resources, we are unable to uncover the importance of neglected organisms. Nemertea is such a phylum that has been overlooked till now as they have no direct impact on human society. But now, importance of Nemertea is well documented in many fields. Below is a discussion of their importance:

Maintain community structure as a top predator:

Predation impacts the structure of infaunal community in intertidal areas (Peterson, 1979; Reise, 1985). Decreasing the number of epibenthic predators leads to an increase of endobenthic species and individual numbers. As an predator nemertea plays an important role to maintain the structure of soft botto communities.Nemerteans act as common predators in a wide variety of marine habitats. Benthic nemerteans prey on different prey organisms, primarily polychaetes and crustaceans (McDermott and Roe, 1985), but some scavenges on recently dead organisms (Hines et al. 1990; Thiel, 1998). Among marine predators, nemerteans are unique in that they are very slow-moving in nature, primarily relying on their rapidly everted proboscis and presence of highly potent toxins. Furthermore, their chemosensory system is strongly developed, permitting them to remain on the trail of a prey item once 'smelled the rat' (Amerongen and Chia, 1982). For this reason, nemerteans may play a vital role in marine habitats in which they occur in high abundance. In order to capture their prey, Nemerteans sat and waited at a particular location. As a result of their body shape and feeding strategy, Nemertea can access habitats that are inaccessible to many other predators. They squeeze themselves through the smallest openings and crevices. Nemerteans preferentially prey on organisms that are well protected from other predators such as decapod crabs, fish and birds (e.g., polychaetes in deep burrows or solid tubes, amphipods between blue mussels, sea grass plants, or algal holdfasts.

As an Indicator Species:

Quantifying pollutants in aquatic habitats is challenging for researchers. Man's economic well-being depends heavily on the marine environment. Biological indicator species are now used to quantify aquatic pollution in order to better understand pollutant loading and its subsequent bioavailability in marine ecosystems. Biological availability of metal in the marine organism determines how much metal is uptaken through their body. However, one group of marine invertebrates with considerable potential for use in such monitoring has to date, received little attention. The organisms belong to the phylum Nemertea, a ubiquitous component of most shorelines' shallow-water fauna and intertidal zones. There are several species of Nemertea that secrete large quantities of mucus when irritated, such as Emplectonema gracile, Lineus longissimus, etc. Mucopolysaccharides can bind with ionic

elements in seawater, similar to ion exchange resin. Mucopolysaccharides can bind with ionic elements in seawater, similar to ion exchange resin. Considering the epidermis' ability to secrete significant amounts of mucus and its high metabolic activity, it could serve as an initial barrier to heavy metal absorption.Accumulation of metals in the mucus could afford protection against potentially toxic levels, whilst at lower ambient concentrations, nemertean could be used as indicator species for particular elements. Protection of this nature may confer a competitive advantage to these organisms in conditions of increasing pollution loading.

Source of Toxin :

In Nemertea, proboscis and epidermal mucus mediate toxicity to predators and prey. Certain nemertean species are known to contain remarkably potent toxins: pyridine alkaloids, tetrodotoxin (TTX), and cytolytic or neurotoxic peptides. The Concentration of toxins is high at the anterior proboscis. In Hoplonemertea, there is a stylet associated with a sac of toxin at the outermost tip of the proboscis. The papillary structure of epithelial cells of probosicis secrets toxin and glue-like substance. Some of these substances seem to be capable of dissolving tissue.Hoplonemertines possess a family of pyridine compounds that affects the nervous system (Kern, 1985). First isolated pyridine, anabaseine, stimulates nicotinic receptors.Two other substances, 2,3' -bipyridyl and nemertelline (a tetrapyridyl) were also isolated. TTX is relevant for the characterization of sodium channels and has promise as a drug candidate; it is expected that nemerteans will supply TTX on a large scale. DMXBA has been extensively investigated in pyridine alkaloids, and its medicinal potential is still under investigation. As for peptide toxins, the use of the α-nemertides in pesticide applications appear feasible. It is difficult to predict the outcome of nemertean toxins, but it is clear that they provide an intriguing addition to the field of toxin research.

Food source:

The proximate analysis of Nemertean muscles represents 15.44% crude protein, 8.71% crude lipid, 69.74% moisture and 6.11% ash . The percentage of crude protein in Nemertean flesh is moderately elevated. Analysis of lipid contents of muscles and food sources of Nemerteans have revealed that the muscles of *Cerebratulus bengalensis* contain the highest amount (2.39%) of total lipids (TL) while detritus exhibited the lowest amount (0.18%). Fractional components of fatty acids of TL showed that food components of Nemerteans included an appreciable amount of α- linolenic acid (ALA). Muscles of Nemerteans have shown to contain 9 different types of MUFAs and 12 different types of PUFAs. Among PUFAs arachidonic acid (AA, 20: 4ω6) registered highest amount (5.00%) followed by eicosatrienoic acid (ETE, 20:3ω3) 4.48%, docosahexaenoic acid (DHA, 22:6ω3) 2.89% and so on. However, mangrove leaves did not reveal the occurrence of AA, ETE and DHA. The quantity of linoleic acid (LA, 18:2ω6) exhibited moderate to the high amount (1.84% - 49.50%) in different studied samples (Samanta et al. 2018). Some species can be used as fish bait, e.g.,*Cerebratulus lacteus*, *Malacobdella* sp., and *Ototyphlonemertes brevis*, as well as *Polybrachiyorhynchus dayi.*

Table 1: Percentage of Total Lipid (TL) obtained from various body parts of *Cerebratulus bengalensis* and its primary food sources (Samanta et al. 2018).

Sample	Amount taken	Total lipid obtained	Percentage of total lipid (w/w)
Nemertean muscles	5.23 gm.	125.34 mg.	2.39
Plankton	2.80 gm	23.6 mg.	0.84
Mangrove leaves	16.3 gm	28.1 mg	0.17
Detritus	9.63 gm	14.2 mg.	0.15

Conservation of Nemertea:

Despite knowing about the importance of biodiversity for a long time, human activity has been causing massive extinctions. Our planet is now in the midst of its sixth mass extinction of plants and animals. We're currently experiencing the most severe spate of species die-offs since the extinction of the dinosaurs 65 million years ago. Although extinction is a natural phenomenon, it occurs at a natural "background" rate of about one to five species per year. It is estimated that we are now losing species at a rate 1000 to 10000 times faster than the background rate.On a daily basis, dozens of species disappears. It could be a scary future indeed, with as many as 30 to 50 percent of all species possibly heading toward extinction by mid-century. 99 percent of currently threatened species are at risk from human activities, primarily those driving habitat loss, introduction of exotic species, and global warming. Because the rate of change in our biosphere is increasing, and because every species' extinction potentially leads to the extinction of others bound to that species in a complex ecological web,the numbers of extinctions are likely to snowball in the coming decades. The International Union for the Conservation of Nature (IUCN) maintains the Red List to assess the conservation status of species, subspecies, varieties, and even selected subpopulations on a global scale.Extinction risks outpace any conservation successes.

Table 2. Little information about the status of nemertea in Red Data Book. In Red Data Book only six species of terrestrial Nemertea are categorized in the following category.

Species Name	Status (According to IUCN Red Data Book)
Prosadenoporus Agricola	CR
Argonemertes stocki	DD
Geonemertes rodericana	EX
Antiponemertes allisonae	EN
Katechonemertes nightingaleensis	VU
Argonemertes hilli	LC
CR-Critically Endangered, **DD**-Data Deficient, **EX**-Extinct, **EN**-Endangered, **VU**- Vulnerable, **LC**-Least Concern * But there is no information on the status of aquatic Nemertea in Red Data Book.	

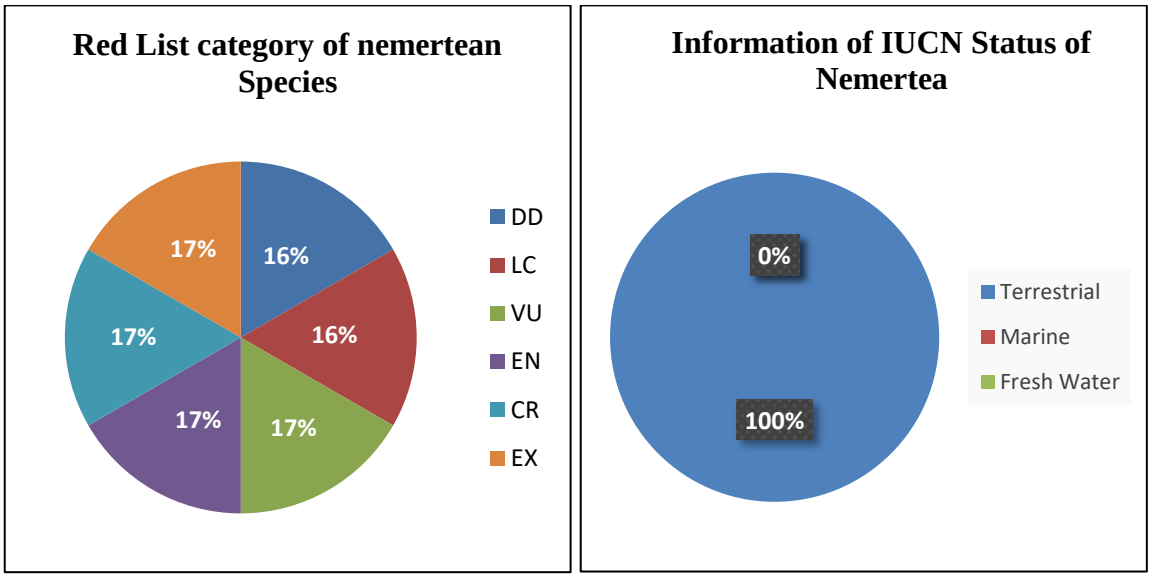


Figure 1. Red list category of Nemertean species and its ICUN status.

Interesting Features:

Nemertea is poorly known to the general public and research on nemertean biology and ecology is limited. However, the phylum includes some remarkable species, including *Parborlasia corrugatus* which is the major scavenger on the sea floor in Antarctica. Having reached 50 meter in length, *Lineus longissimus* is the longest animal on earth.They have a remarkable power for contraction and relaxation. They can extend upto 5-7 times than their original body length. In this case anoplan Nemertea is more suited than enoplan Nemerteas. Papillary epithelial cells of Nemertean proboscis secrets a glue-like substance that is effective even under water.

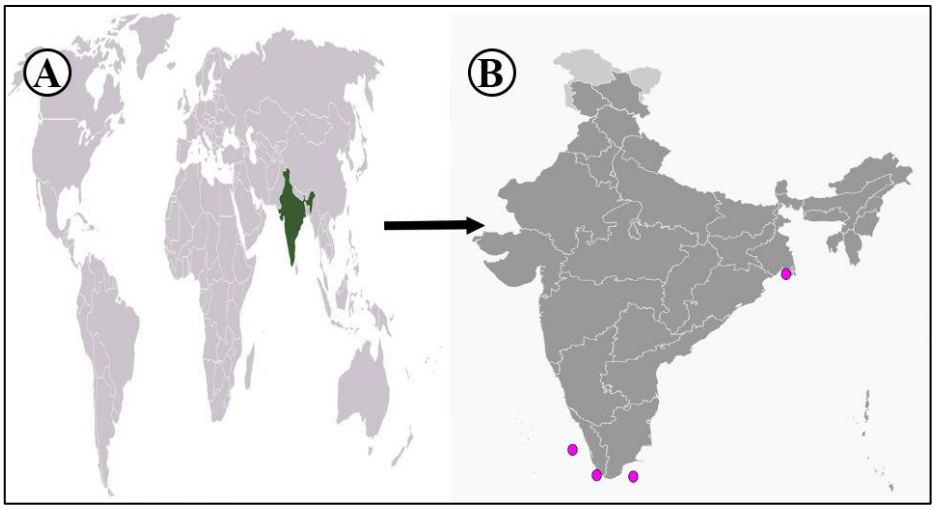


Figure 2. (A) Position of India on global map. (B) Violet spot shows the Nemertean distribution in India

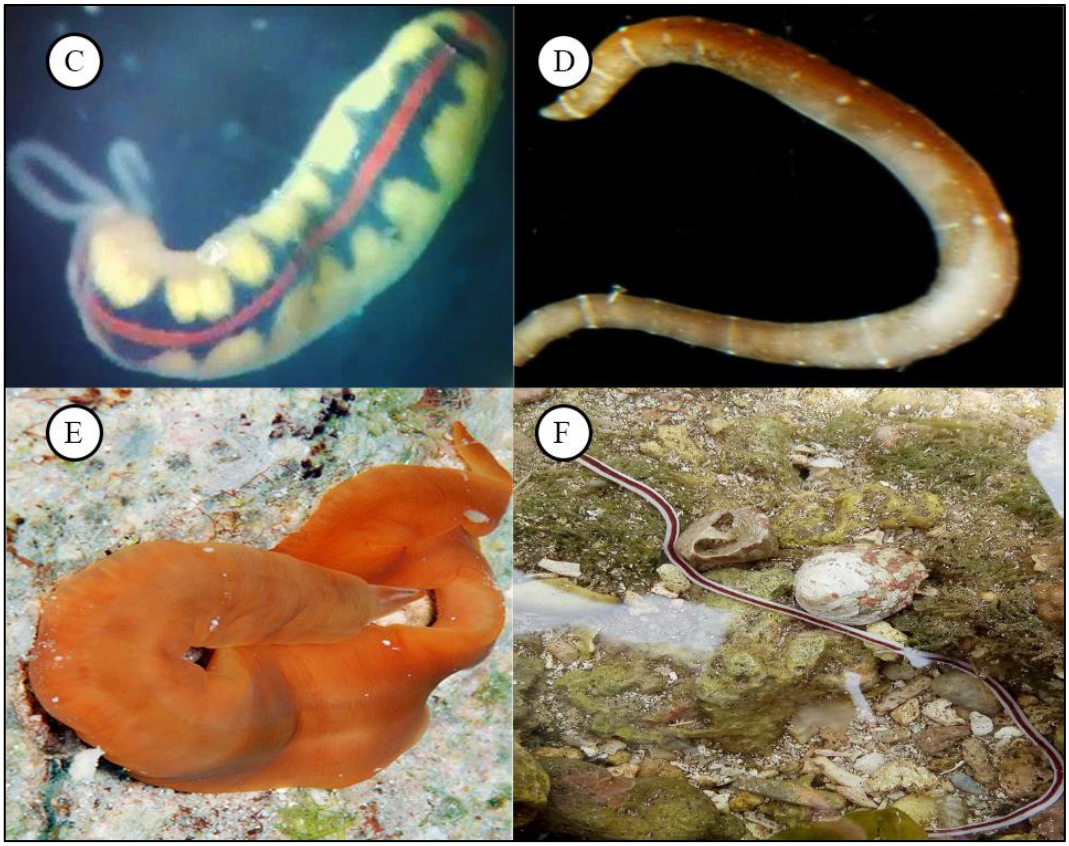


Figure 3. (C-F) Four nemertean species found in India, Evelineus mcintoshii Balionemertes australiensis, Gorgonorhynchus repens, Baseodiscus hemprichii respectively.

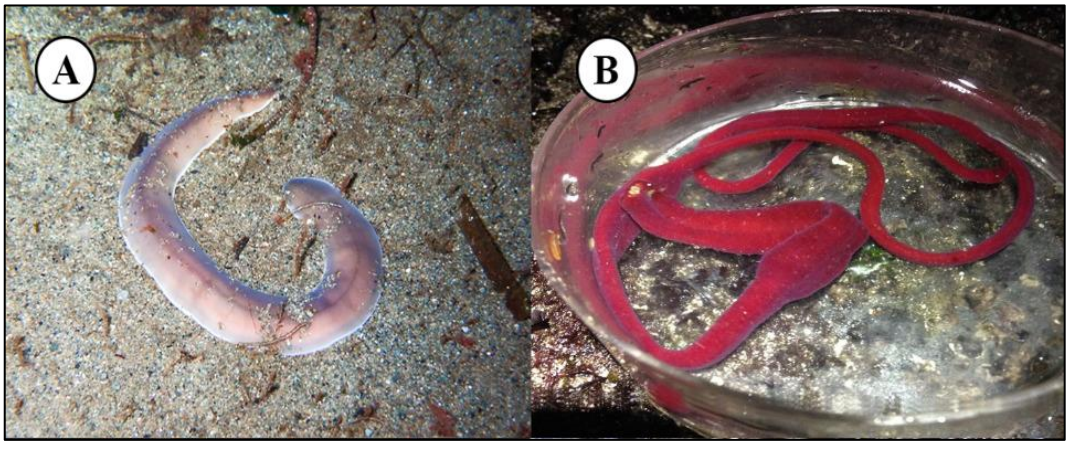


Figure 4. (A) *Cerebratulus marginatus* (B) *Kulikovia montgomeryi*

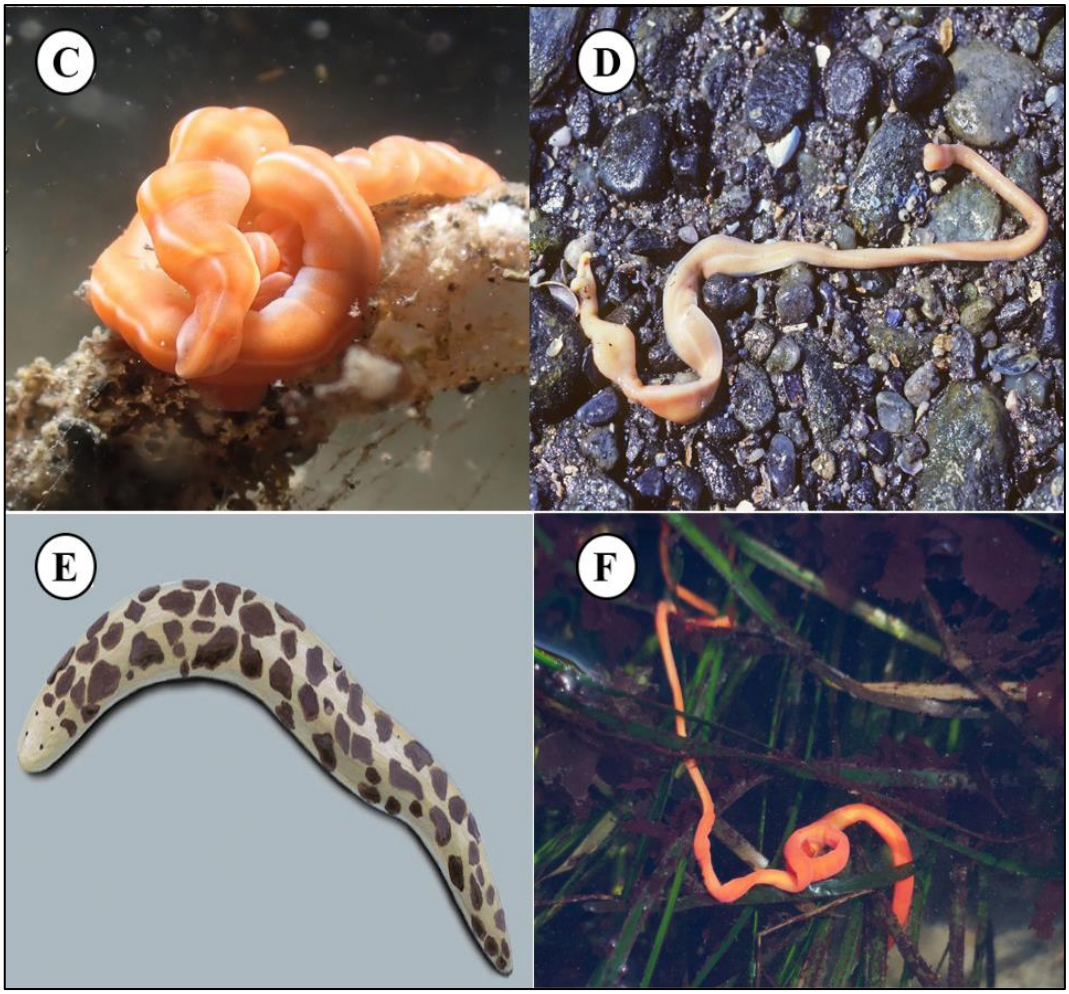
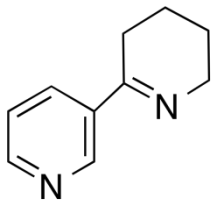
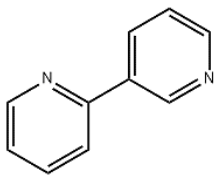
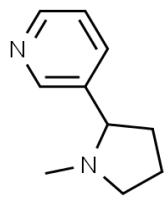


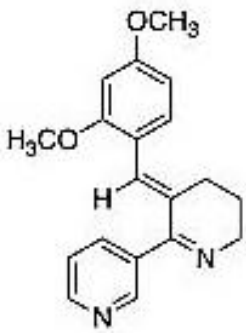
Figure 5. (C) Quasitetrastemma nigrifrons (D) Cerebratulus lacteus (E) Oerstedia dorsalis (F) Tubulanus polymorphus

Some bioactive compounds found in Nemertea

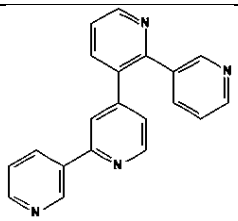

Anabaseine

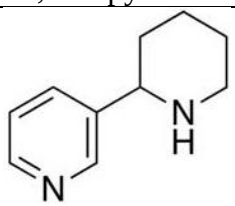

2,3'-Bipyridine


(-)-nicotine

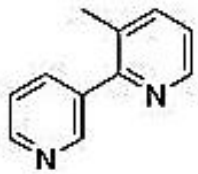


DMXBA (GTS-21)


Nemertelline



Anabasine



3-methyl-2,3'-bipyridine

Conclusion:

The contribution of Nemertea to human society is very limited. Therefore, they caught little attention. Although they are rich in resource, we are unable to extract them. Nemertean represents the source of bioactive compounds, given that only less than 5% of the world's ribbon worm species have been analysed for toxin content to any extent. There is also a geographical limitation to these efforts. Sampling has been carried out at a limited number of sites globally. They are currently facing a huge threat of extinction. *Prostoma jenningsi* has been listed in the Red Data Book as a taxon under threat from habitat usage.It is crucial to determine whether nemertea numbers decreases rapidly in the background due to anthropogenic forces and other unknown factors.So, we should monitor the existing species and find a new ones and protect them from the threat of extinction.

Acknowledgement:

The authors are thankful to Science and Engineering Research Board, India (SERB) for providing financial support to Coastal Environmental Studies Research Laboratory, Egra SSB College, for supporting with instruments and library facilities.

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HOW TO CITE

Soumik Dhara, Biplab Mandal, and Sudipta Kumar Ghorai (2022). Let's cut the ribbon of ribbon worm conservation with special reference to India: A review. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 55-65. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.005

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.006

Chapter- 6

Environment, Education and sustainable development

Somnath Das

Keywords: Environment, Sustainable development, Education

Abstract:

The process of development is education. The totality of all external factors that affect human life and the growth of other living things is known as the environment. Every living thing has a unique environment. Both the natural and sociocultural environments make up man's environment. In order to achieve the desired modification of his own behaviour, education may change and improve the quality of man's environment (awareness, attitude shift, etc.). Education deals with the different issues and rules influencing pupils' interactions with their surroundings. The school develops this and the teacher, both formally and informally. Education is Human Ecology, which examines how people and their environment interact in the context of human growth and development. Sustainable development is the ultimate goal of "mankind," according to UNESCO.

Introduction:

Environmental education deals with environmental knowledge, whereas educational environment concerns teaching concepts and education. Together, they create awareness, which may influence a change in attitude and ultimately create a healthy atmosphere. The public's attitude toward the environment has seen a significant metamorphosis during the past few decades. Education is a distinct area of study focused on the growth process (teaching-learning, training and instruction). It emphasises overall growth. The environment's biological and physical elements contribute to and impact social and economic transformation. The environment is a comprehensive world perspective as it exists at any given time, with numerous spatial components and socioeconomic systems.

Environment and sustainable development:

The ability of people to live in peace and harmony on earth for an extended period is known as sustainability. Therefore, as per ACARA, the goal of education for sustainability is to develop the knowledge, skills, beliefs, and worldviews required for people to act in ways that support a sustainable pattern of living.

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

Education for sustainability:

This educational strategy aims to provide students the principles and drive to act sustainably in their own lives, their communities, and on a global scale, both now and in the future.

Education and sustainable development:

It strives to increase understanding of sustainability challenges as well as educate students and schools that can engage in critical thinking, ingenuity, and the provision of solutions that lead to more sustainable living habits. Where we live, which means we use fuel, energy, natural resources, etc., from our local environment, the interaction between the environment and sustainable development is the main determinant in preserving sustainability.

Environment and Education:

The process of development is education. The environment is the culmination of all external factors and affects the survival and growth of people and other living things. The habitat is unique to each organism. Both the natural and sociocultural environments make up man's environment. To achieve intended behaviour modification, education may alter and enhance the quality of man's surroundings (awareness, attitude shift, etc.). Education addresses the many issues and rules controlling the interactions between students and their surroundings. The school develops this and the teacher, both formally and informally.

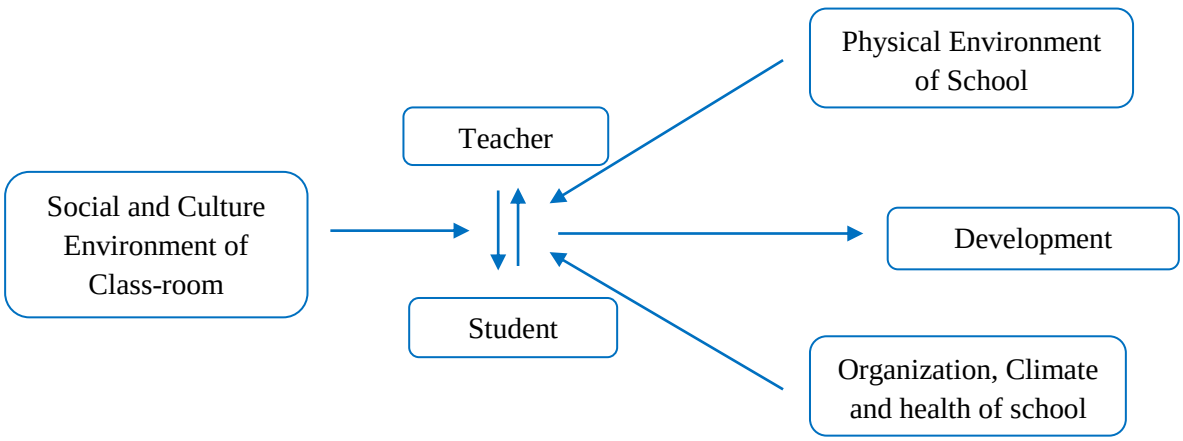

Figure 1. Education is Human Ecology, which examines how people and their environment interact in the context of growth and development

Meaning of Environmental Education:

Environment education is problem centred, interdisciplinary, value-oriented, community-oriented, and concerned with man's survival as species, based on student-initiated activities and involvements of present and future-oriented.

Preparing the individual and communities for life involves understanding the key issues arising from the interaction of the individual and communities' biological, physical, social, economic, and cultural components. It offers the knowledge, abilities, and attitudes needed to contribute positively to life's advancements and the principles necessary for people to lead healthy, fulfilling lives. Sustainable

development and environmental education are both conceptualised differently. This idea has an impact on how environmental educators are defined and applied. Creating responsible societies is the ultimate goal of these interconnected aspects of modern education, and sustainability is one of the anticipated results. Speaking of accountability and sustainability now seems unnecessary. Environmental organisations have used the idea of sustainable development to support education.

Environment and Education :

The process of development is education. The environment is the culmination of all external factors and affects the survival and growth of people and other living things. The habitat is unique to each organism.

Environmental awareness through Education :

Environmental education is a continuous process for the advancement of civilization and the welfare of humanity (Fig. 2). It is intended for all age groups taking part in the town's social, economic, and cultural growth. Groups or clubs organise exhibitions, public talks, meetings, and environmental initiatives. We require fresh approaches to environmental education in the form of graduate and professional programmes that place a strong emphasis on practise. There are three types of environmental education: informal, formal, and non-formal. Here, we can connect our overall knowledge development to a topographical idea of the environment.

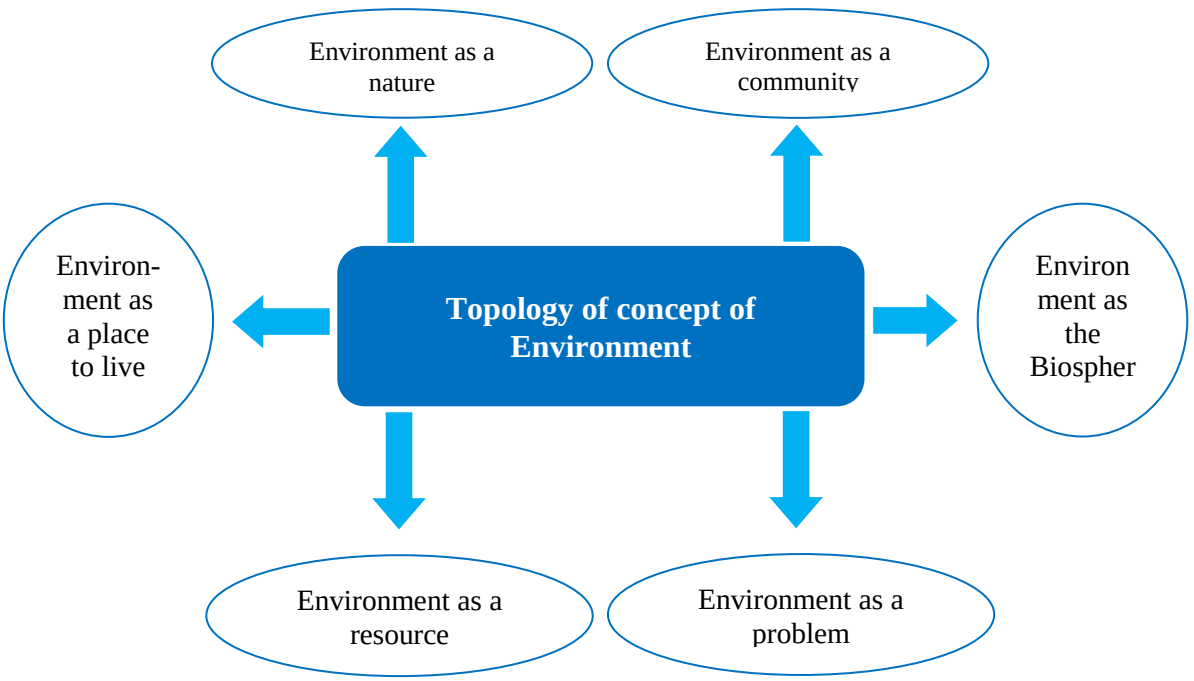

Figure 2. Topology of concept of Environment

Conclusion:

India's environmental situation is quite diverse in terms of its climate, geology, and geography. Fantastically in terms of flowers, ethnicity, language, society, and economy. India is a very diversified nation. As a result, environmental education must be largely regional. First-level female residents, who

make up around 50% of the population should receive special attention. Health, family planning, and nutritional development must be made known to them. Slum improvement, sanitation, hygiene, access to water, prevention of contamination, and other factors. Non-Governmental Organizations ought to have a big part. Approximately 200 private organisations are listed in the Department of Environment's Directory as working in nearly 150 different fields related to environmental education and awareness. Children should also be taught the true meaning of wildlife. Most kids only think about tigers and lions.

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HOW TO CITE

Somnath Das (2022). Environment, Education and sustainable development. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 66-69. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.006

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.007

Chapter- 7

Impact of some selected organophosphate pesticides on non-target fish species

Goutam Biswas

Keywords: Organophosphate, Toxic, Sublethal effect, Fish

Abstract:

Pesticides are important for protecting agricultural crops against harmful pests. However, pesticide usage has become a serious issue of concern as they cause severe damage to the ecosystem and environment. Organophosphates are one of the most extensively applied insecticides in agriculture. Agricultural runoff containing pesticide-laden effluent ultimately pollutes the aquatic environment. Pollutants introduced to aquatic ecosystems are absorbed by various flora and fauna, including fish, causing harmful effects and mortality. The LC50 values of a few organophosphate pesticides in several fish species and other investigations relevant to sublethal toxic effects such as haematological, biochemical, histopathological, and behavioural alterations were reviewed in this article.

Introduction:

Pesticides are harmful toxic substances used to kill, reduce, or restrict the growth of certain target organisms known as pests (Aktar, 2009). In the agricultural field, they are commonly used because of their quick and successful action and also to increase crop output (Popp et al., 2013). Apart from safeguarding crops, pesticides have become a serious issue of water pollution. Extensive use of pesticides causes severe damage to the ecosystem and environment (Murthy et al., 2013; Samal et al., 2017; Dey and Dey, 2022). Agricultural runoffs carrying a variety of pesticide residues damage the groundwater and neighbouring aquatic bodies. Regardless of where it occurs, pesticide contamination is expected to eventually end up in aquatic environments (Fırat et al., 2011; Mondal et al., 2022). The majority of pesticides have various half-lives and are difficult to break down. They persist for long periods in the soil, sediments, and aquatic environment (Ramaswamy et al., 2007). Due to the restriction on organochlorine pesticides, farmers in tropical nations like India are increasingly turning to organophosphate as a viable option. Organophosphate insecticides have become the most popular as they are cheaper and have little environmental persistence (Özcan Oruç et al., 2006; Banerjee et al., 2021). Soil samples collected from several agricultural farms in India revealed residues of various organophosphate pesticides such as chlorpyriphos, malathion and quinalphos (Kumari et al., 2008).

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

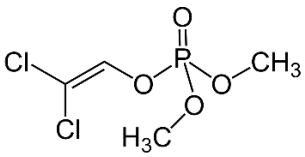
Organophosphates are a powerful neurotoxin and block synaptic transmission Imetaln cholinergic neurons by suppressing AChE activity. These pesticides are toxic to fish and other non-target aquatic animals and have been associated with various detrimental effects on development, physiology and behaviour (Saha et al., 2017). They can cause parasympathetic disorder and possibly death if taken directly (Van Cong et al., 2008). Some of the organophosphates are very dangerous and recognized as hazardous classes (1a and 1b) by World Health Organization (Kumar et al., 2016). According to recent studies, just 0.1% of pesticides applied on agricultural land are efficient, whereas the remaining 99.9% contaminate water, land, and the air, eventually being taken by non-target organisms (Zhang et al., 2011). When these toxicants enter water bodies at much higher concentrations than acceptable limits, the environment becomes hostile for all aquatic organisms, resulting in high mortality for all fish and shellfish. Lower concentrations of these toxicants cause sub-lethal effects on multiple organs and bioaccumulation, eventually reaching humans via the food chain (Xie et al., 1996; Morel et al., 1998; Abedi et al., 2013). In this article, selected organophosphates such as profenofos, dichlorvos, chlorpyrifos induced hazardous effects in different fish species are taken into consideration.

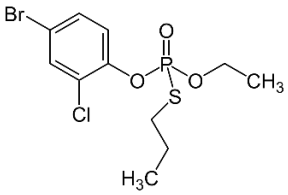
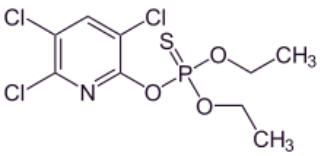
Direct impact:

Pesticides cause a variety of sublethal toxicity in fish, including changes in fish behaviour, changes in the architecture of tissues, blood parameters, changes in histopathological architectures (Das et al., 2000; Rani et al., 2014), changes in enzyme function and different biochemical components, genotoxicity, interruption in endocrine function (Gupta et al., 2015), and changes in the antioxidant enzyme (Rani et al., 2014). When a fish is exposed to a pesticide, various organs display distinct sorts of harmful effects. The gills, liver, and kidneys were shown to be the organs with the most impact in several investigations. Some of these changes have been detailed in the following under different subheadings to make it more comprehensive.

LC50 Value of some organophosphate pesticides:

Several researchers have studied the acute toxicity and other impacts of different organophosphates on various commercially important fish species. The following are a few of them:

Pesticides	Chemical Class	Fish Species	Duration	Measured LC50 value
Dichlorvos 	Phosphate	*Anabas testudineus*	96 hours	2.35mg/L (Patar et al., 2015)
		Aphanius iberus	96 hours	3.17mg/L (Varó et al., 2018)
		Clarias batrachus	96 hours	0.07ml/L (Gautam, 2013)
		Channa punctatus	96 hours	0.024ml/L (Wokoma, 2019)
		Cirrhinus mrigala	96 hours	20mg/L (Srivastava et al., 2014)
		Cyprinus carpio	96 hours	0.95mg/L (Tak et al., 2014)

		Labeo rohita	96 hours	0.11mg/ml (Rao et al., 2017)
		Heteropneustes fossilis	96 hours	6.4mg/L (Ahmad et al., 2013)
Profenofos 	Phosphorothiolate	*Channa punctatus*	96 hours	2.68 µg/L(Pandey et al., 2011)
		Labeo rohita	96 hours	0.1mg/L (Khan et al., 2018)
		Catla catla	96 hours	0.0079ppm (Maharajan et al., 2013)]
		Cyprinus carpio	96 hours	62.4 µg/L (Ismail et al., 2009)
		Oreochromis niloticus	96 hours	0.435 mg/L (Bhatnagar et al., 2015)
Chlorpyrifos 	Phosphorothionate	*Cirrhinus mrigala*	96 hours	0.44 mg/L (Bhatnagar et al., 2017)
		Labeo bata	96 hours	109.64µg/L (Samajdar et al., 2015)
		Cyprinus carpio	96 hours	0.160 mg/L (Halappa et al., 2009).
		Puntius chola	96 hours	0.219mg/L (Verma et al., 2013)
		Labeo rohita	96 hours	442.8µg/L (Ismail et al., 2009)

Behavioural Changes:

Indian major carp *Cyprinus carpio* treated with a sublethal concentration of chlorpyrifos showed loss of schooling behaviour, swimming independence, lack of co-ordination in movement and localised to the bottom of the test tank (Halappa et al., 2009). According to one study, rainbow fish subjected to chlorpyrifos displayed behavioural aggression, rapid water gulping, fast movement of the operculum, and unpredictable abnormal swim pattern. Fishes were increasingly agitated, stressed, lethargic, and showed hyperactivity before death (Sharbidre et al., 2011). Fish treated with profenofos exhibited hyperactivity, greying colouration, erratic swimming, and profuse mucous production on the body and gills before dying (Pandey et al., 2011). *Oreochromis niloticus* displayed frantic movement, loss of balance, and death following exposure to low concentrations of dichlorvos. At a higher dose of toxicant, a period of inactivity was seen, then a phase of air gulp and finally death (Mallum et al., 2016). *Clarias*

gariepinus exposed to low concentrations of dichlorvos displayed unusual behavioural patterns, including restlessness, quick circular motions, flipping on the back, and increased mucous production on the body (Ogamba et al., 2014).

Haematological Changes:

Organophosphate insecticides have been proven to induce deadly impact on different hematological parameter, cytological changes in blood corpuscle (RBC. WBC), changes in hemoglobin (Hb) levels, mean cell volume (MCV) and volume percentage of RBC or haematocrit (Hct). For chronic toxicity analysis, tilapia fish treated with a sublethal dose of profenofos (1/10 of LC50) exhibited a sufficient increase in total white blood cell count and a huge fall in red blood cell count, marked decline in haemoglobin content and hematocrit percentage (Sharafeldin et al., 2015). *Oreochromis niloticus* subjected to dichlorvos treatment for 96 hours revealed a significant decrease in packed cell volume, haemoglobin, erythrocyte, and leucocyte count, as well as the lowest haematocrit (Hct) values (Mallum et al., 2016). *Channa punctatus* was treated with two sublethal chlorpyrifos dosages and its mean erythrocyte, leukocyte, haemoglobin, and hematocrit values were lowered (Ali et al.. 2012). Changes in haematological indicators such ESR rate were seen in *Channa punctatus* treated with chlorpyrifos. Increasing chlorpyrifos dose and exposure increases ESR rate (Malla et al., 2009). When compared to control fish, *Cyprinus carpio* treated with chlorpyrifos for 24 hours had lower RBC (-72.43%) and haemoglobin (18.35%) and more WBC count (+57.94%). (Ramesh et al., 2008). Blood glucose rose and Total Count increased very high after sublethal exposure to nuvan (dichlorvos) for 45 days in *Labeo rohita* compared to the control value, whereas total Hb dropped (Das et al., 2001).

Effects in Acetyl cholinesterase (AChE):

Acetyl cholinesterase activity is a good biomarker for pesticide exposure, particularly organophosphates. 66% brain AChE inhibition was seen in *Poecila reticulata* treated with a sublethal chlorpyrifos concentration (Sharbidre et al., 2011). Dichlorvos treatment for 40 days with three sublethal doses (0.47, 0.047, 0.0047mg/L) on AChE activity in Anabas testudineus tissues revealed lower AChE action in the liver, kidney, gills and brain. After 20 days, when fishes were withdrawn to fresh water, restoration of AChE in the liver, kidney, brain and gill was found (Patar et al., 2015). In research involving different age groups of chlorpyrifos-treated tilapia, brain tissue exhibited a higher degree of enzyme inhibition than the liver. After being moved to clean water, most exposed fish recovered their AChE activity. The liver tissue restored its function faster than the brain. Recovery of AChE activity in tiny fish was much faster than in larger fish. The degree of recovery is inversely proportional to the length of exposure (Rath et al., 1981). AChE enzyme isolated from the Amazonian fish *Colossoma macropomum* at low dichlorvos treatment concentrations showed 18% enzyme inhibition. An exponential reduction in AChE function was recorded after incubation with high levels of dichlorvos dosage (Asis et al., 2007).

Biochemical Changes:

Three sub-acute concentration dosages of profenofos were taken to inspect biochemical alteration on *Catla catla* and a significant dose-dependent drop in total protein, carbohydrate, and cholesterol levels were observed (Jagadeesana et al., 2012). Significant decline in liver glycogen, protein, lipid, alkaline phosphatase, and acid phosphatase levels and elevation in serum glutamic oxaloacetic transaminase and

serum glutamic pyruvic transaminase levels, were seen in *Channa punctatus* treated to pesticide nuvan at 0.024ml/L for 4 days (Kumar, 2014). *Heteropneustes fossilis* exposed to nuvan with varied sublethal doses for consecutive 60 days show a progressive reduction in total protein and albumin content but a rising bilirubin level was observed with a steep elevation on the last day of investigation. A dramatic increase in urea and creatinine levels was also observed (Ahmad et al., 2013). *Oreochromis mossambicus* was treated with different sublethal doses of dichlorvos for three weeks and decreased levels of tissue glycogen, protein, and albumin levels in gill and muscle were found (Lakshmanan et al., 2013). In an investigation, organophospahte nuvan exposed *Clarias batrachus* group compared to the control level of cholesterol declined exceedingly and a rise in glucose and urea level was observed with the substantial increase in AST and ALP enzyme levels (Gautam et al., 2013). *Heteropneustes fossilis* exposed to significant sublethal doses of Chlorpyrifos and hypocalcemia is observed in fish [58]. Sub-lethal dose of chlorpyrifos for 30 days revealed alterations in thyroid hormones in *Heteropneustes fossilis*. Significant decline in blood TSH, T3 and T4 hormone levels revealed diminished thyroid gland function (Khatun et al., 2014). Dichlorvos induced acute toxicity on *Danio rerio* was determined by providing various dosages during 24-h, 48-h period and the result revealed total protein content and lipid peroxide levels were elevated in brain tissue. In contrast, sodium dismutase and catalase enzyme levels became lower. The glutathione peroxidase activity reduced drastically in the different treatment groups (Usharani, 2013). *Oreochromis niloticus* chlorpyrifos exposure caused reduced levels of oestrogen and testosterone. The levels of estradiol also dropped after 15 days of exposure. Cortisol hormone levels reduced significantly when the concentration of chlorpyrifos was increased compared to the control (Oruç, 2010).

Histopathological Changes:

The effects of toxicants, particularly chronic ones, can be quickly detected by changes in histological architecture in various tissues and organs. *Channa punctatus* subjected to a sublethal dose of nuvan, after 24 hours the liver showed increasing sinusoid space, cirrhosis, mild necrosis, fat accumulation, cytoplasmic granule deposition, and shrinkage. 48 hrs. later, tissue necrosis, sinusoid inflammation, and ischemic symptoms were observed (Kumar et al., 2016). After two sublethal doses of nuvan in *Cirrhinus mrigala*, degenerative alterations in the epithelium of the gill filament and secondary gill lamellae were observed. It was discovered that the secondary gill lamellae showed thickening and the epithelium of gill filaments was associated with adjoining secondary lamellae. In epithelium, there was also a significant decrease in the density and area of mucous-producing goblet cells (Srivastava et al., 2014). Rainbow trout exposed to chlorpyrifos to investigate histopathological damage in gill and liver tissues hyperaemia and severe liver damage were also found hyperaemia of gill lamellae, oedemas, clump formation, cellular damage, overgrowth, and decaying of all gill tissues observed (Topal et al., 2003). *Oreochromis mossambicus* subjected to a sublethal dose of chlorpyrifos displayed terminal bulge formation on secondary lamellae, lesions, and demolished base of lamellae. A dense layer of mucous coat on the gill filament was also observed (Rao et al., 2003)

Genotoxicity:

Phenmenon of nuclear abnormalities in the erythrocytes of the fish *Cirrhinus mrigala* subjected sublethal dose of chlorpyrifos was evaluated using the micronucleus (MN) test and the formation of micronuclei was observed. The existence of nuclear abnormalities was marked by changes in cell shape,

broken eggs and large micronuclei (Bhatnagar et al., 2016). A substantial dose-dependent increase in the creation of micronuclei inside the erythrocytes was found in *Clarias gariepinus* treated with sublethal concentrations of dichlorvos for for 28 days (Oladokun et al., 2020). Comet assay was used to study the toxicity of dichlorvos in *Mystus vittatus* and considerable DNA damage was found (Shukla et al., 2010). Comet assay and RAPD analysis was done on profenofos exposed *Channa punctatus* in a semi-static system, revealing a sub-lethal dose of profenofos can induce considerable DNA damage compared to the control (Pandey et al., 2018).

Conclusion:

Fishes are a crucial biotic component of aquatic ecosystems and the most nutritious vertebrate food to humans, rich in protein, fatty acids, and vitamins. They are extremely valuable for economic, nutritional, medicinal, and industrial purposes. Organophosphate pesticides in aquatic environments create many sublethal impacts on fishes, such as in behaviour, histopathology, haematology, biochemical alteration, inhibition of AChE enzyme activity, endocrine system, genotoxicity etc. Research on various natural plant extracts that can reduce these pesticide-induced adverse effects in fish should also be encouraged. Furthermore, there is a possibility that these pesticides can contaminate the food chain and end up in humans. So, it might be concluded that extreme caution must be taken while using organophosphate pesticides in farming activities, particularly those conducted close to aquatic habitats, to reduce their negative impacts on aquatic biota and the environment.

Conflict of interest:

None

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HOW TO CITE

Goutam Biswas (2022). Impact of some selected organophosphate pesticides on non-target fish species. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 70-79. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.007

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.008

Chapter- 8

Culicoides species: The Biting Midges

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Keywords: *Culicoides*, insect vector, environmental changes, disease emergence

Abstract:

The haematophagous flies known as Culicoides are important carriers of veterinary and human arboviruses. Since 1998, dramatic changes took place in epidemiology as number of global disease cases associated with vector Culicoides was increasing. In temperate locations, this epidemiological shift also contributes to the appearance of exotic viruses. These epidemiological changes are the result of changes in the climate, land use, and animal husbandry. This haematophagous dipteran is a vector for numerous arboviruses that are significant for both veterinary and public health. Although there are important gaps in our knowledge of geography, biology, and taxonomy, recent advances in genomics, molecular biology tools, and methodologies will help us fill those gaps. We explore their life cycle, ecology, phylogeny, and classification in addition to their role as carriers.

Introduction:

Small biting midges in the family Ceratopogonidae are flies of the genus *Cullicoides*. These flies have significant role in medicine, veterinary medicine, and economics because they stress their hosts and spread disease through their blood-feeding behaviour. Numerous species in the genus serve as biological carriers of important pathogens for human and animal health (Bagchi & Saradar, 2021; Ivanišová et al., 2022). This role garners the genus substantial attention. Over 50 arboviruses have been isolated from *Cullicoides* species in addition to various protozoan and nematode species, and their role in the transmission of veterinary (Borkent, 2004; Meiswinkel et al., 2004b; Mellor et al., 2000) and human (Carpenter et al., 2013; Linley, 1985; Debnath, 2020; De & Dey, 2019).) pathogens has been reviewed. Tourism, forestry, and agricultural industries may be negatively impacted by *Cullicoides* feeding opportunistically on humans (Mellor et al., 2000).

Morphology:

About 1-3 mm long, adult insects are tiny and black. In males, the antennae are longer (15 segments) and more thickly haired than in females. The two wings have thick hairs that provide

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

distinct colouring patterns. Biologists utilise these wing patterns to distinguish between different species. The bases of the 15 segmented antennas are more or less continuous with the enormous compound eyes. The Johnston's organ is located in the pedicel of the males' antennae. While both men and females consume nectar, only females consume blood, which is necessary for the maturation of fertilised eggs. In general, females bite during twilight or dawn, frequently in large swarms, and usually close to water, marshes, or decaying vegetation.

Adult head:

The head bears enormous compound eyes. They are barely separated, and the degree of separation can serve as a species-level distinguishing characteristic. The arched supraorbital suture, which is present between the eyes in some species (like the subgenus *Avaritia*), is lacking in other species (Battle and Turner, 1971). *Cullicoides* have significant antennae that include taxonomic, phylogenetic, and ecological data. On the antennae of *Cullicoides*, there are five different types of sensilla that serve as chemoreceptors and mechanoreceptors (Wirth and Navai, 1978).

Flagellomeres having Sensilla coeloconica (functions as mechanoreceptor and chemoreceptor) have been extensively employed in the development of the *Cullicoides* classification and are important from a taxonomic perspective. Sensilla like these are signs of host association. The majority of species with Sensilla coeloconica on 4-6 flagellomeres are mammophilic, while those with sensilla on 8-13 flagellomeres are typically ornithophilic (Jamnback, 1965; Chu-Wang et al., 1975; Braverman and Hulley, 1979; Felippe-Bauer et al., 1989; Blackwell et al., 1992). These sensilla coeloconica reacts to carbon dioxide and humidity, according to Blackwell et al. (1992). The maxillary palps on either side of the proboscis are an important source of ecological and taxonomic data. The palps of Cullicoides have five segments. There are several sensilla basiconica on the third segment (referred to as capitates sensilla in some of the literature, e.g., Borkent, 1995). Females have palps with larger, more developed third segments due to sexual dimorphism.

The third segment's length to width ratio, as well as the size and depth of the sensory pit or region, provide taxonomically useful information. It was established that the sensilla basiconica are sensitive to changes in carbon dioxide concentration, an essential cue in host location (Grant and Kline, 2003). Sensilla count is correlated with host size and can indicate host relationships (Rowley and Conford, 1972). Adult mouth components are extended into a proboscis that is made up of the labrum, mandibles, hypopharynx, maxillary laciniae, and labium from anterior to posterior. Information on the ecology can be gleaned from the structure of the mouth parts. Typically, non-biting species lack lacinial, labral, mandibular, and hypopharyngeal teeth (Borkent, 1995).

Thorax:

The legs, wings, and halters of the pro meso and meta thorax, as well as the sclerites, form the thorax. The prominent pre scutal pits have been employed as a diagnostic characteristic for

the genus, according to Downes and Wirth (1981), but it was discovered that this property is difficult to discern and found in other genera. For species diagnosis, the colour pattern of the scutum, scutellum, and post-scutellum are employed. The characteristic of important taxonomic relevance in *Cullicoides* is the pattern of bright and dark spots on the wings. The length and colouring of the macrotrichia on the wing surface produce these patterns (Blanton and Wirth, 1979). These patterns offer the current *Cullicoides* subgeneric classification scheme. A leg is composed of six segments i.e. coxa, trochanter, femur, tibia, basitarsus, tarsus.

Abdomen:

Segments II through VII of the abdomen's ten segments contain spiracles (Downes and Wirth, 1981). Male terminalia were reported to possess a variety of taxonomic and phylogenetic characteristics.

Life cycle:

Cullicoides are holometabolous. For completing their life cycle they need two to six weeks, depending on the species and the surrounding circumstances. Typically, male *Culicoides* emerge before the females do, and they are prepared to mate when the females leave the pupal stage. Mating occurs during flying.

Egg:

Males and females consume nectar, the females need blood for the development of their eggs. Depending on the amount of the blood meal, different species lay different numbers of eggs.

Larvae:

Larvae are not exclusively aquatic and terrestrial; they need air and water. Moisture is necessary for their development. The larvae can be found in and near muddy substrates, mangrove swamps, and salt marshes. The larval habitat in the tropics is found in rotting fruit, bromeliads and other water-holding plants, cattle waste, and pond edges. The larval stage can last between two weeks and a year, depending on the species, local climate, and other factors. Some larvae can grow in damp, manure-contaminated areas, but they do not grow inside the animal (Mullen, 2002).

Pupae:

Normally, the pupal stage lasts between two to three days.

Public health and veterinary impact of *Cullicoides:*

Cullicoides is an important human and animal pest with major economic impact and is a key vector for the development of various diseases. The saliva of some *Cullicoides* species can cause horses to have severe allergic reactions, causing painful sores (Van der Riit et al., 2008). It was discovered that their significance for veterinary or public health stems from their role in

the transmission of pathogens, particularly viruses, but also protozoans and filarial parasites like avian hamosporidians (Veiga et al., 2018; Chagas et al., 2018) and *Tetrapetalonema* sp. (Carpenter et al., 2013 ; Yates et al., 1982; Lowrie et al., 1978; Linley et al., 1985).

They are the most prevalent hematophagous vectors for 66 viruses, including the Blue tongue virus (BTV), the epizootic hemorrhagic disease virus (EHDV), the African horse sickness virus (AHSV), and the equine encephalitis virus (EEV), as well as 15 species of protozoans and 26 filarial nematodes, and they are also in charge of causing allergic reactions in hosts all over the world (Borkent, 2004; Mullen, 2009). Monitoring of diseases spread by biting midges is being done in numerous nations across several continents. In the Indian states of Andhra Pradesh, Assam, Gujrat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Nagaland, Punjab, Rajasthan, Sikkim, Tamilnadu, Tripura, Uttar Pradesh, and West Bengal, it was discovered that they are in charge of spreading livestock diseases (Mehrotra et al., 1991; Kulkarni et al., 1992; Prasad et al., 1992; Joardar et al., 2016; Chand et al., 2015).

Diseases caused by *Culicoides* are closely related to climate and weather. The seasonal pattern of virus transmission in temperate areas occurs during the hot, humid summer and fall months. High rates of vertebrate infection have been observed in tropical and subtropical locations during wet summers, but transmission rates decline during dry seasons (Braveman et al., 1996). Several articles claimed that though midges may only fly a few hundred metres, the wind can spread them passively over a very large area (Carpenter et al., 2001; Hunt et al., 1994). High humidity of more than 80% aids adult midges in their reproduction, and this climatic condition affects their vector competence, according to Halder et al. (2016). According to research by Joardar et al. (2016), *C. oxystoma* and *C. schultzei* were shown to be possible carriers of the bluetongue virus and the epizootic haemorrhagic sickness virus among the *Cullicoides schultzei* complex that had been gathered from various agroclimatic zones of West Bengal. A thorough description of the ecology, breeding locations, and biology of immature and adult organisms is still missing.

Ecology:

The *Cullicoides* genus is found all over the world. Each species of biting midge needs a different ecological environment. Many different species of biting midges are mostly produced in areas with significant salt marsh habitat. Highly organic soil with significant manure loads from swine, sheep, and cow farming activities are additional supplies for some species. These insects don't establish themselves inside of buildings, houses, or inside of people or other animals. Under a range of environments, including damp, muddy regions, faeces, and plant waste, midges breed in moist conditions. The removal of organic debris from these places and drainage of muddy areas are crucial components of the *Cullicoides* control approach. High lignin content in silage residue was favourably correlated with the development of *C. obsoletus* and *C. scoticus* larvae (Zimmer et al., 2013b). The two main areas of interest in studies on the ecology of adult midges are (1) seasonality and (2) activity and blood feeding. Though certain

species exhibit bimodal activity, one at dawn and the other at night, the majority of *Cullicoides* are active around dusk (Blanton & Writh, 1979). (kline and Roberts, 1982). In temperate locations, the population of many species peaks in the spring, with some species persisting throughout the summer (Blanton and Writh, 1979). A secondary peak in some species' populations occurs in the fall after their spring peak (Kline and Axtell, 1979). To find hosts, biting midges use a variety of indicators. Carbon di oxide is one of the most significant indicators. Carbon dioxide is released during vertebrate exhalation, which prompts female midges to fly upwind in the direction of the source (Bhasin et al., 2000). The midges react by acting erratically and failing to fly upwind if the concentrations above a certain level (Bhasin et al., 2000). Even after feeding on vertebrate hosts, blood-fed females were recovered more frequently at 10m above ground than at ground level (D.A. Swanson unpublished data). The distribution of adult midges is strongly determined by the larval habitat because they rarely move far from these areas. *Cullicoides* larvae can be found in a range of aquatic and semiaquatic environments. Higher organic loading is a favourable indicator of the habitat for *C. variipennis*, *C. sonorensis*, and *C. nubeculosus* larvae (high phosphate, % organic matter, and nitrate) (Meigen, 1830, Schmidtmann et al., 2000; Uslu and Dik, 2010). Members of the *C. variipennis* complex are distributed in areas with high salt ion concentration (Schmidtmann et al., 2000).

Phylogeny:

Within the genus *Cullicoides*, the phylogenetic relationship has to be revised. The genus has been classified into subgenera and species groups by numerous writers (Root and Hoffman, 1937; Edward et al., 1939; Fox, 1948, 1955; Vagus, 1953; Khalaf, 1954). 35 subgenera of *Cullicoides* were recognised by Borkent and Wirth in 1997. The way that species are now classified is based on their overall similarity. The relationship between the subgenera was first examined by Khalaf (1954), however these connections were based on phenetic similarities rather than cladistic synapomorphies. Recent research has concentrated on using molecular traits to infer phylogenetic relationships, such as nuclear ribosomal DNA and mitochondrial DNA (Dallas et al., 2003; Nolan et al., 2007; Pages et al., 2009 ; Gomulski et al., 2005; Perrin et al., 2006; Matsumoto et al., 2009; Schwenkenbecher et al., 2009).

There have been some attempts to break up this vast genus into smaller subgenera. These groupings have been identified by adult morphological characteristics, while Glukhova (1977) also employed larval characteristics. The initial division theory was put forth by Root and Hoffmann (1937) and Edward et al. (1939) using characteristics of male genitalia and female spermathecae. The phylogeny of *Cullicoides* has recently been tested using a variety of markers. Studies employing internal transcribed spacer 1 (Mathieu et al., 2007), 2 (Gomulski et al., 2005), or in combination (Matsumoto et al., 2009), as well as studies combining data from cox1 and cox2 analyses, are also successfully employed to study the phylogenetic relationship. Insightful information about taxonomic investigations is being provided by the combined use of

molecular markers and mitochondrial DNA, and this information is offering guidance for future research.

Taxonomy:

More than 1400 species of the genus *Cullicoides* are found globally (Borkent, 2012a). It was discovered that the requirement to identify females and medicinal and veterinary concerns have spurred the taxonomic investigations of the genus. As a result, even though males offer more diagnostic features to identify species, many identification keys are written for females. The taxonomy is further complicated by the lack of complete identification keys for all biogeographical zones and the numerous species that still require descriptions. One must check numerous regional keys, subgeneric keys, and species group keys in order to identify the specimen.

It is difficult to pinpoint immaturity down to the genus level. The only family of nematocerous Diptera lacking a key to genera for the larvae or pupae is Ceratopogonidae (bortkent and Grogan, 2009). For young *Cullicoides*, there is currently no complete species key. It was discovered that research on the immature stages can help with ecological studies, disclose cryptic species, provide phylogenetic features, and provide information for vector management and surveillance. Similar to the adults, pupal *Cullicoides* have not been the subject of extensive investigations that include a wide variety of species and geographies. Although the pupal stage is the most well-known of the juvenile stages, there is still much to learn about the biology and taxonomy of many *Cullicoides* species. The taxonomy of larvae still requires a lot of investigation. We need to increase our understanding of larval taxonomy in order to comprehend larval ecology and potential phylogenetic traits.

Kieffer (1910) conducted the first taxonomic investigation on *Cullicoides*, which was followed by Patton (1913), Dover (1921), Edwards (1922), Smith (1929), Mukherji (1931), Smith and Swaminathan (1932), and Macfie (1933). Sen and Dasgupta (1959); Dasgupta (1962) examined the Indian *Cullicoides* fauna in and around Kolkata after a protracted hiatus. In several regions of West Bengal, taxonomy research on numerous Cullicoides species has recently been ongoing.

In order to identify and describe new species, Dasgupta and colleagues researched the taxonomy, biology, and ecology of *Cullicoides* species in India (Sen and Dasgupta, 1958, 1959; Dasgupta, 1961, 1995). Sen and Dasgupta conducted a survey at Presidency College in Kolkata (West Bengal). Although there is no information on their biology in this area, *Cullicoides imicola*, *C. actoni*, *C. fulvus*, and *C. brevetaris* have also been identified in India (Dasgupta, 1995). 6 new species of *Cullicoides* were discovered on a cattle farm in the coastal saline districts of Howrah, North, and South 24 Parganas in West Bengal, according to Mukhopadhyay et al. (Mukhopadhyay et al., 2017).

Although a relatively small number of studies have taken into account characteristics of juvenile stages in their evaluations, Borkent (2014a) emphasised that the subgeneric classification of Cullicoides is almost totally phenetic, generally of adult specimen (Glukhova,

1977; Nevill and Dyce, 1944; Nevill et al., 2009). The vast bulk of *Cullicoides* taxonomy investigations relies on morphological examinations. Many people believe that the introduction of molecular entomology for systematics offers a quick substitute for the development of traditional taxonomic competence (Tautz et al., 2003).

The small size of the specimen, a poorly defined subgeneric classification, the absence of descriptions for con-specific life stages and sexes, the lack of phylogenetic data, intraspecific variation in diagnostic morphological characters, the identification of potentially synonymous species, and a lack of agreement on defining appropriate intraspecific genetic distances are some of the major difficulties the *Cullicoides* taxonomists are facing. Without finding a solution to these issues, it will be impossible to precisely define the geographic range of many species, and we will only have scant knowledge of their regional distribution and seasonal patterns of abundance. Understanding the association between species richness and climate, latitude, landcover, terrain, host availability, and seasonality would benefit from proper specimen identification (Andrew et al., 2013).

DNA characterisation and other developments in molecular entomology offer fresh perspectives and motivation for comprehending morphological and functional disparities within the genus *Cullicoides*. Molecular and morphological analysis have already been shown to be coherent (Gomulski et al., 2005; Pages et al., 2009; Pages et al., 2005), demonstrating that both techniques can aid in the investigation of phenotypic plasticity. Their usage in investigations into morphologically related species, such as those in the subgenus *Avaritia*, has begun (Bellis et al., 2014a; Mathieu et al., 2007; Pages et al., 2005).

Key knowledge gaps:

Because of their tiny size, the scarcity of principle vector species' colonies, and the relatively minor impact of *Cullicoides*-borne animal disease agents in affluent nations, research on *Cullicoides* has lagged.

Geographical gaps:

The most recent waves of arbovirus transmission in Europe have reignited interest in *Cullicoides* across the globe. However, there is still a dearth of fundamental survey data in huge regions, especially the tropics (Africa, Asia, and South America). *Cullicoides* arbovirus transmission is likely steady and endemic in tropical areas. Rare reports of outbreaks may be due to local animals' mutual adaption to these viruses. The ability to comprehend epidemiology is severely hindered in endemic tropical zones due to a lack of epidemiological data.

Parameter gaps:

Researchers can characterise parameter gaps using vectorial capacity. It's important to look at host biting behaviours. The host biting rates of immature midges are ultimately influenced by environmental factors, and further research is required to identify the factors that regulate the

density of these populations at different stages. To understand transmission dynanics, complex and opposite interactions between vectorial capacity parameters are need to be studied.

Ecological knowledge gap:

The inability to comprehend *Cullicoides*' distribution and the mechanisms controlling their abundance is still hampered by a lack of knowledge about their biology. Various moist microhabitats are used by *Cullicoides* for oviposition and larval development. Although the value of more natural habitats is less researched in relation to virus vectors, many of these habitats are located in close proximity to live cattle. Except for a few new morphological descriptions, there is little current research on *Cullicoides* pupae (Ronderos et al., 2013). Pupal ecology has largely been disregarded. We need to learn more about the *Cullicoides* larvae, including their eating habits, winter behaviour, and interactions with other environmental factors. Then we will be better able to comprehend their population dynamics and distribution, their control methods. Predicting the possible ranges of vector species may be aided by research into how eggs, larvae, and pupae react to environmental conditions.

Taxonomy:

Taxonomy of the embryonic stages of *Cullicoides* lags much behind than that of the adults. Only 3% of *Cullicoides* species are known as eggs, 13% as larvae, and 17% as pupae, according to Borkent's (2014) analysis. While the immature stages of a few more *Cullicoides* species are still being described (Ronderos et al., 2010), the majority of species lack even the most fundamental morphological descriptions.

Genetics:

Cullicoides are still difficult to describe on a global scale. Expert morphological identification is being used to identify the fauna of South and Central America, India, North and Central America, and Russia. Although some of the most esteemed taxonomists in the history of *Cullicoides* research have been sponsored by these areas, it is obvious that fundamental revisions utilising genetic and morphological methodologies will be necessary. As it has recently been perceived, the advent of molecular marker sequencing also permits routine study of the source of blood meals in *Cullicoides* as a means of inferring host-preference (Martinez-de la Puente et al., 2015).

Genomics:

The interactions between vectors, viruses, and hosts have been revealed by emerging genomic technologies. The recent application of approaches based on genomics are now exclusively applied to the North American vector *C. sonorensis*, has been a significant advancement since 2003. Innate immunity and developmental biology in *C. sonorensis* have already been studied using transcriptomic studies (Nayduch et al., 2014b) (Nayduch et al., 2014c). Additionally, work on *Cullicoides'* first complete genome has begun. Despite the fact that the majority of current research focuses on *C. sonorensis*, it is expected that in the coming

decades similar techniques will be applied to other species and that entomologists, geneticists, and bioinformaticians will collaborate more frequently.

Conclusion:

Uneven research on *Culicoides* has led to information gaps. The biology of adult midges has received more research, while several elements of survival, resting site choice, and dispersal strategy have received less attention. The immatures of *Culicoides* require additional work (taxonomy and detail ecology) to be done. A comprehensive review of the *Culicoides* fauna of the Indian subcontinent was not included in the authoritative taxonomic review of the *Culicoides* fauna of the oriental region (Wirth WW, Hubert AA. 1989), and the *Culicoides* fauna of India has only occasionally been the subject of morphological studies. West Bengal is the home of 62 of the 78 *Culicoides* species that have been recognised as existing in India based on morphology (Sen and Dasgupta, 1958, 1959), Kolkata and the surrounding areas (Sen and Dasgupta, 1962), Assam and Bengal and other parts of India (Sen and Fletcher, 1962), Chennai (Jayalakshmi, 1966), Marathwada region of Maharashtra (Narladkar et al., 2009). But the majority of India has very little information available. Additionally, only a single DNA barcode from a single place can be used for molecular DNA analysis of the Indian *Cullicoides* fauna. DNA barcoading is a popular genetic technique used to research biodiversity and identify species (Hebert et al., 2003). To comprehend the morphological and biological studies of the Indian *Culicoides* fauna, additional molecular research is required.

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HOW TO CITE

Shrinka Ghosh (2022). *Culicoides* species: The Biting Midges. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 80-91. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.008

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.009

Chapter- 9

Sustainability and sustainable development

Kabita Kundu

Keywords: Sustainable, Economic, Environmental, Development, Goals, Protection, Concept

Abstract:

The ability to "maintain some thing, outcome, or process over time" is the precise definition of the phrase "sustainability", which also refers to the practice of engaging in activities that do not deplete the resources upon which that capacity is dependent. At the United Nations Conference on Environment and Development (UNCED), often known as the Rio Conference, which took place in 1992, a clear discussion on sustainable development evolved. A solution should be provided by sustainable development in terms of providing fundamental human needs, integrating environmental development and conservation, attaining equality, ensuring social self-determination and cultural variety, and preserving the integrity of the natural system.

Introduction:

The traditional view of development considers economic expansion to be synonymous with development. It views the transition from a traditional agrarian civilization to an industrialized society with high consumption as a sign of development and emphasises this movement. The overall rise of humanity over the past few decades, humanity's overall rise has had a severe influence on the environment and has led to conflicts and instability on political, socioeconomic, and economic fronts (Endress et al., 2005; Ramsey et al., 2015; Purvis et al., 2019). It has created a threat to the continued existence of the human species on this planet. Because of this, we have been forced to rethink our approach to the concept of development (Dasgupta, 2007). In today's parlance, "development" refers to a process that should result in improving people's overall quality of life and an expansion of the ability of economies to support themselves. Since the 1970s onward, people have been making efforts to manage resources in a more rational and efficient manner, with the goal of reducing the strain and influence they have on the environment. Within the context of the notion of sustainable development, this mode of development is understood to refer to an approach that will guarantee the productive use of resources over the long term without

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

putting the wellbeing of future generations at risk (Barbier, 1987; Williams et al., 2004; Shulla et al., 2020).

The Brundtland Report, which the World Commission compiled on Environment and Development, is the document that is credited with being the first to introduce the idea of sustainable development (1987). Brundtland gave the definition of sustainable development as "development that meets the demands of the present without sacrificing the ability of future generations to satisfy their own needs." Brundtland was a Norwegian politician. The United Nations Environment Programme published another definition of sustainable development in 1991. This definition states that sustainable development is "Improving the quality of human existence while living with the carrying capacity of the supporting mechanisms." At the United Nations Conference on Environment and Development (UNCED), often known as the Rio Conference, which took place in 1992, a clear discussion on sustainable development evolved. It asserted that human beings have the right to a healthy and fruitful life and that they should be placed at the centre of concerns regarding sustainable development. It did so by adopting Agenda 21, a worldwide action agenda for sustainable development in social, economic, and political contexts.

Concepts of Sustainability

The basic objective of sustainable development is to reach a level of economic prosperity that is both reasonable and fairly distributed throughout the world (Schleicher et al., 2018). It is founded on three different ideas.

The idea of progress or advancement (socio-economic development in line with ecological constraints),

The idea that one has needs (redistribution of resources to ensure the quality of life for all) and

The idea of having children and grandchildren in the future (the possibility of long-term usage of resources to ensure the necessary quality of life for future generations).

The ability to "maintain some thing, outcome, or process over time" is the precise definition of the phrase "sustainability," which also refers to the practice of engaging in activities that do not deplete the resources upon which that capacity is dependent. The core of the idea of sustainable development is derived from the Triple bottom line concept, which emphasizes the importance of striking a balance between the following three pillars of sustainability: economic, social, and environmental.

The concept of environmental sustainability centers on the upkeep of environmental quality, which is essential for people's ability to engage in productive economic activities and to have a high standard of living (environmental protection, reduced emissions of pollutants, rational use of resources, etc.)

A social sustainability that works toward the goal of ensuring human rights and equality, the maintenance of cultural identity, respect for the plurality of cultural expressions, including race and religion, and

The maintenance of the natural, social, and human capital required for income and living standards was contingent on economic sustainability.

Finding a balance between each of these pillars is necessary in order to achieve comprehensive sustainable development. However, establishing the necessary condition is not as simple as it may seem. This is because for each pillar of sustainability to achieve its goals, it must respect the interests of the other pillars and not throw them out of balance in the process. Therefore, even when one pillar of sustainable development achieves sustainability, others may be heading in the opposite direction and become unsustainable. The amount of resources that may be harvested from the earth is finite and cannot continue to increase endlessly. Even while we cannot make accurate predictions regarding the outcomes of certain types of economic development, all forms of economic development will inevitably have to take place within the carrying capacity of the ecosystems that support it. Consumption shouldn't go over regeneration, and changes shouldn't be permitted to go past the system's tolerance level. Both of these things should be avoided at all costs (Endress et al., 1994). The three pillars that make up sustainable development are the generation of equal resources, the promotion of socio-economic development, and the conservation of the environment. Sustainable development assures consistent economic and long-term development. It recognizes that the demands of humans and the requirements of the environment are interdependent in some way.

The following is a list of the fundamental tenets that are stated under the notion of sustainable development:

Ensuring the community's requirements and providing for its future generations

Constant enhancement of equality and general quality of life

Keeping the environment, biodiversity, and ecosystems safe and intact

Utilizing renewable resources wisely and reducing the use of non-renewable resources to protect and preserve natural resources

A shift in production and consumption that takes environmental limits into account

Reducing the harmful effects on the environment through the use of innovative technologies and renewable energy, fostering global collaboration at the national, regional, and local levels

Establishing an institutional framework with a broad stakeholder base engaged in putting the idea of sustainable development into practice, etc.

Sustainable Development Goals

The term "sustainable development" has gained popularity today, and hundreds of projects are operating under its banner. The concept's execution has involved participation from numerous international organizations. The world committed to achieving the eight anti-poverty Millennium Development Goals (MDGs) by 2015. These goals were approved in 2000. Slashing poverty, hunger, sickness, gender inequality, and access to

water and sanitation were some of the challenges it addressed. The MDGs had made great strides, but the goals had not yet been fully attained. The gap between wealthy and impoverished nations has widened and many nations are not even close to sustainable development. The degree of socioeconomic development that many nations have not yet attained, linked to a lack of financial resources and technology, as well as the diversity of political and economic goals on a global scale, are the fundamental obstacles to the implementation of the concept of sustainable development.

The 2030 Agenda for Sustainable Development, which contains a set of 17 Sustainable Development Goals (SDGs) to end poverty, combat inequality and injustice, and address climate change by 2030, was endorsed by world leaders at the United Nations Sustainable Development Summit on September 25, 2015. The framework for achieving a better, more sustainable future for everybody is found in the Sustainable Development Goals. The 17 objectives are:

1) No Poverty
2) Zero hunger
3) Good health and well-being for people
4) Quality education
5) Gender equality
6) Clean water and sanitation
7) Affordable and clean energy
8) Decent work and economic growth
9) Industry, Innovation, and Infrastructure
10) Reducing inequalities
11) Sustainable cities and communities
12) Responsible consumption and production
13) Climate action
14) Life below water
15) Life on land
16) Peace, justice and strong institutions
17) Partnerships for the goals

Sustainability is the ultimate objective for protecting the environment and improving people's lives worldwide. The understanding that humans and nature are intertwined and that one's prosperity depends on another's is developing (Dyllick et al., 2002 ; Geissdoerfer et al., 2017).

Real progress has been made in resolving local, regional, and global environmental challenges as a result of numerous beneficial improvements in perception and policy. Only when human resource demand is within Earth's carrying capacity and resource harvest is at sustainable levels is sustainable development conceivable (Heal et al., 2009). However, quantifying these criteria is challenging and frequently causes dispute amongst many stakeholders. There are still billions of people who do not have access to decent housing, food, or medical care. A stable human population that is aware of the finite capacity of the earth's systems to create resources and absorb waste must shift as quickly as feasible to a sustainable civilisation. Sustainable development is achievable when average folks are knowledgeable, sensitive, mobilized, and involved in direct action for their environment (Basiago et al., 1995).

Following the publication of the World Commission on Environment and Development (WCED) report, "Our Common Future," in 1987, the idea of sustainable development—the integration of economic and ecological systems—became popular.

United Nations Conference on Environment and Development (UNCED), the second worldwide environmental conference, took place in Rio de Janeiro, Brazil, in 1992. More than a hundred heads of state were present. Several publications were produced by UNCED, notably Agenda 21, a comprehensive action plan for sustainable development in the twenty-first century.

The World Summit on Sustainable Development (WSSD), the subsequent summit, which took place in Johannesburg, South Africa, in 2002, signaled a change from agreements on principles to a more modest but tangible plan of action.

The world's leaders gathered once more in Rio de Janeiro in 2012 & they signed a document titled ‘The Future We Want’ in which they reaffirmed their commitment to sustainable development objectives and supported concerns related to the global green economy.

The UN 2030 Agenda for Sustainable Development, which outlines 17 development goals to be attained by 2030, was published by the UN Sustainable Development Summit 2015 in New York.

Conclusion

Meeting fundamental human needs, integrating environmental development and conservation, establishing equality, safeguarding social self-determination and cultural variety, and protecting ecological integrity should all be addressed by sustainable development. Even though sustainable development goals have changed, they have helped people behave more conscientiously and tailored to environmental constraints. Additionally, other worldwide discussions and agreements deal with particular environmental problems, including ozone layer loss, biodiversity loss, climate change, and others. As a result, environmental awareness and activities are increasing from a local to a

global scale. To address environmental issues, many governments are creating laws and regulations. Additionally, environmental education is becoming more significant, and our knowledge of environmental systems is expanding.

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HOW TO CITE

Kabita Kundu (2022). Sustainability and sustainable development. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 92-97. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.009

OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.010

Chapter- 10

Conservation and prospects of Indian Lacustrine fisheries to reach the Sustainable Developmental Goals (SDG 17)

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Keywords: Aesthetic Value, Biodiversity, Ecosystem, Lacustrine Fishery, SDGs.

Abstract:

According to the FAO, aquatic resources that have merit for exploration, exploitation, and extension for commercial purposes would be referred to as "fish." Fish provide an important source of food and livelihoods for millions of people, and they are a renewable resource that can be managed sustainably if managed properly. Aquatic resource exploration, capture, catching, cleaning (post-harvest technique), transit, merchandise, processing for semi-prepared food or prepared food, scientific culture (propagation, grow-out operation, seasonal capture), etc., are all examples of lacustrine fisheries. Lacustrine fisheries are capable of providing a source of sustainable economic growth, employment and income opportunities, food security, and improved nutrition. Furthermore, well-managed fisheries can be an integral part of conservation and ecosystem management efforts, providing sustainable access to aquatic resources that are essential to maintaining healthy ecosystems. In addition to providing a source of food and livelihoods for millions of people, lacustrine fisheries also have the potential to help mitigate poverty and increase access to healthy foods. To ensure the long-term sustainability of fish populations, fisheries must be carefully managed, including implementing rules and regulations governing the amount that can be harvested, setting quotas for different species, and enforcing them. In this chapter, we will look at how the lacustrine fishery achieved some long-term development goals, either directly or indirectly.

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

Introduction:

Today, aquaculture and commercial fishing are the world's fastest-expanding sectors (Tacon, 2020), and they play an important role in food production and employment (Kumar & Shivani, 2014). Aquaculture and commercial fishing are two forms of fisheries that rely on wild caught and farmed fish, respectively. Capture fisheries act as a protein source for about 10% of the global population (*The State of World Fisheries and Aquaculture*, 2020, 2020). India is the hub of both inland and marine fisheries. The country has a wide variety of marine and freshwater fish species and accounts for over 4.3 million metric tonnes of fish production, making it the second largest producer in the world. Despite the fact that India produces a lot of fish, a lot of resources are taken from the natural environment to support these industries. India has made significant efforts to ensure the sustainability of its fisheries, but overfishing, by catch, and water pollution are still very much a problem. This country's coastline is 8,118 kilometres long, and our jurisdiction covers approximately 2.02 million square kilometres, according to the 1977 Exclusive Economic Zone. There are different zones of fisheries, such as inland fisheries (1.96 lakh km), 3.15 million hectares of reservoirs, 2.44 million hectares of ponds or lakes, 0.798 million hectares of beels, 1.24 million hectares of brackish water, and estuaries that also develop at 0.29 million hectares (Ngasotter et al., 2020). According to Holčík (1998), an ancient lake's fish yield capacity is far greater than that of any newly natural or man-made lake. Because true lacustrine species occupy all available habitat in ancient lakes, fish yield capacity is much higher (Holčík, 1998). There are two types of lakes present in India: floodplain lakes and upland lakes. Floodplain lakes occur due to seasonal flooding and the receding of rivers, whereas upland lakes are formed by natural processes such as glacier-induced depressions and human interventions like irrigation. A floodplain is a flat area near the river; it is formed due to the deposition of alluvium, which occurred due to the declining speed of the river. In India, there are over 200000 hectares of floodplain lakes known as jheel, beel, chaurs, mans, and pats in states such as Assam, Bihar, and West Bengal. However, the declining diversity of fishes in these water bodies is now due to the evolution of the river bed, infestation of many aquatic weeds, eutrophication, and devastating floods that can cause habitat destruction as well as bottom muck accumulation (Sugunan, 1997). These threats can have a devastating effect on the species diversity and ecological balance of these lakes, resulting in the gradual elimination of many species that used to inhabit these water bodies. In addition, the introduction of invasive species and excessive extraction of aquatic resources for agricultural, industrial, and recreational activities can further threaten the balance of these water bodies. To prevent further damage to the aquatic species in these water bodies, it is essential to implement conservation measures that would protect the diversity of fish and other species.

Table 1: Distribution of floodplain lake throughout India (Sugunan, 1997).

State	River basin	Area (ha)
Arunachal Pradesh	Kameng, Subansiri, Siang, Dibang, Lohit, Dihing and Tirap	2500
Assam	Brahmaputra and Barak	100000
Bihar	Gandak and Kosi	40000
Manipur	Iral, Imphal and Thoubal	16500
Meghalaya	Someswari and Jinjiram	213
Tripura	Gumti	500
West Bengal	Hooghly and Matlah (Ganga)	42500
Total		**202213**

Another type of lake is an upland lake or mountain lake, and its tropical water quality is different from other tropical regions due to its high altitude (Sreenivasan, 1964). Upland lakes are typically found in mountainous or hilly regions and are fed by glacial meltwater, precipitation, snowmelt, and springs. This causes mountain lakes to have different levels of dissolved oxygen than other lake types, which can affect the organisms that live in them. Upland lakes are usually situated in mountain valleys and tend to be less than 20 m in depth, meaning their water quality is largely dependent on the surrounding ecosystem. There are several upland lakes present in India, such as Dal Lake at Jammu, Suraj Tal Lake at Himachal Pradesh, TSO Lhamo Lake at Sikkim, Tarsar Lake at Kashmir, Sela Lake at Arunachal Pradesh, Prashar Lake at Himachal Pradesh, Pangong Lake at Ladakh, Gurudongmar Lake at Sikkim, Kodaikanal Lake at Madras, Yercaud Lake at Madras, Ooty Lake at Madras, etc.

Definition of Lake:

Lakes, according to Forel (1901), are bodies of stagnant water that span basins but do not connect to the sea. Lakes are large amounts of stagnant water that are deep enough just to stratify thermally. Lakes, according to Welch (1952), are masses of standing water that are fully separated from the sea and have a region of broad, fairly deep water large enough to form a barren, rapid shore somewhere on their border. According to Vernberg & Vernberg (1972), a lake is an inland depression on the surface of the earth, ranging from a few metres to about 150 metres in depth, and containing standing water. A lake is an area of variable extent covered usually by water, where freshwater and saltwater meet, in which water moves in relation to a shoreline. Lakes are contrasted with rivers or streams, which are un-bounded elements of surface or lying mostly in one direction, but are natural lowlands near a stream bed or shore. They may be temporary or permanent entities. A lake exists when there is more water within the lake than outside it (total volume). The deeper parts of lakes retain their water for longer periods of time compared to shallow part. Lakes thus have a greater density because they have more volume for their surface area; however, not all bodies if lakes can be called "lakes".

Fish Diversity in India:

India has 1027 freshwater fish species. The Indian fish biodiversity is classified into two groups: Chondrichthyes and Osteichthyes. On the Indian subcontinent, the Chondrichthyes are represented by 131 species divided into 67 genera, 28 families, and 10 orders. Indian chondrichthyes harvest a total of 33,500 metric tonnes per year, with 15,500 metric tonnes from the eastern coast, 17,600 metric tonnes from the western coast, and the remainder from the islands of Andaman and Nicobar. The Indian bony fish include approximately 2,410 species from 900 genera, 225 families, and 30 orders, with five families, most prominently the Parapsilorhynchidae, being indigenous to India. All those little hill stream fishes are classified into a single genus, *Parapsilorhynchus*, that comprises three members. Furthermore, the species of the family Psilorhynchidae, including the sole species *Psilorhynchus*, are indigenous to the Indian subcontinent. The indigenous fish families account for 2.21 % of the Indian region's total bony fish population. Approximately 22,000 fish species have been identified worldwide, with around 11% present in Indian waters. Among the 2200 species now recorded, 73 (3.32%) are cold-water freshwater fish, 544 (24.73%) are temperate-water freshwater fish, 143 (6.50%) are brackish water species, and 1440 (65.45%) are marine species. Appropriate ecological conservation is required for the persistence of all populations, and sufficient care is required to resist anthropogenic pressures. In the case of commercial species, rational resource utilisation is required.

There are approximately 450 families of freshwater fish worldwide. In India, around 40 species (warm freshwater species) are recorded. Approximately 25 of these families contain economically significant species. In warm water, there are around 544 endemic species. The following are the most important warm-water species: *Bagarius bagarius, Catla catla, Channa punctatus, Cirrhinus mrigala, Clarias batrachus, Heteropneustes fossilis, Labeo bata, L. calbasu, L. rohita, Notopterus chitala, Rita rita,* etc. Cyprinids, live fish (family: Anabantidae, Clariidae, and Heteropneustidae), catfish, clupeids, and mullets are the most common freshwater fish found in India. Cyprinidae comprise one of the biggest categories and are extensively distributed throughout India, with genera varying in size from a few centimetres to nearly a meter. Cyprinidae account for about 24% of India's 544 species of freshwater fish. Many cyprinids are collected and cultured, particularly carps. The carps are divided into major (*Catla catla*, *Cirrhinus mrigala*, *Labeo calbasu*, and *Labeo rohita*) and minor (*L. fimbriatus*, *L. bata*, and *C. reba*) (Mukherjee et al., 2022). A few foreign carps like *Cyprinus carpio* have also been imported for cultural reasons. Mahseers are also classified as Cyprinidae. Many Tor species reside in high-altitude, frigid waters, even though some, like *Tor putitora*, thrive in milder waters. As a result, the genus Tor exhibits a wide variety of species diversity when it comes to adaptability to varied ecological situations. Mahseer fisheries are in critical decline in several habitats, threatening their very survival and necessitating sufficient protection for the fish (Ngasotter et al., 2020).

Commonly Found Lacustrine Fishes:

Table 2: Different group of fishes found in Indian lakes (Sarkar et al., 2015).

Fish Group	Example
Indian Major Carps	*Labeo rohita, Labeo calbasu, Labeo fimbriatus, Cirrhinus mrigala, Catla catla*
The Mahseers	*Tor tor, T. putitora, T. khudree, Acrossocheilus hexagonolepis, A. hexastichus*
Minor Carps	*Cirrhinus cirrhosus, C. reba, Labeo kontius, L. bata, L. dero, L. gonius, L. boggut, L. dussumieri, Puntius sarana, P. dubius, P. carnaticus, P. kolus, P. dobsoni, P. chagunio, P. pulchellus, P. jerdoni, P. curmuca, P. shalynius, Thynnichthys sandkhol, Osteobrama vigorsii*
Snow Trouts	*Schizothorax* spp., *S. plagiostomus*
Large/Medium Catfishes	*Wallago attu, Sperata aor, S. seenghala, Pangasius* spp., *Silonia childrenii, Silonia silondia, Ompok bimaculatus, O. pabda, Glyptothorax* spp.
Featherbacks	*Chitala chitala, Notopterus notopterus*
Air Breathing Catfishes	*Clarias magur, Heteropneustes fossilis, C. batrachus*
Murrels	*Channa marulius, C. striata, C. punctatus, C. gachua*
Garra species	*Garra gotyla, G. lissorhynchus, G. mcclellandi*
Minnows and miscellaneous species	*Puntius sophore, P. ticto, Ambassis nama, Esomus danricus, Aspidoparia morar, Amblypharyngodon mola, Oxygaster bacaila, Laubuka laubuca, Barilius barila, B. vagra, B. bola, Osteobrama cotio, Gudusia chapra, Salmostoma bacaila, Johnius coitor, Lepidocephalus guntea, Glossogobius giuris, Danio dangila, Badis badis, Chanda nama, C. baculis, Chagunius chagunio*
Exotic fishes	*Oreochromis mossambicus, Hypophthalmichthys molitrix, Cyprinus carpio specularis, Cyprinus carpio communis, Cyprinus carpio koi, Gambusia affinis, Ctenopharyngodon idella, Clarias gariepinus*

Some other aquatic faunas are also found in Indian lakes, which have their own socio-economic values, such as shrimp, crab, and shrimp, as well as some zooplankton such as copepods, Cladocera, rotifers, veliger larvae of gastropods, mysids, and crustacean larvae (Mohanty et al., 2009).

Fish Consumption Rate in India:

Fish is not only the best protein source, but it also provides a range of essential fatty acids and minerals. Fish is an important part of a balanced diet, providing a wide range of nutrients, including proteins, essential fatty acids, and minerals that can help support healthy growth and development. Eating fish on a daily basis has been linked to a variety of health advantages, including reduced inflammation and a lower risk of heart disease. Studies have shown that consuming fish at least once a week can lower triglyceride levels, reduce the risk of stroke, and decrease the chances of developing type 2 diabetes (Saha et al., 2022a). Fish items are becoming increasingly popular. As more people become aware of the many health benefits of eating fish, there has been an increase in demand for fish-based products. With the growing demand for fish-based products, food retailers are now offering a wide selection of fish items. Approximately 24.8% of the Indian population requires fish on a regular basis, with rural areas accounting for 26.5% of the demand and urban areas accounting for 21%. The pattern of fish consumption in northern India was 6.7%, in western India it was 9.1%, and in central India it was 1.8% (Figure 1) (Barik, 2016).

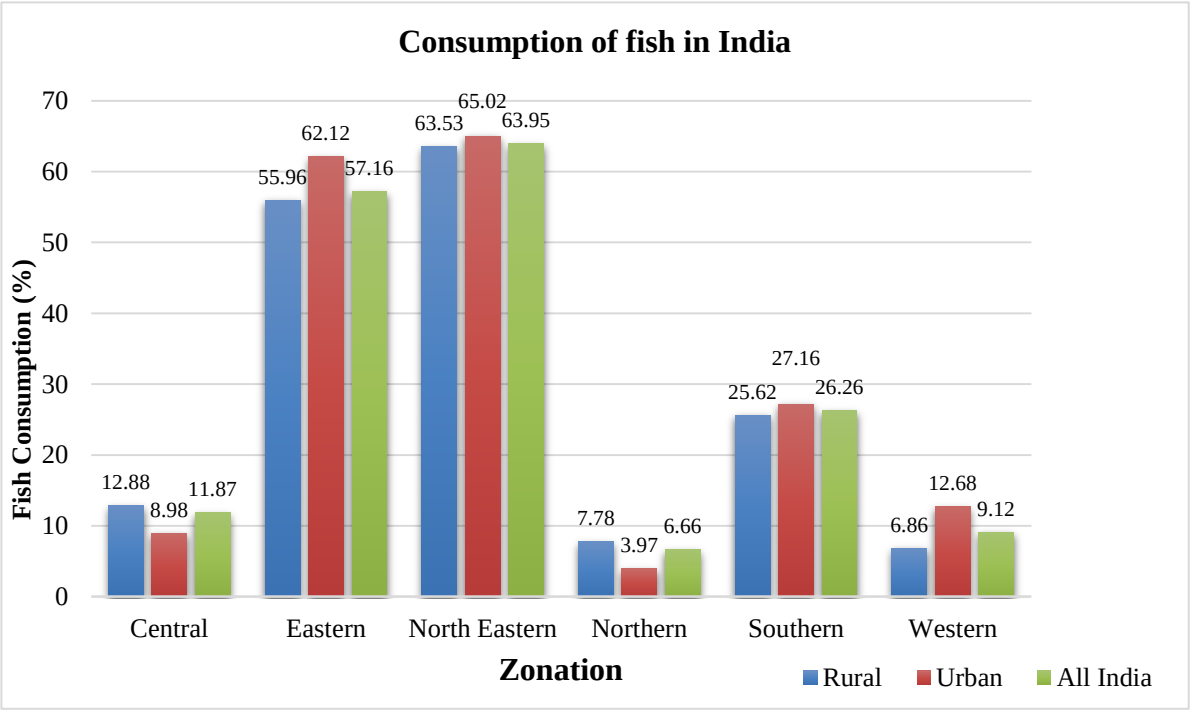

Figure 1. The graphical representation shows that the rate of fish consumption by Indians varies by zone. This figure shows that the North Eastern region of India consumes the highest number of fish in their regular diet, while Northern India consumes the least.

Nutritive Value of Fish:

Fish is high in protein, especially lysine and Sulphur-containing amino acids, as well as essential amino acids and carbohydrates. It is also an excellent source of vitamins and minerals, including iodine, zinc, selenium, calcium, magnesium, vitamins A and D, and omega-3 fatty acids. Fish is an important dietary component for maintaining a balanced, healthy diet. Fish oil is high in vitamins A and D, as well as minerals such as phosphorous. Fish oil is beneficial for promoting healthy hair, skin, and nails, as well as supporting cardiovascular health and neurological development. Eating fish regularly provides numerous health benefits, including a decreased risk of heart disease and stroke, improved cholesterol levels, and increased weight loss. Iodine and omega-3 fatty acids are found in marine fish. Iodine helps to regulate the thyroid, which is a gland in the body that regulates metabolism. Omega-3 fatty acids are important for healthy brain function and can help reduce inflammation. Fish is an excellent source of energy since it is bigger than other bulky carbohydrate sources. Therefore, eating fish on a regular basis can provide the body with the essential nutrients needed to keep it healthy and functioning optimally (Kent, 1987).

Sustainable Development Goals (SDGs):

Globally, mankind is currently confronted with severe ecological, cultural, and economic issues. The United Nations created the 17 Sustainable Development Goals in 2015 to resolve such global concerns on a global, cross-border scale and also to create a more environmentally friendly and brighter life for all. The 17 Sustainable Development Goals aim to protect the world’s ecosystems, end poverty and hunger, provide quality education to all citizens, promote economic growth while protecting the environment, reduce inequality between countries and among individuals, and create peaceful societies with access to justice. Each one of the SDGs contains indicators that are used to track progress toward the objectives. Individual objectives do not exist independently, but instead affect and are related to one another; each goal tackles ecological, cultural, and economic concerns. Therefore, all 17 goals should be worked on in tandem with one another in order to achieve the intended global impact. It is critical to understand how people throughout the world interpret, embrace, and assess the SDGs. Internationally, "combating climate change," "excellent health," and "well-being and excellent education" are prioritized. In comparison, domestically, the emphasis is on creating a clean environment, reducing poverty and inequality, and empowering communities through job creation and sustainable economic growth. People all throughout the globe have such high standards of approval for the SDGs' substance. Despite the wide range of priorities from nation to nation, the core principles and objectives of the SDGs remain constant: to ensure human rights and wellbeing, protect our planet and future generations, foster peace, and promote prosperity (Kleespies & Dierkes, 2022). The United Nations SDG 14: Life Below Water is possibly one of the most difficult of the 17 objectives because of the vastness of the oceans (nearly three-quarters of the planet's area) and the numerous ties to certain other Goals

(Cisneros-Montemayor et al., 2020). Consequently, this goal is tasked with preserving and protecting marine ecosystems, preventing pollution, and conserving and sustainably using the oceans, seas, and marine resources. For example, the Sustainable Development Goals of No Poverty (SDG 1), Zero Hunger (SDG 2), and Great Health and Well-Being (SDG 3) ultimately depend on a stable life below water (SDG 14). If we fail to protect our marine ecosystems and preserve life below water, we risk destabilizing a large portion of the food chain, putting strain on food security and the health of humans and animals alike (Andriamahefazafy et al., 2022). Climate change action (SDG 13) is required to accomplish SDG 14, as well as the ocean, which is critical to attaining SDG 13. Therefore, SDG 14 serves as a vital and urgent goal to protect our marine environment from the threats posed by human activities (Armstrong, 2020). There is still a lot we don't know; in fact, the ocean comprises more than 99% of the area where creatures may dwell, and more than 80% of the ocean, particularly the deep water, remains undiscovered (Molony et al., 2022). It is clear that to protect our marine ecosystems, our oceans, and the life within them, we must take action. We must work together to reduce the human impacts that have already harmed underwater life, such as overfishing, pollution, and climate change.

Figure 2. Diagrammatic representation of some goals of sustainable development achieved through lacustrine fisheries. Here 1–8 denote livelihood, income, food resource and nutritional value, recreational aspects, cultural aspects, educational development, and respectively.

Sustainable Developmental Approaches In Lacustrine Fisheries:

Indian lakes and the fish that inhabit them play a significant role in achieving some goals of sustainable development (Figure 2). Inland fisheries contribute to economic growth by selling and trading fish and fish products, as well as providing employment (Welcomme et al., 2010). The inland fishery industry provides nutritional value to more than billions of individuals throughout the world (Youn et al., 2014). It helps to develop the ecotourism industry through sport fishing (Cooke et al., 2015). The inland fishery also has its own aesthetic values. It contributes cultural heritage and iconic traditions to fishers' cultural services (Noble et al., 2016). Inland fisheries also play a significant role in education, and they provide research opportunities (Postell & Carpenter, 1997). Lacustrine fisheries provide good environmental services by maintaining water ecosystems, biodiversity, and water quality and quantity (Postel & Carpenter, 1997). Because of the high demand for these services, we must ensure the sustainable use of not only lacustrine but also inland fisheries resources (Lynch et al., 2020). Indian lakes have aesthetic value on their own, and they also play an important role in the tourism industry. Lacustrine fisheries provide a cultural sense of the fisher community, and they also help to maintain their cultural heritage and traditions (Noble et al., 2016). Lacustrine fisheries have a high educational value and also provide opportunities for research and training, which ultimately affects the growth of fish productivity (Postel & Carpenter, 1997). Lacustrine fisheries also help to preserve aquatic ecosystems and water quality (Postel & Carpenter, 1997).

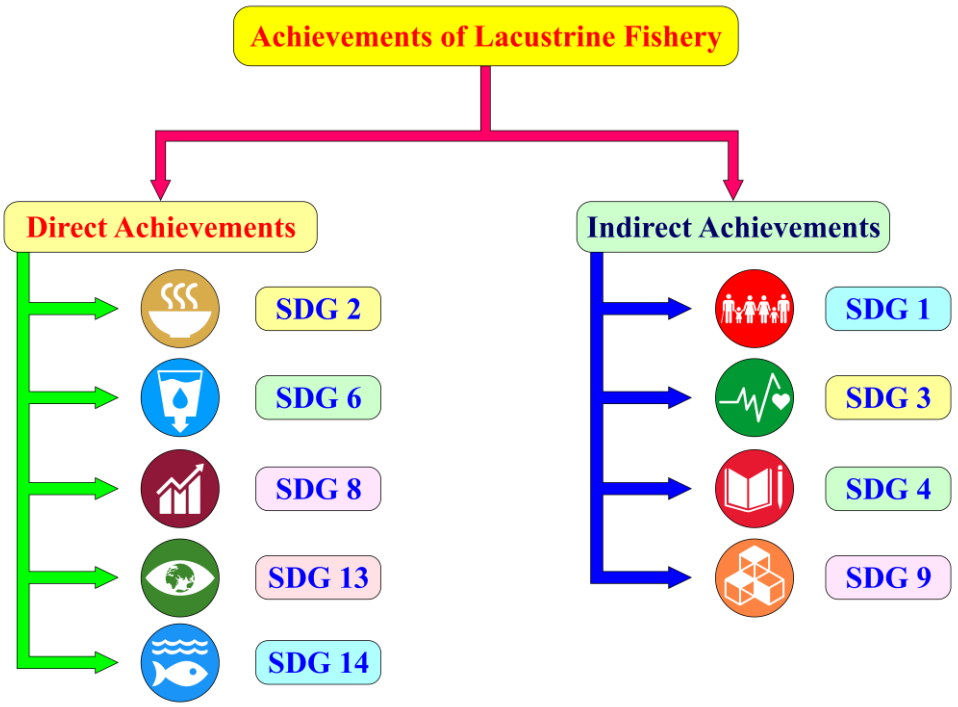

Figure 3. Direct and indirect achievements of lacustrine fishery.

A well-developed lacustrine fishery can achieve the following goals: sustainable development (fish is a good source of protein); Indian lakes play a major role in producing fish, which ultimately achieves the zero-hunger goal (SDG 2); and betterment of the lacustrine fishery through the cleaning of lake water, which achieves the goals of clean water and sanitation (SDG 6). Moreover, by taking steps to ensure the sustainability of the fishery, such as reducing fishing pressure, conserving habitats, and protecting biodiversity, it also contributes to achieving a number of other Sustainable Development Goals (SDGs). The lacustrine fishery has a strong potential to reduce hunger and improve nutrition, support economic growth and provide decent work, promote sustainable consumption and production patterns, protect the environment, combat climate change, and build resilience. Lacustrine fisheries also play a major role in economic growth, which fulfils SDG 9. Finally, by providing employment opportunities for fishers, especially for marginalized communities living in and around lakes, the lacustrine fishery contributes to achieving gender equality (SDG 5) and decent work and economic growth (SDG 8). Moreover, the lacustrine fishery also supports communities in maintaining sustainable livelihoods and strengthening their resilience to climate change. It also meets SDG 12 by producing and consuming fish in Indian lakes. In addition to these contributions, the lacustrine fishery also contributes to ending hunger and achieving food security (SDG 2) by providing access to food and nutrition. A healthy lake is also positively associated with life below water (SDG 14) and climate action (SDG 13). A well-built lacustrine fishery can indirectly achieve (Figure 3) some other SDGs such as no poverty (SDG 1), good health and well-being (SDG 3), quality of education (SDG 4), and industry development (SDG 9) (Lynch et al., 2020).

The Current State of India's Lacustrine Fishery:

Lacustrine fisheries in India can be broadly classified into three categories: benthic fisheries, sub-benthic fisheries, and pelagic fisheries. Benthic fisheries include preparations of benthic creatures, such as crustaceans and mollusks such as prawns, small fish, and aquatic insects. Sub-benthic fishing includes fishing for fish and other organisms using nets or trawls. The catch in this category includes fish like prawns, small fish (bait), aquatic insects, and other crustaceans. Pelagic fishes include turbot, lobsters, and crabs, which are caught through trawling (dragnet fishing) methods. Lacustrine fisheries take place in lakes, ponds, and reservoirs in India. They are not just confined to specific regions but can be found everywhere across the country. The Indian lacustrine fisheries are diverse, with over 60 varieties of fish, most of them exotic species like pomfret and snappers. These shores also house almost all the commercial species indigenous to Asia.

The yield of inland fisheries is relatively higher than that of marine fisheries. Inland fisheries contribute approximately 38.79%, whereas marine fisheries contribute 34% (Paul et al., 2017). In India, there are 19,134 small reservoirs, 180 medium reservoirs, and 56 large reservoirs, and

fish yields in those reservoirs are 174 kg/ha, 94 kg/ha, and 33 kg/ha, respectively (Paul et al., 2017).

Lacustrine fisheries in India provide a significant amount of forage for domesticated animals, primarily sheep and goats. Large-scale production of fish meal and fish oil, co-products obtained during the processing of aquatic products (fish products), played major roles in increasing the production of these two commodities in India. Lacustrine fisheries in India are an important part of the country's economy. The main food staples, rice and wheat, are sourced from these fisheries. Neighbouring countries also depend on Indian freshwater resources for their requirements. There is a high risk of the misuse of this water supply resulting in impacts such as salinity increases and depletion of fish stocks, which can result in the elimination of a major source of nutrition, especially if soil health is negatively affected by salinity or reduced levels of nutrients. Indian lakes have a great economic impact in the fishery industry, but currently they are facing some problems that ultimately affect the production of fish. Now we discuss the problems of lacustrine fisheries.

Major Problems of the Lacustrine Fishery:

Table 3. Some popular lakes in India and their major problems.

Name of the lake	Latitude & Longitude (According to Google Earth)	Problem
Dal lake, Kashmir	Latitude: 34°06'N Longitude: 74°51'E	Water quality is the most important factor influencing Dal Lake, which has nearly 15 drains connected to it. Dal Lake receives phosphorus and nitrate-rich sewage, which raises the pH value of the water. These 15 drains carry about 18.17 tonnes of phosphorus and 25 tonnes of inorganic nitrogen (Qadri & Yousuf, 2007). This raises alkalinity and nutrients such as phosphorous, nitrate, ammonium, and potassium that ultimately contribute to eutrophication. Some heavy metals are also present in this lake, such as Cd, Cr, Cu, Mn, Ni, and Zn. *Azolla pinnata* and *Eichhornia crassipes* are the new floral species in Dal Lake. These plants spread rapidly and have a harmful effect on native flora as well as faunal diversity. *Azolla* acts as a nutrient blocker by hampering water circulation in Dal Lake, which ultimately prevents the growth of water ferns. *Azolla* also prevents penetration, which affects floral and faunal diversity (Mir et al., 2022).

Chilka lake, Odisha	Latitude: 19^{o} 41’ N Longitude: 85^{o} 22’ E	The introduction of pesticides in Chilka Lake is one of the remarkable problems in lacustrine fisheries. The origination of pesticides comes from different sources, such as Palur Bridge, the Daya River Estuary, and the Makara River. Basically, organo-chlorinated (OC)-based pesticides recorded about 25% of the water sample from Chilka, and some other pesticides were also found in varying concentrations (0.025 to 23.4 µg/l) such as HCH (α, γ & δ), DDD, DDE, heptachlor, and some others, chlorpyrifos (0.019–2.73 µg/l), dichlorvos (0.647 µg/l). Residues of OP and OC pesticides were not recorded in the sediment sample, but one synthetic pyrethroid (SP) pesticide was recorded (Nag et al., 2020).
Santragachi lake, West Bengal	Latitude: 22^{o} 35’ N Longitude: 88^{o} 16’ E	Both biodegradable waste such as vegetables, paper, etc. and nonbiodegradable waste such as plastic are dumped into the lake (Roy et al., 2011). Because water containing petroleum and other wastes is mixed with the lake's water, train washing at Santragachi station poses a threat to Santragachi Lake (Roy et al., 2011). People from the slum are bathing, washing clothes, and also congregating near the lake's approximately 21 toilets. The drainage from the toilets directly opens into the lake (Roy et al., 2011). establishment of non-native species of hyacinth (*Eichhornia crassipes*), which cover the whole lake. the dissolved oxygen and light penetration decline, which ultimately affect the water ecosystem (Roy et al., 2011).
Loktal lake, Manipur	Latitude: 24^{o} 33’ N Longitude: 93^{o} 48’ E	In Loktal Lake, phumdis is a floating mat. It has some ecological importance, but rapid proliferation of phumdis can affect lacustrine fisheries. A lot of fertilizer is used in the catchment area, which increases the nutrients in the water and causes phumdis to grow quickly. Phumdis nutrient extracts are to blame for declining fish production. The rotting of phumdis also reduces water quality, emitting a foul odour and eventually causing many diseases in fish and local communities (Singh & Khundrakpam, 2011).

Some Other Major Problems of Lacustrine Fisheries in India:

Unplanned urbanization:

Rapid urbanization is an important problem for lacustrine fisheries. Unplanned urbanization can destroy small or medium lakes and make multi-story buildings, such as apartments, shopping malls, hotels, etc. This destroys the natural environment and affects the species that inhabit it, leading to a decrease in local fishery production. The destruction of the natural environment can lead to the depletion of fish stocks and the destruction of their habitats, leading to a decrease in local fisheries production. Furthermore, the release of untreated wastewater from factories and residential areas into the lake water can lead to a further decrease in the quality of the water, impacting the health and populations of fish as well as making it difficult for aquatic vegetation to survive. Because of its geographically advantageous location, the lake has recently been transformed into bungalows or hotels. Lake destruction causes ecosystem imbalance, resulting in more landslides and habitat fragmentation, which is a problem for Uttarakhand's Tehri Dam (Singh, 2018). This further worsens the situation for fish populations in the lake as well as other species relying on the lake for their survival.

Heavy metal:

In metropolitan cities, environmental pollution is a major source of toxic metals that are entering the ecosystem through geo-accumulation, bio-accumulation, and biomagnification. This environmental pollution is having a devastating effect on the environment, poisoning wildlife, damaging habitats, and threatening human health. Industrialization and urbanization near the lake are another source of heavy metal deposition into the lake. The metal contaminants are introduced into the environment through various industrial and urban activities such as metal plating, tanning, smelting, sewage, and water runoff. Some heavy metals, such as Fe, Cu, As, Zn, Ni, and Cd, affect lake ecosystems. These pollutants are absorbed by organisms and biomagnified up the food chain, impacting the health of humans and other species. For example, excessive Cu content can affect aquatic flora by damaging the root and preventing its growth. It also reduces the offspring production capacity of animals as well as plants. Secondary roots are also brown in colour, and a high amount of Zn can cause necrosis and chlorosis in plants (Singare et al., 2010).

Conservation Strategies for Indian Lacustrine Fisheries:

Laws:

The Water (Prevention and Control of Pollution) Act was established in 1974. The purpose of this act was to control and prevent water pollution. This Act established the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs), which are responsible for implementing the legislation. This act was also performed to restore useful water in this country. The Water (Prevention and Control of Pollution) Act also mandated that industries would have to obtain a licence before being allowed to release pollutants into water bodies.

This act provides a rule to collect taxes for water consumption in industrial activities (CPCB, 2019). By providing such a framework, the Water (Prevention and Control of Pollution) Act of 1974 was designed to promote a cleaner environment in India. The Ramsar convention was held on February 2, 1971, in the Iranian city of Ramsar. This convention was signed by representatives from 18 countries and was aimed at preserving wetland habitats for wildlife as well as providing recreational opportunities for humans. This act was enacted for the purpose of conservation and sustainable utilisation of wetlands and their resources (Benstead & JoseJosé, 2001).

Sacred lakes:

SNS, or sacred natural sites, are the lands or bodies of water that have spiritual importance to a particular community. For centuries, SNS have been respected and protected by the people of the community, who believe that these places are connected to their cultural history and spirituality. Sacred Lake is one type of SNS where fishing, washing clothes, and bathing are restricted. As a result of this protective action, these sacred natural sites remain undamaged and are maintained as part of the local community's spiritual beliefs and practices. In India, many sacred lakes are situated, such as Bindu Sarovar in Gujarat, Narayan Sarovar in Gujarat, Pampa Sarovar in Karnataka, Pushar Saraver in Rajasthan, etc. These sacred natural sites hold immense value for the people of the community, and their protection ensures that the local cultural practices, which are closely intertwined with the sacredness of these sites, are preserved for generations to come.

Phytoremediation:

Phytoremediation is a promiscuous and cost-effective tool for lacustrine pollution remediation. Phytoremediation is a process that uses plants and trees to absorb pollutants from the environment, making it an effective and cost-efficient solution for cleaning up contaminated lakes. In this method, pollutants are removed and degraded by aquatic plants and their associated microorganisms (Flathman & Lanza, 1998). Phytoremediation is a sustainable method of pollution remediation that can help reduce the environmental impact of pollutants, improve water quality, and protect aquatic ecosystems. This method occurred through several mechanisms, including phytostabilization (the stabilisation of soil contaminants), rhizofiltration (the removal of pollutants from water bodies), volatilization (the extraction of heavy metals and their release into the atmosphere through plants), and phytoextraction (the accumulation of heavy metals in the shoots) (Saha et al., 2022b). Phytoremediation is not only cost-effective but also a low-maintenance method of dealing with environmental contamination. The introduction of some macrophytes such as *Typha* spp., *Paspalidium geminatum, Eriochloa* spp., and *Nymphaea* spp. can prevent heavy metal accumulation (Amare & Workagegn, 2022).

Prevention of illegal fishing:

To prevent illegal fishing, the government will set up a licence facility for fishermen and implement a rule that only validly licenced fishermen will be allowed to fish in conserved lakes. This will ensure that only fishermen who are certified and trained can access the lakes, preventing illegal practices like dynamite fishing and over-harvesting of species (Sarkar et al., 2018). This approach will also allow the government to monitor the number of fish in each lake, which can be used to ensure that the lake's populations remain stable. The Indian government also organises training and workshops for fishermen to learn better techniques for catching large quantities of fish. This will enable them to be more efficient and successful in their fishing, as well as reduce any potential damage that their techniques may cause to the lake's ecosystem. Furthermore, the government has increased its efforts to encourage conservation and sustainable fishing practices.

Avoiding invasive species:

Any kind of invasive species introduction should be restricted in lake ecosystems. Introducing a non-native species into a lake ecosystem can have a devastating effect on the environment, as these organisms may outcompete native species for resources, leading to an imbalance in the food chain and the displacement of many native plants and animals. *Azolla* is a type of exotic flora that can destroy native flora and fauna, and its rapid proliferation in Dal Lake has also contributed to eutrophication (Mir et al., 2022). In lacustrine fishery introduction, some invasive fish, for example, Tilapia, and some ornamental fishes such as the Red Piranha (*Pygocentrus nattereri*), *Osphronemus goramy*, *Xiphophorus maculatus*, and *Trichogaster trichopterus* must be prohibited (Knight, 2010). In order to protect a lake's ecosystem, all kinds of introductions of non-native species should be closely monitored, and any introductions should only occur after an extensive risk assessment. Therefore, a responsible approach to managing aquatic ecosystems should include the implementation of rigorous risk management policies that prohibit any introductions of non-native species into the lake environment.

Conclusion:

Indian lakes not only act as a protein hub but also have some medicinal, economical, conservational, and aesthetic values. We should try to expand the spectrum of lacustrine fisheries by organising some workshops and training for fishermen. Women are also seeking employment in this fishery industry, which contributes to gender equality (SDG 5). Some other strategies, such as integrated fish and poultry farming and sewage water management, will be used for better production and economic growth. As a responsible citizen, we should maintain the water quality of lakes and also maintain the ecosystem of the lakes. Through this chapter, we try to express the important role of lacustrine fisheries in achieving not only the SDGs but also greener development, social reform, and women's empowerment.

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HOW TO CITE

Pronoy Mukherjee, Aloke Saha, Koushik Sen, Hadi Erfani, Nithar Ranjan Madhu and Tanmay Sanyal (2022). Conservation and prospects of Indian Lacustrine fisheries to reach the Sustainable Developmental Goals (SDG 17). © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 98-116. ISBN: 978-81-957954-2-0 DOI: https://doi.org/10.52756/boesd.2022.e01.010