OPEN ACCESS PEER REVIEW

DOI: https://doi.org/10.52756/boesd.2023.e02.001

Chapter- 1

Root Causes of Biodiversity Loss with Special Reference to India

Sourav Bar, Soumik Dhara, Nithar Ranjan Madhu*, Biplab Mandal, Bhanumati Sarkar, Sudipta Kumar Ghorai*

Keywords: Biodiversity, Conservation, Pollution, Climate change, Extinction

Abstract:

The study analyses Indian case studies and examples to determine the main causes of biodiversity loss. India's biological variety presents particular challenges to biodiversity loss, a global issue with major ecological, economic, and social impacts. It may explore habitat degradation and climate change of natural resources, pollution, and invasive species as causes of biodiversity loss in India. It may also illustrate how biodiversity loss disrupts ecosystems, threatens food security, and affects human well-being. There are several causes of biodiversity loss. Most are linked. To combat biodiversity loss more effectively, we must understand its causes. Pollution, climate change, habitat loss, overexploitation, invasive species, etc. cause biodiversity loss. India is one of 17 mega-diversity countries with high biological diversity. India is one of the world's most populous nations. Thus, India's biodiversity is dwindling as its population grows. Since humans started to use fire, they have constantly changed the environment. Industrialization, agriculture, and fast urbanization have raised extinction rates for decades. Loss of life variety can break ecosystems from local ecosystems to the global biosphere. The loss of biodiversity might create a niche that disrupts the ecosystem. For instance, the extinction of tree species can impact its relatives. We must protect our biodiversity because we are deeply connected to it. The manuscript briefly examines Indian biodiversity conservation policies, tactics, and efforts.

Sourav Bar
Coastal Environmental Studies Research Centre, Egra SSB College,Affiliated to Vidyasagar University, West Bengal, India
E-mail: souravbar89@gmail.com; Orcid iD: https://orcid.org/0009-0003-9690-6893
Soumik Dhara
Department of Zoology, Vidyasagar University, West Bengal, India
E-mail: soumikdhara0214@gmail.com; Orcid iD: https://orcid.org/0000-0002-7957-2970
Nithar Ranjan Madhu*
Department of Zoology, Acharya Prafulla Chandra College, New Barrackpore, West Bengal, India
E-mail: nithar_1@yahoo.com; Orcid iD: https://orcid.org/0000-0003-4198-5048
Biplab Mandal
Department of Zoology, Vidyasagar University, West Bengal, India
E-mail: biplab16zoology@gmail.com; Orcid iD: https://orcid.org/0000-0001-8543-7209
Bhanumati Sarkar
Department of Botany, Acharya Prafulla Chandra College, New Barrackpore, West Bengal, India
E-mail: bsarkar328@gmail.com; Orcid iD: https://orcid.org/0000-0001-9410-9311
Sudipta Kumar Ghorai*
Coastal Environmental Studies Research Centre, Egra SSB College,Affiliated to Vidyasagar University, West Bengal, India
E-mail: sudiptag8@gmail.com; Orcid iD: https://orcid.org/0000-0003-3478-3632
***Corresponding Author**: sudiptag8@gmail.com & nithar_1@yahoo.com

Shubhadeep Roychoudhury, Tanmay Sanyal, Koushik Sen & Sudipa Mukherjee Sanyal (eds.), A Basic Overview of Environment and Sustainable Development [Volume: 2]. ISBN: 978-81-962683-8-1, pp:1-34 ; Published online: 17th December, 2023

Introduction:

The term biodiversity or biological diversity, describes the variety present in every field of biology. Our food, fuel, shelter, medicine, and more depend on biodiversity. It's tied to humans and all the lives that interact to preserve the ecosystem. Biodiversity is defined as the variability among living species from all sources, including terrestrial, marine, and other aquatic habitats and their environmental complexes, according to the Convention on Biological Diversity, which was established in 1992 at the time. This includes diversity within species, between species, and within ecosystems. Biodiversity and its decline are natural until extinction rates are controlled. Earth has experienced five catastrophic extinctions before humans due to large volcanic eruptions, long ice ages, meteorite impacts, and colliding continents.

The current extinction scenario is different. This is happening quickly due to human activity. The current pace of extinction is one hundred to one thousand times higher than the rate before humans (Verhulst et al., 2018). This major change in biodiversity may cause dangerous consequences like the loss of resilience of the ecosystem and we may go through another mass extinction event (Barnosky et al., 2011). At present, diversification is lower than extinction. Human survival depends on biodiversity because we are part of it. So, it's a significant worry today. Every habitable place on Earth has biodiversity. Identified some of it which is known to become susceptible daily and we've tackled its extinction causes. Thus, we must understand biodiversity's past and present to respond soon (Gaston, 2003; Sigwart et al., 2018; Kundu, 2022; Haldar & Haldar, 2022).

Human activities are responsible for the profound changes that are currently occurring on Earth. At this point, we cannot determine the extent to which diversity has been lost. If we continue to be unable to take precautions about biodiversity, the entire ecosystem will be destroyed. We are aware that the living things that make up an ecosystem communicate with one another to produce the interconnected network necessary to maintain biodiversity. Therefore, eliminating one component from it may disintegrate that network. Before we can take action to stop the loss of biodiversity, we need to have a solid understanding of the many factors that contribute to it.

Major types of Biodiversity:

The presence of several levels of variety at every stage of biodiversity is beneficial to the health of ecosystems, species, and the planet as a whole. When catastrophe hits, an increase in biodiversity can be necessary for survival and it can serve as a form of environmental insurance for the entire globe (Hans et al., 2017).

Genetic Diversity:

The concept of "genetic diversity" refers to the variation that exists within the gene pool of a species, as well as the variation that occurs at the DNA level. Even while it is possible to infer

genetic diversity based on the appearance of an animal, direct investigations of the DNA of a species provide a more accurate assessment of the genetic diversity of that species

(Poommouang et al., 2021). A population's ability to adapt to change is improved when it is genetically diverse. The presence of high amounts of genetic variety, for example, raises the chance that some members of the community may be less impacted by a disease that plagues a population and causes widespread devastation. By preserving a portion of a population, genetic diversity reduces the likelihood that that population would become extinct (Banks et al., 2013).

Species Diversity:

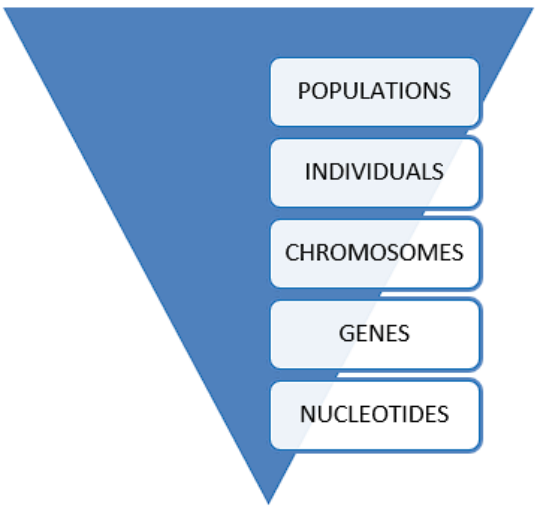
The concept of species diversity considers not just the total number of species found in a community, but also the relative abundance of each species and its function. For instance, there might be several distinct species in a group, yet only one predator might hunt a certain prey species. The prey's population numbers stay within what the community can sustain, while the predator's population levels are healthy (Heupel et al., 2014).

But suppose the predator suddenly becomes less common. In that case, the population of the prey species can rise in reaction, overeating its prey and creating a domino effect that would upend the entire community. On the other hand, a population with greater species diversity can have several predators pursuing the same prey. The community is thus shielded from any further destabilizing consequences if one predator population experiences a dramatic change (He et al., 2021).

Ecosystem Diversity:

The "ecosystem diversity" describes the variation in environments within a region. In contrast to species diversity and genetic diversity, ecosystem diversity takes into account both biological and non-biological sources of variety, such as sunlight and temperature. Regions with high ecological diversity form a geographic mosaic of communities that serve to shield a whole region from unfavorable developments (Alsterberg et al., 2017).

If, for instance, there is a diversity of less sensitive ecosystems surrounding a dry vegetation area that is prone to wildfire, the wildlife may not be able to spread to other dry vegetation areas in the same year, giving the species that make up the burned ecosystem an opportunity to relocate to an unaffected habitat while the burned land heals. Ecosystem diversity thus contributes to the preservation of species variety (Steel et al., 2021).



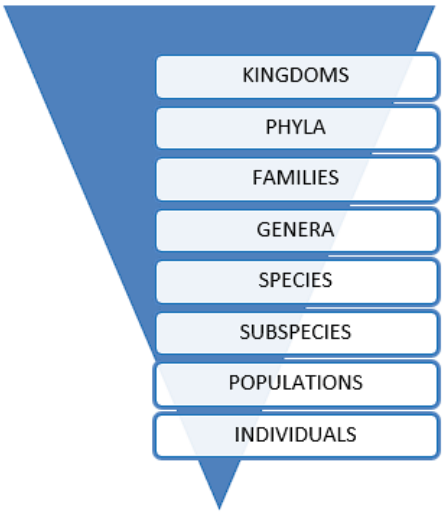


Figure 1.1: Species Diversity Figure 1.2: Genetic Diversity.

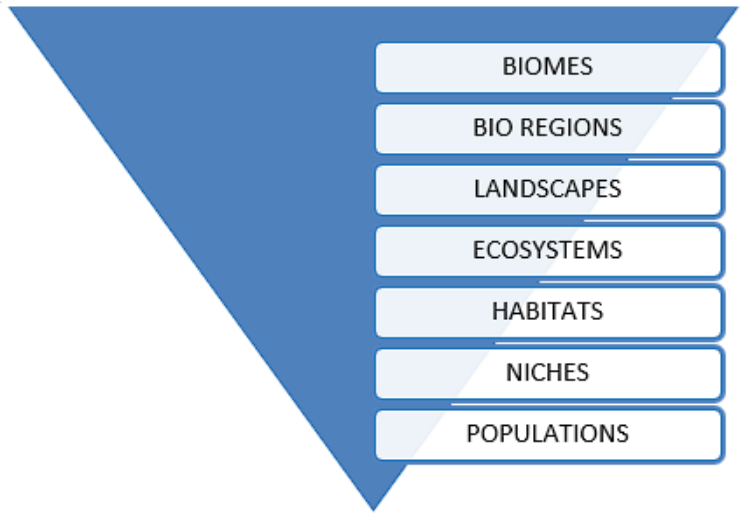


Figure 1.3: Ecosystem diversity.

Figure 1. 1, 1.2, 1.3 show the levels of biodiversity.

India as a megadiversity country:

The geographic coordinates of India are between latitudes 60 and 380 N and longitudes 690 and 970 E in South Asia. The Afro-tropical, Indo-Malayan, and Paleo-Arctic regions all converge in India. India has a great deal of diversity because of its distinct biogeographical location. The Bay of Bengal lies to the east, the Arabian Sea to the west, the Indian Ocean to the south, and the Himalayas to the north encircle India. India is home to four significant hotspots for biodiversity: Sunderland, Indo Burma, the Himalayas, and the Western Ghats (Stephen et al., 2015; Venkataraman et al., 2020).

However, India is losing biodiversity owing to a wide range of reasons. Endemism and species richness decrease as a result of rapid extinction. The IUCN lists the number of threatened animals that are endangered, vulnerable, and critically endangered below (Fig. 2.1). Figure 2.2 below lists the principal protected areas in India that support biodiversity conservation.

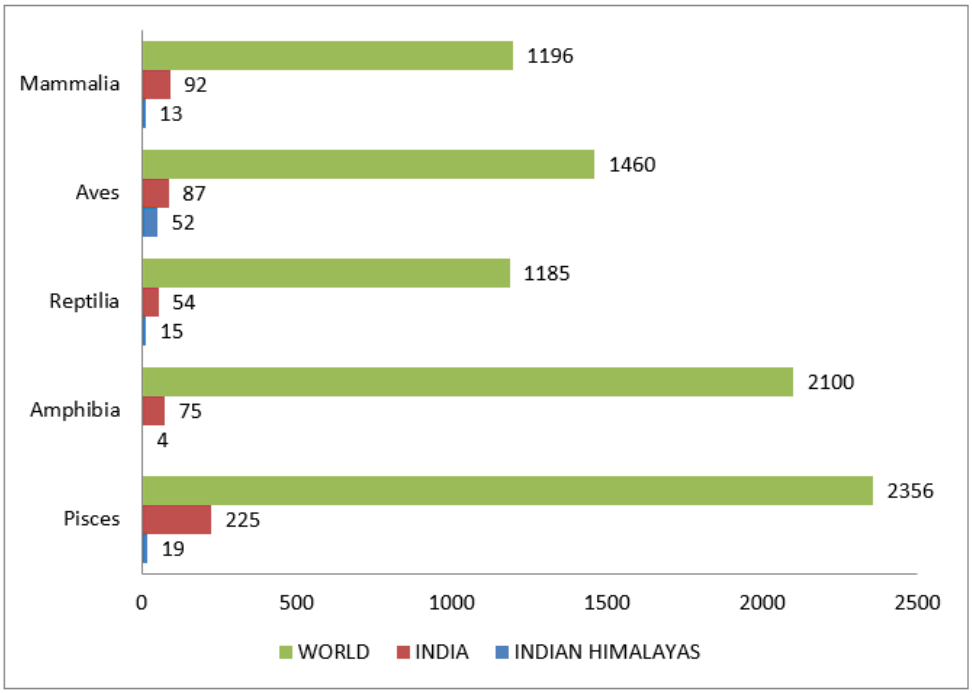


Figure 2.1: No of threatened vertebrates in the world, India and Indian Himalayas (IUCN- Red List 2017).

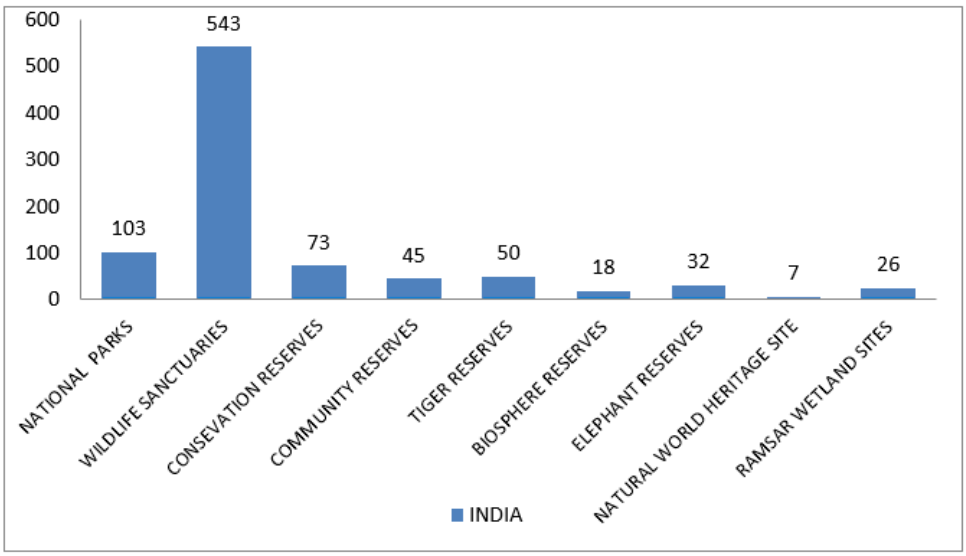


Figure 2.2: No of different protected areas notified from India (Source: Chandra et al., 2018).

Causes:

Various factors, including pollution, climate change, habitat loss, and overexploitation cause the loss of biodiversity. Due to human dominance over the past century, ecosystems have changed quickly, resulting in biodiversity loss worldwide. Most of the causes are related to the overuse that pertains to natural resources and the expanding human population. Here, we are concentrating on seven core causes of biodiversity loss (Fig. 3), which can trigger numerous other processes and initiate numerous induction cascades, leading to a sharp fall in biodiversity.

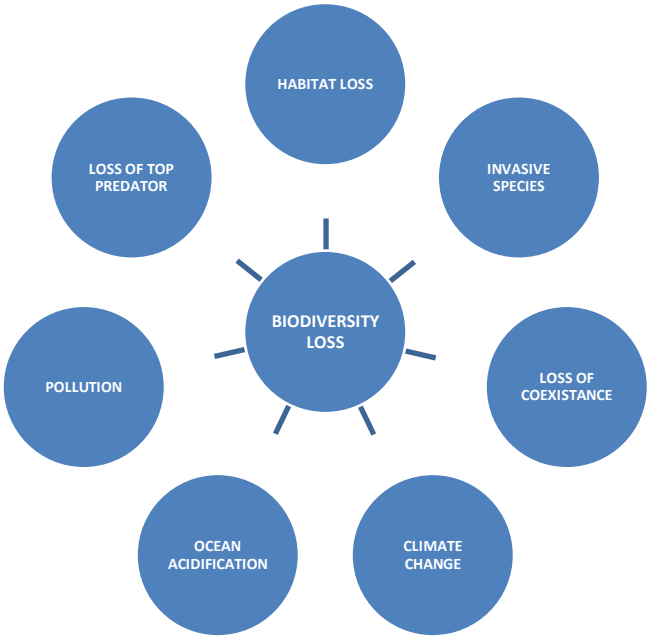


Figure 3: Major causes of Biodiversity loss.

Loss of habitat:

By the year 2100, it is predicted that changes in land use patterns, as well as changes in the atmosphere's CO_2 content, nitrogen deposition, and introduction of new species, will have had a global impact on biodiversity. Rapid rates of habitat loss are occurring (Verhulst et al., 2018). The destruction of habitat is ultimately the result of human action, such as clearing forests to make way for agriculture, filling marshes, building massive structures, etc.

To accommodate development and the insatiable needs of humans, the vast wilderness regions are connected into smaller land fragments. Genetic diversity is restricted by large biodiversity areas being divided and isolating plant and animal groups. There is a sharp fall in species diversity due to human overuse of natural resources, such as destructive fishing (Mukherjee et al., 2022; Sanyal et al., 2023).

The pace at which urbanization is occurring is accelerating the process of habitat destruction, and this trend is well-documented. The loss of many species that depend on these habitats is a

result of habitat deterioration (Deb et al., 2022). The residence of native species is lost as a result of numerous other human activities and natural catastrophic catastrophes.

Natural causes like fire, flood, cyclone, etc are increased due to human activity. One of the most important factors for this is the formation of super cyclones like Amphan in West Bengal and Odisha coast. India is facing rapid population growth in the last decades. As a result of rapid population growth in India, the urbanization rate has been increasing daily. Fig.4.1 shows how fast the urbanization process has been in the last decade (from 2010 to 2020).

In recent years, several forest fires have been seen in India. The forest fire burned Shimlipal Biosphere Reserve, Odisha, in March 2021. A forest fire in Bandipur National Park happened in February 2019. Many other forest fire events have been seen in India, like the Uttarakhand Forest Fire, the Himachal Pradesh Forest Fire, etc. Fig. 4.2 shows how many forest fires have recently happened in India. Most of these forest fires are manmade and responsible for habitat loss, causing biodiversity loss.

According to the report of the Forest Survey of India (FSI), forest fires have increased from 8,654 in 2004 to 35,888 in 2017. A total number of 277,758 forest fire points are distributed in the following states - 20686 in Maharashtra, 24422 in Madhya Pradesh, 25995 in Chhattisgarh, 20862 in Assam, 32659 in Mizoram and 26719 in Odisha.

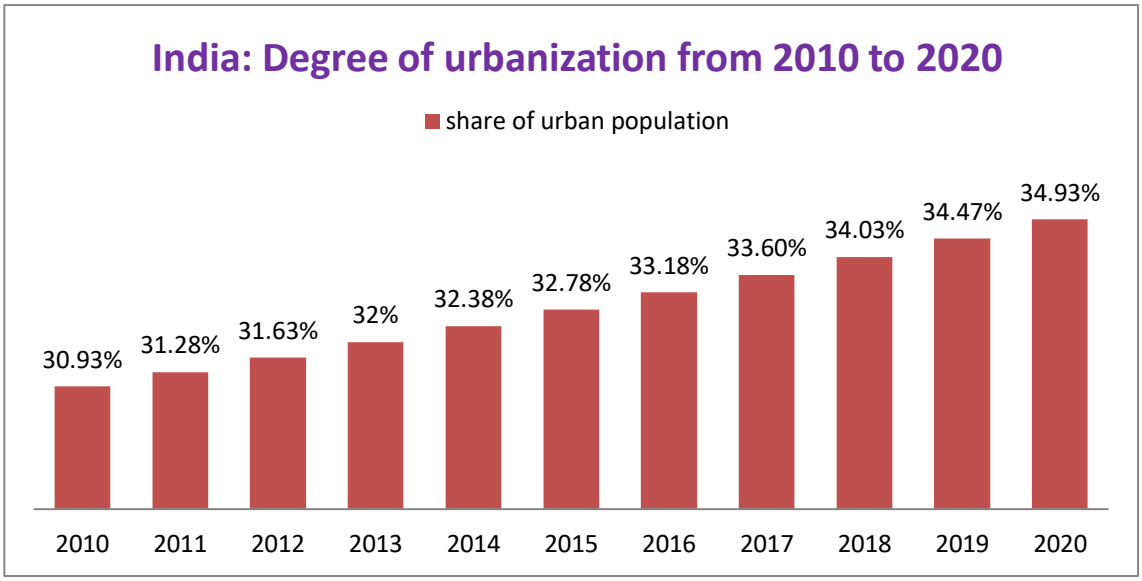


Figure 4.1: statistical representation of the rapid increase of urbanization in India.

Data source: ©Statista 2022 (https://www.statista.com/statistics/report-content/statistic/271312)

Invasive species:

An important factor that contributes to the loss of natural biodiversity is the introduction of species that are considered to be invasive. When the non-native alien species arrives in the new environment or is introduced there by humans, it begins to outcompete the native species and eventually becomes their dominant species. There is a small percentage of new species that are brought into an ecosystem that end up becoming invasive species and hurting the environment.

Figure 4.2: Forest fire at different places in India (Source: Forbes, India) https://www.forbesindia.com/article/take-one-big-story-of-the-day/can-wildfires-be-prevented-in-a-world-dealing-with-climate-change/68127/1

However, the majority of these new species do not become invasive (Vijeta et al., 2021). Through the modification of the habitat, the introduction of viruses, and the destruction of plants that are herbivorous in the native ecosystem, invasive species can manipulate the native ecosystem in several different ways. This ultimately results in a decrease in genetic diversity as a result of hybridization with native species. Competition for the usage of resources takes place between species that are native and species that are not native (Vijeta et al., 2021).

Ten species of invasive alien plants are regarded to be among the most dangerous in the world. *Lantana camara* is one of these species, and it is fast spreading throughout India. The physicochemical properties of the soil are changed as a result of this. Additionally, it is connected to the environmental and economic benefits and drawbacks that are related to the scenario of global climate change (Rai and Singh, 2019). More than 40% of the total range of Tiger's habitat in India is occupied by it and the southern Western Ghats, Shivalik hills and central India are the worst hit in India.

Parthenium sp. known as congress grass in India has spread over many tropical and subtropical countries. Although it is a native species of tropical America, it is found in almost all states in India and it is reported that its invasion causes loss of yield in several crops.

The introduction of species that are not native to the area is either accidental or intended. The introduction of noxious weeds, insect pests, and other undesirable organisms is done on

Figure 5.1: *Parthenium* sp. (Congress grass)

Figure 5.2: *Lantana camara*.

purpose. It was European ships that brought foxes, rabbits, and cats to Australia, and these animals have been responsible for the extinction of Australia's native biodiversity. In the instance of freshwater fish, the introduction of alien fish into rivers for a variety of reasons has resulted in the extinction of at least 18 species of native fish that were found in rivers in North America. The Nile perch was introduced into Lake Victoria, which resulted in a decrease in the fish biodiversity of the lake (Hens and Boon, 2005). The eucalyptus tree, which is native to Australia, has been brought to several tropical and subtropical regions around the world, including India, where it just acts as a nuisance (Hens and Boon, 2005).

When compared to natural prairie grasses, the perennial tussock grass known as Agropyroncristatum, which was introduced into the northern Great Plains of North America, has a relatively smaller root allocation. In comparison to the soil of natural prairies, the soil of *A. cristatum* contains lower levels of both accessible nitrogen and total carbon. Due to the presence of this species, the amount of carbon that was stored in the soil was reduced by 480 x 1012 grams. The quantitative content of organic matter and nutrients in the soil can be altered by soil invertebrates such as earthworms and termites. This, in turn, affects the composition of the flora and animals that are found above ground. However, even though they are very flammable, several grasses that are useful for cattle grazing have been introduced to the Hawaiian Islands. In the protected woodlands, these grasses spread quickly and caused the fire to spread farther and further. These grasses can rebound quite fast, in contrast to the many woody plants and endangered species that have been eradicated as a result of this fire.

Temperatures of the soil have a significant impact on the availability of nutrients and the level of productivity in late-successional boreal forests. When moss is present, it decreases the amount of heat that enters the soil, which in turn makes the permafrost, which is frozen earth, more stable. Because of this, the pace at which nutrients are cycled is slowed down after that.

The moss biomass decreases and the permafrost becomes less stable as a result of the increased fire frequency that occurs as a result of the climate change that occurs at high latitudes. As a consequence of this, the availability of nutrients increases, and the species composition of forests transforms.

According to the Zoological Survey of India, *Achatina fulica*, commonly known as the African Apple snail, is among India's most invasive exotic alien fauna. This molluscan species was first found in Andaman and Nicobar Island. It is harmful to many native species in India. *Paracoccus marginatus*, commonly known as Papaya Mealy Bug which is native to Mexico and America, has damaged huge papaya crops in West Bengal, Assam, and Tamil Nadu. *Phenacoccus solenopsis* commonly known as Cotton Mealy Bug, which is a native species of North America has severely destroyed the crops of cotton in Deccan. *Pterygoplichthys pardalis* commonly known as Amazon sucker mouth sailfin catfish, has destroyed the population of fish in many aquatic water bodies of Kolkata (Zoological Survey of India).

Figure 5.3: *Achatina fulica*.

Figure 5.4: *Pterygoplichthys* sp.

Biotic invasion has multiple effects on the ecosystem, directly or indirectly affecting biodiversity. As we have discussed, biotic invasion causes forest fires, ultimately leading to land use changes. Nutrient composition will be changed if the species' composition is changed. Less carbon sequestration is caused by biotic invasions that cause the climate change. Fig.5.5 shows various effects of biotic invasion that ultimately cause biodiversity loss.

Loss of coexistence:

The diversification of the ecosystem depends on some major mechanisms that help sustain so many species. Coexistence is one of those mechanisms. Coexistence demands the ability to use evolutionarily sustainable interspecific tradeoffs to deal with the factors limiting species' fitness and abundance. There are many limiting factors and trade-offs that exist in ecosystems. Species may coexist due to their interspecific trade-offs between their abilities to compete and their abilities to disperse, between their abilities to compete and their sensitivity to disease, herbivory, and predation, and between their abilities to survive with average conditions and their abilities to exploit resource (Tilman, 2000).

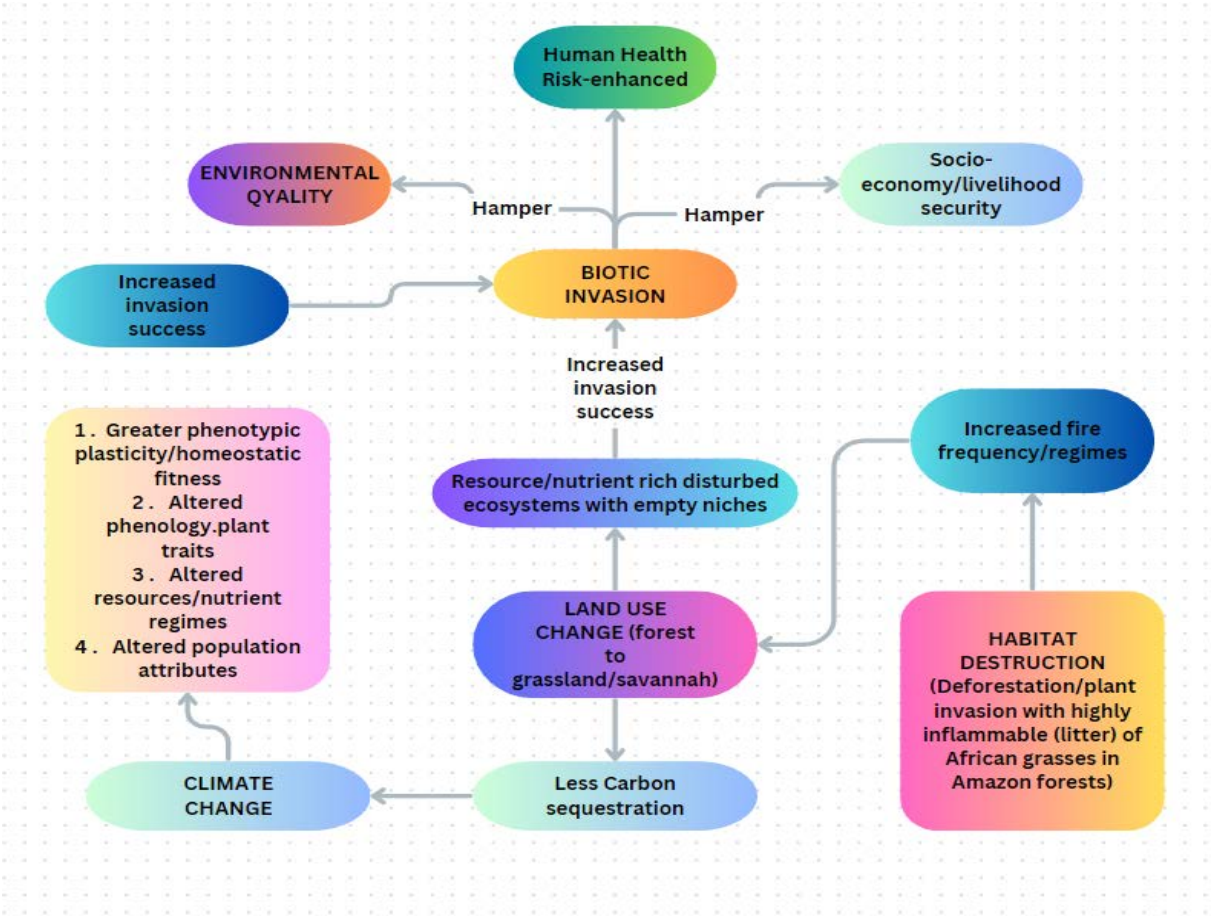


Figure 5.5: Impact of Biotic invasion.

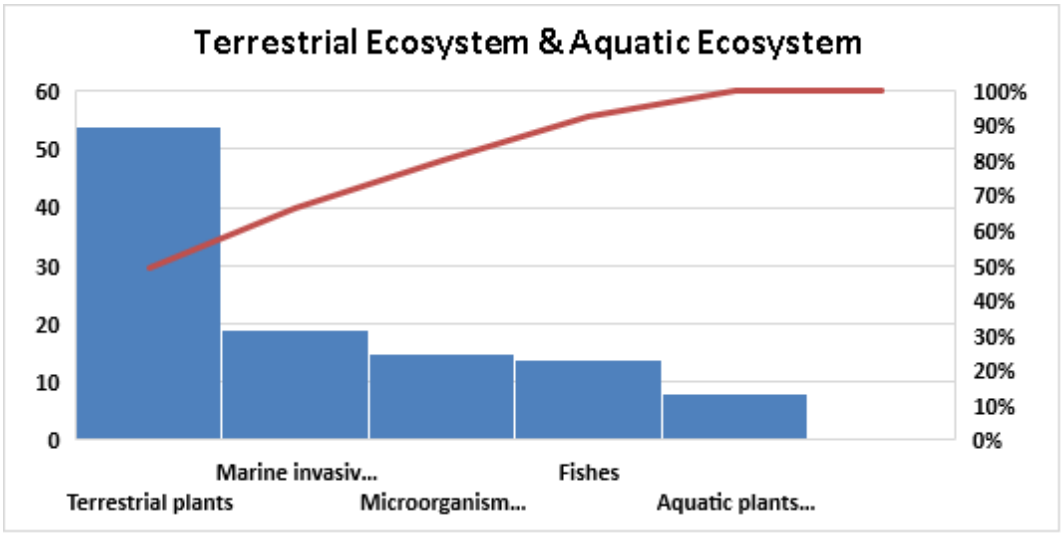


Figure 5.6 (a): Terrestrial Ecosystem & Aquatic Ecosystem.

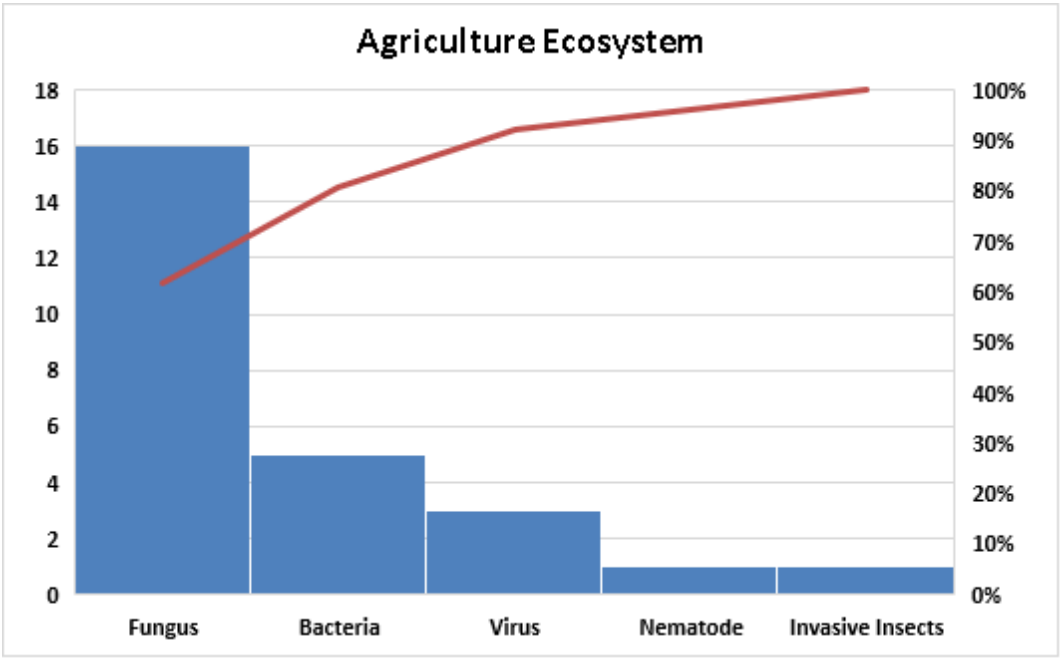


Figure 5.6 (b): Agriculture Ecosystem.

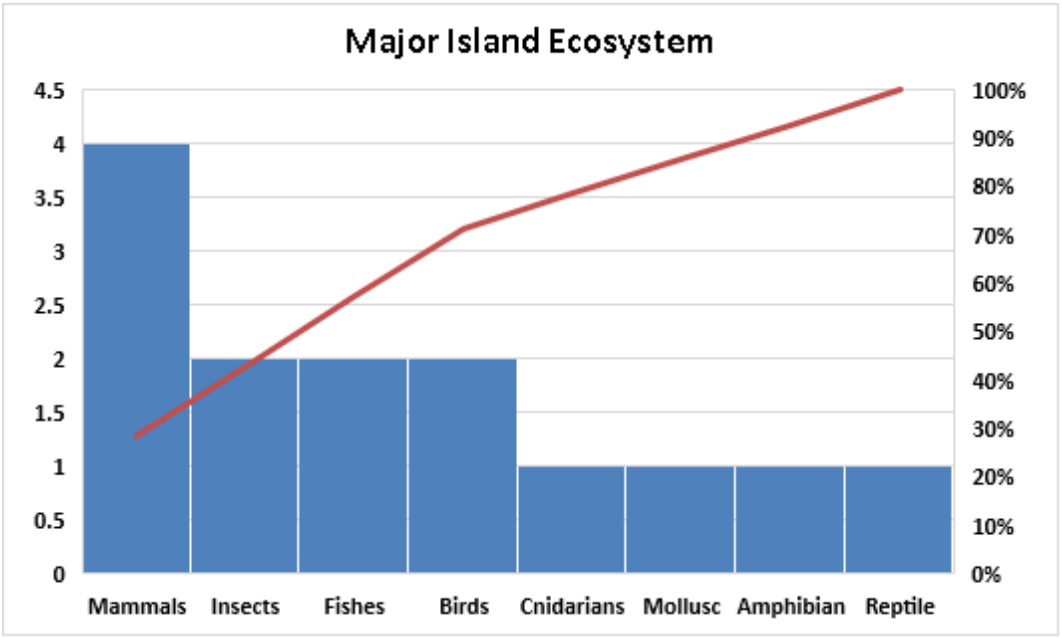


Figure 5.6 (c): Major Island Ecosystem

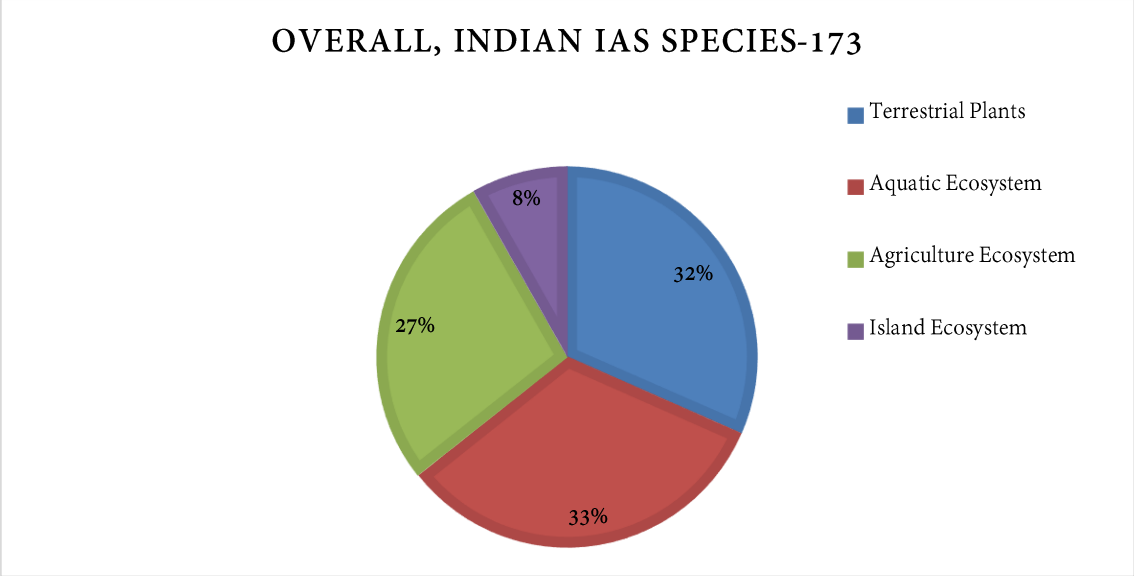


Figure 5.6 (d): Overall, Indian IAS Species-173

Figure 5.6: Information about alien species that have been reported in India [Data source: Invasive Alien Species of India Compiled by S. Sandilyan (National Biodiversity Authority, Ministry of Environment Forests and Climate Change Government of India)].

Species are coevolved with one another such as plants with their specific pollinators, medicinal plants, hosts with their specific parasites, etc. (Ghosh et al., 2022; Sarkar et al., 2021). Upon passing the final passenger pigeon (*Ectopistes migratorius*) passed away during the '90s, two of its parasites that are unavoidable and two lice species went extinct with the passenger pigeon. Moabi (*Baillonella toxisperma*) is an essential tree in West Africa, but it depends on elephants for its reproduction because only the elephants can swallow and disperse the Moabi seeds. So if elephants go extinct, probably Moabi will also extinct. These phenomena are known as the “Knock On” effect (Hens and Boon, 2005).

Darwin and Wallace proposed that a monoculture should be less productive than a diversified combination of plants because of the diversity of the plants. In addition, they proposed the underlying biological mechanism due to the ecological differences that exist between multiple species that cohabit. When a species goes extinct, it leaves behind a vacant niche space, which may affect the processes that occur within the ecosystem. A basic biological principle that predicts that communities that are intact and varied are generally more stable and function better than communities that have lost species is provided by Darwin and Wallace's hypothesis, assuming that it is valid (Purvis and Hector, 2000).

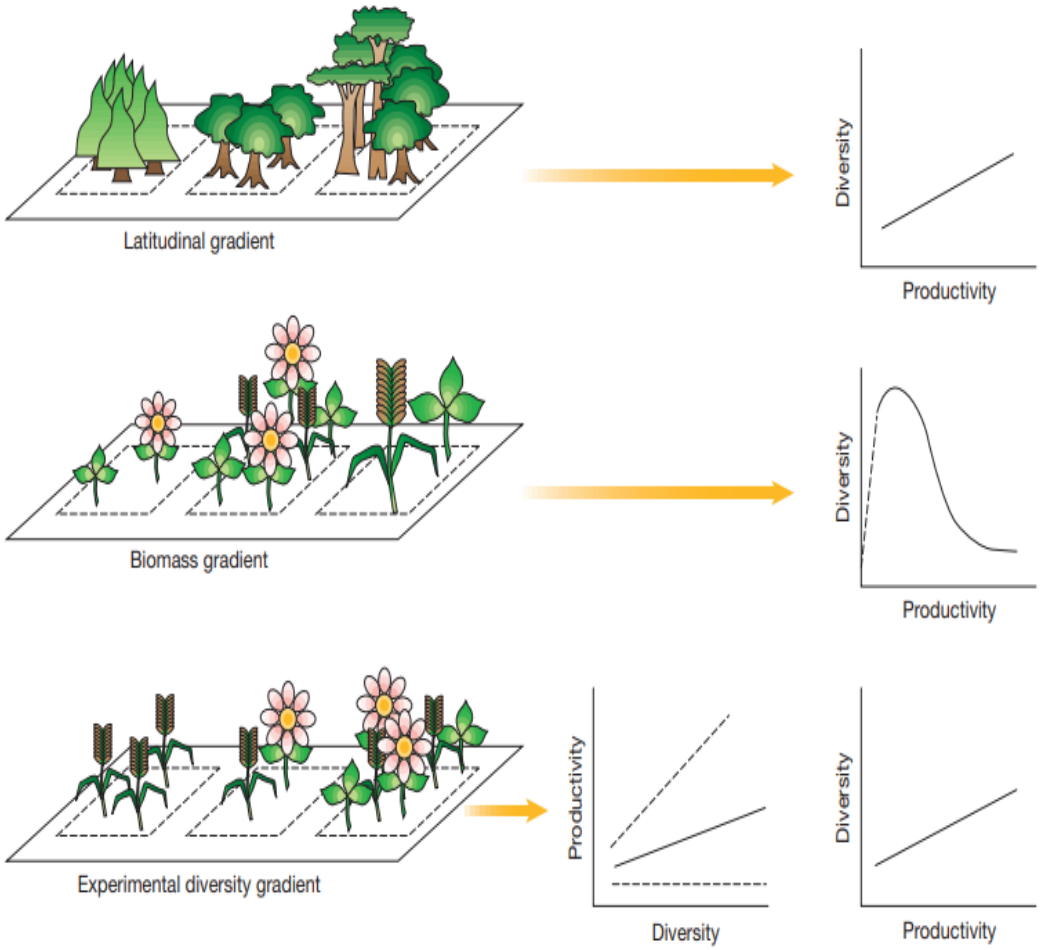


Figure 6: Relationship between diversity and productivity. According to the uppermost panel, it is observed that the presence of plant diversity in wide areas is positively associated with an increase in production, ranging from high latitudes to the tropics. The middle panel demonstrates that the diversity of plants that belong to small plots is inversely proportional to increased productivity and frequently results in a bigger unimodal distribution of diversity that is shaped like a hump. The number of species correlates with a variety of parameters, including as size, spatial heterogeneity, and competitive exclusion, and this correlation increases as productivity rises. In the lowermost panel, it is demonstrated that productivity has a tendency to grow with diversity, which in turn causes an increase in interactions between species that are either complimentary or positive. This indicates that there is a higher probability that varied communities contain a species that is extremely productive (Picture Source: Measure of biodiversity, Nature, Vol-405).

Climate change:

Biodiversity and climate change are strongly associated with each other. Climate has been changing from primitive Earth to the present Earth. So, climate change is quite a natural process through which species have evolved, but accelerated climate change disrupts ecological systems. Species cannot acclimate to the environment and hence, biodiversity loss is enhanced at an unnatural rate. Various human activities mainly induce climate change. As a result, the

distribution of species is changed and many species become extinct, ultimately affecting the humans and global ecosystem.

Two key components of climate change have a direct and considerable impact on the biodiversity of India. These features are the variation in temperature and the rate of precipitation. According to Thuiller (2007), a temperature increases of one degree Celsius will cause a change of 160 meters vertically and 160 kilometers horizontally in the zone of occurrence of various species that are considered to be specialists. It has been noted by Sukumar (1995) that endemic mammals such as the Nilgiri Thar are in increased danger of going extinct (Soni and Ansari, 2017).

The impact of climate change on biodiversity is expected to increase due to the continued rise of CO_2 levels and temperature. As a result, the frequency and intensity of heat and storms will increase daily (IPCC, 2007). It has been analyzed that the rapid increase of greenhouse gases threatens global biodiversity. The prediction of IPCC, 2007 is that by the end of the 21st century global surface temperature may rise to 4^0C and also stated that an increase of 1.5^0C to 2.5^0C would threaten 20-30% of plant and animal species of the world, resulting in extinction. According to Bates et al. (2008), climate change may have a negative influence on over 5,000 plant species as a result of the loss of habitats that are suited for them. Additionally, the Intergovernmental Panel on Climate Change (IPCC) (2007) has noted that the primary function of increasing the levels of CO_2 in the global atmosphere is indicated by the increase in CO_2 concentration from 280 ppm in 1750 to 379 ppm in 2005. According to the assessments of the Intergovernmental Panel on Climate Change (IPCC), human activities have had a significant impact on the worldwide water cycle by altering the global carbon cycle (NASA, 2010). According to Goswami et al. (2006), more instances of heavy rainfall have been seen over India, whereas the number of instances of low and medium rainfall has dropped. Climate change has been shown to have widespread effects on several levels of biodiversity, including genes, species, communities, and ecosystems, according to research conducted (Parmesan, 2006; Bellard et al., 2012; Soni and Ansari, 2017).

Table 1: Physical change associated with climate change and its potential impact on biodiversity (Soni and Ansari, 2017).

Observed physical changes	Potential impacts on biodiversity
Rise in the temperature of the environs	Shifts in the range of species and populations, as well as changes in phenology, might eventually result in the modification or elimination of biotic interactions.
Modifications to the yearly and seasonal precipitation patterns	Modifications to the makeup of the community
Significantly increased occurrences of extreme	Deaths that occur as a consequence of flooding following storms or droughts; injuries or deaths that occur as a

events	consequence of extreme cold or heat waves
Modifications to the hydrologic regimes	Reduced stream flow has an impact on the permanence of the population and the makeup of the community
Modifications to the fire regimes	Modifications to the makeup of the community
Acidification of the oceans	The calcification rates of marine species are affected by changes in the water's chemical composition.
Rise in sea level	The loss of habitat and its fragmentation
An increase in the stratification of the ocean	The decreased productivity of ecosystems that are pelagic
Variations in the upwelling of the coast	Variations in the productivity of fisheries and ecosystems along the maritime coast.

The Olive Ridley turtle one of the smallest sea turtle present on Earth is facing the threat of extinction due to climate change. Rushikulya Beach of Odisha is one of the biggest nesting sites of this turtle. Due to intense floods and cyclones, the eggs of this turtle are affected. Turtles show temperature-dependent sex determination. Apart from the egg destruction, the rising temperature due to climate change causes a change in the gender ratio. The male turtle will be born if the egg hatches below 290C and if the temperature increases above 290C or 310C, the female will be born. As temperatures start to increase due to climate change, more females are produced. Thus, sex bias has been seen in Turtles (WION, 2023).

Ocean acidification:

The ocean covers almost 70% of the Earth's surface and any kind of abnormal condition in the ocean due to anthropogenic CO_2 emission can cause massive damage to the Earth's biodiversity. Ocean acidification is nothing but the lowering of the ocean's pH. Due to the increasing amount of CO_2, the ocean absorbs CO_2 much faster during the last few decades than previous thousands of years. The term "Ocean Acidification'' does not mean that the oceans have become acidic or will become acidic shortly rather it indicates a shift of ocean pH towards a less alkaline level. The present shift in ocean pH has already threatened the Coral reefs and calcifying organisms in the oceans. Oceans absorb two other acid-forming gases SO_x and NO_x. Globally, their impact is relatively minor but is expected to increase as the emission continues to increase (Abbasi and Abbasi, 2011).

One of the most important roles of the ocean is the exchange of carbon dioxide with the atmosphere, thereby maintaining the Earth's carbon cycle, which helps sustain the Earth's ecological balance and enables many life forms to survive. A complex web of interactions controls the exchange of CO_2 from the atmosphere to ocean water and vice versa. This exchange has continued since the last 800 thousand years, the average ocean pH would have remained at about 8.2. But from 1950 onward, CO2 emissions have risen sharply due to increased use of fossil fuels, cement production, agriculture, and various changes in land use.

One-third of the anthropogenic CO_2 that is absorbed by the ocean is responsible for the shift of ocean chemistry and causes more H+ to be released than before. It means that the ocean becomes less alkaline (Abbasi and Abbasi, 2011).

Figure 7.1: Olive Ridley Turtle at Rushikulya Beach (Source: WION, 2023).

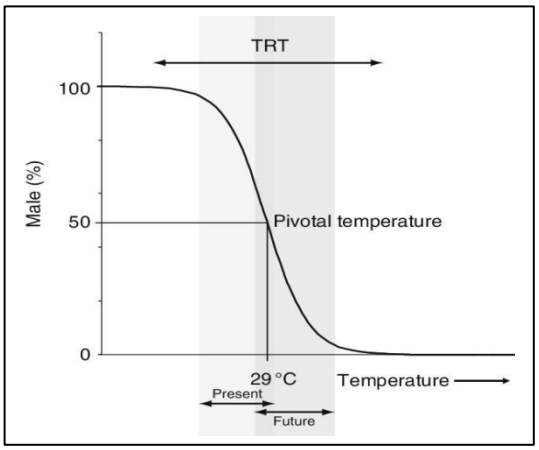


Figure 7.2: Temperature dependent sex bias in turtle (Source: Advances in Marine Biology).

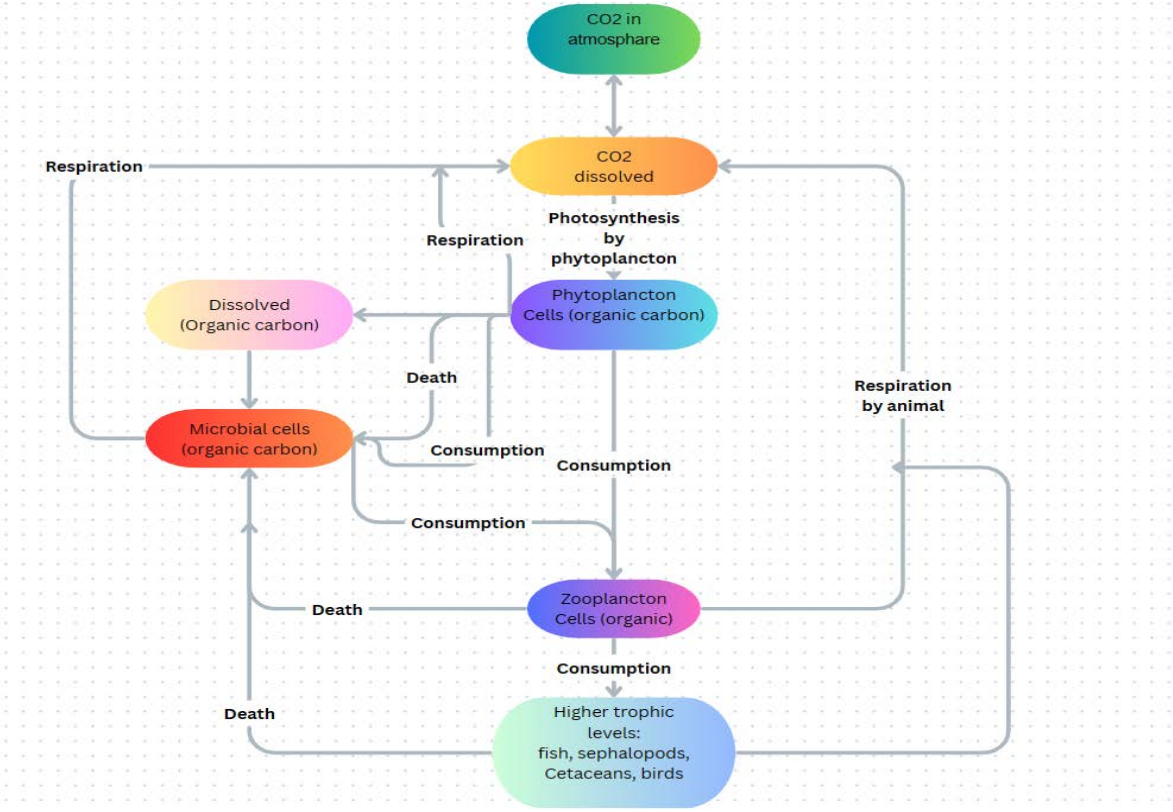


Figure 8.1: Interactions within the intricate web that are linked with the carbon dioxide cycle in the ocean.

Effect of ocean acidification on the biodiversity of Lakshadweep:

The coral reef ecosystem is popularly known as 'The Rainforests of the Sea' as it is the second most diverse ecosystem on Earth. It is one of the most beautiful ecosystems on our planet. Coral reef consists of the greatest number of species among all the marine ecosystems. A coral reef prevents coastal erosion by acting as a barrier against wave action along coastal areas, thus providing ideal conditions for the seagrasses to establish and flourish along the seashore. Coral reefs are mostly associated with seagrass beds and mangroves with active physical, chemical, and biological interactions and mutual benefits.

The islands of Lakshadweep are the only atolls that may be found in the oceans of India. The Union Territory of Lakshadweep is an archipelago that is located in the Arabian Sea where it is situated between the latitudes of $08^0$00' North and $12^0$30' North and the longitudes of $71^0$00' East and $74^0$00' East. It is around 220 to 440 kilometers away from the western coast of India. Lakshadweep is the Union Territory of India that is the smallest in size. The islands are the most northern section of the Laccadive-Chagos Ridge. They are made up of eleven atolls, each of which contains approximately thirty-six islands, as well as several submerged coralline banks, which are coral atolls that have expansive lagoon areas. In addition to having sandy beaches and seagrass meadows in the lagoons, islands are distinguished by the presence of huge coral reefs that surround them.

Table 2: Number of coral species reported from 12 islands of Lakshadweep (Pillai and Jasmine, 1989).

Sl.No.	Islands	No. ofgenera	No. ofspecies
1.	Minicoy	28	73
2.	Sheila	7	11
3.	Kavarathi	18	38
4.	Kalpeni	11	23
5.	Androth	7	15
6.	Agathi	10	27
7.	Bangaram	5	8
8.	Amini	15	37
9.	Kadamath	21	45
10.	Kiltan	19	42
11.	Chethlath	23	57
12.	Bitra	6	15

The corals in these islands are mostly dominated by *Acropora* sp. and *Porites* sp. (Anon, 2000). Occasionally, young colonies of *Psammocora* sp., *Stylophora* sp., *Pocillopora* sp., and *Leptoria* sp. are found on the reef flats. *Acropora* sp. is found to be dominant in the reef areas of Kavarathi, Agathi, and Kadamath islands.

Foraminifera plays a major role in ocean calcification in Plankton and bottom-dwelling environments. During the calcification process, the pH of encapsulated seawater decreases, so the alkalinity automatically declines. To prevent this, foraminifera increases the pH and raises the carbonate ion (CO_3^{2-}) concentration. If the pH of ambient water decreases due to ocean acidification, this process needs more energy. This is the reason why the calcifying organism is adversely affected by decreasing pH. Allowing more energy to calcify to counteract the effect of decreasing pH could avail less energy for other crucial metabolic processes, which may reduce organisms' growth (Abbasi and Abbasi, 2011; Sharma et al., 2022).

The coral reefs in warmer water regions generally exist within a narrow range of temperature, light, and aragonite saturation states. Due to ocean acidification, these physicochemical parameters are altered. Ocean acidification causes the rapid loss of symbiotic Dinoflagellate and ultimately results in coral bleaching. Coral calcification is directly proportional to the aragonite saturation, which solely depends on carbonate ion concentration. Doubling atmospheric CO_2 could cause a 10%-30% reduction in the calcification rate (Abbasi and Abbasi, 2011).

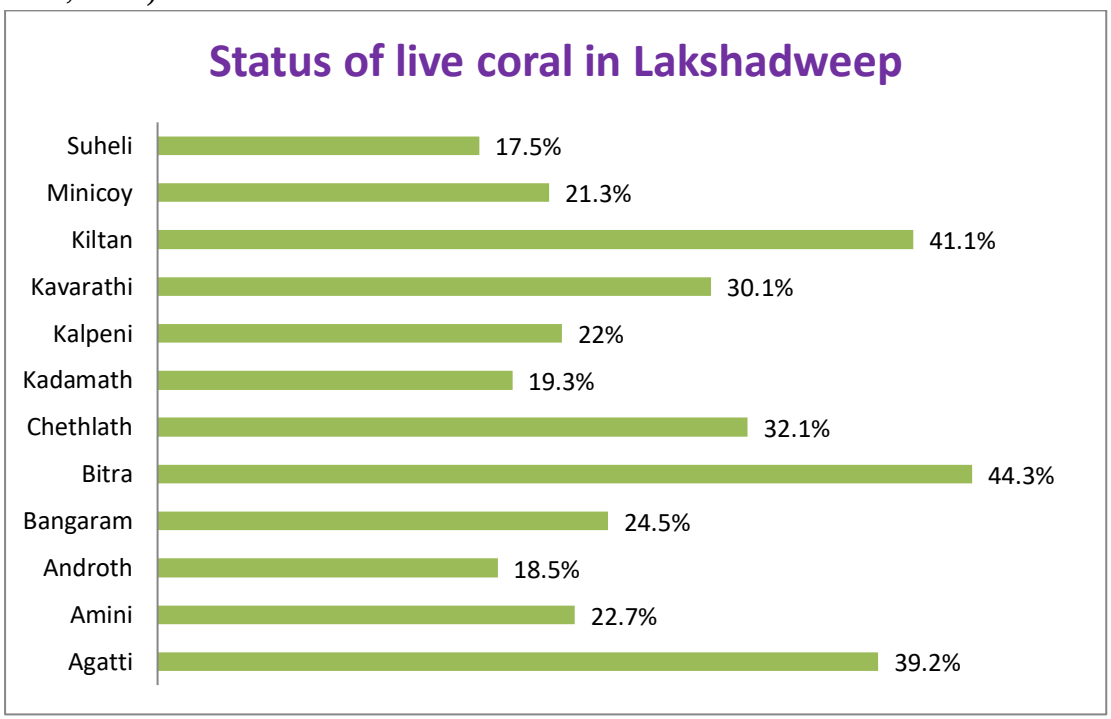


Figure 8.2: Status of live coral covers in 12 islands of Lakshadweep (2007) (Source: Ministry of Environment and Forest).

Pollution:

Pollution has many adverse effects on biodiversity and most of them are manmade. Basic abiotic components of an ecosystem, like soil, water, and air, are contaminated and the living components of an ecosystem are affected due to the unexpected change in physical parameters. Turtle fails to regurgitate due to the air pollution, causing internal injuries leading to death.

Microplastics in the environment also contaminate the air reduce the survival rate of larvae, diminish food consumption, and gradually weight loss in aquatic animals. The increasing concentrations of heavy metals in the soil are not easily broken down and accumulate by plants. Agricultural pollutants such as nitrogen from fertilizers alter the soil's pH and nutrient level (Maiti, 2010, 2013; Raha et al., 2023; Vijeta et al., 2021).

Light is also an essential factor for creatures' survival because it regulates the biological clock of every organism accordingly. The late-night street lights, lights from buildings, and headlights of vehicles have very harmful effects on the biological clocks of nocturnal animals like bats. The feeding habits of bats have decreased. The behavior of the Moth is altered due to light pollution and the prey-predator relationship of the moth gets affected. The moth is known as an efficient pollinator for many species but pollination is also affected due to behavior change (Vijeta et al., 2021).

Plastic pollution:

The marine ecosystem is globally affected by human-made waste products mostly made up of plastic. The marine debris, such as bottles, bags, balloons, rubber, medicinal wastes, etc., end up in the ocean and accumulate all along the coastline. UNEP/IOC has included the following items in the list of marine debris:

-Plastic (molded, soft, foam, nets, ropes, buoys, monofilament line)
-Fisheries related equipment,
-Smoking-related items such as cigarette butts or lighters,
-Metal (drink cans, bottle caps, pull tabs),
-Glass (buoys, light globes, fluorescent globes, bottles)
-Processed timber (including particle board),
-Paper, rubber, and cloth.

The sizes of debris can be broadly classified into the following categories, which are commonly acknowledged worldwide: The term "macro-debris" refers to waste with a diameter more than 20 millimeters, whereas "meso-debris" refers to debris with a diameter between 5 and 20 millimeters, and "micro-debris" refers to debris with a diameter of 100 millimeters (Barnes et al., 2009). Plastic is a major marine debris, so it affects marine animals and birds. At least 267 different marine species, like turtles, sea birds, seals, whales, fish, sea lions, etc. have been reported to be harmed by entanglement or ingestion of marine debris (Pawar et al., 2016).

As we already know, India is partly surrounded by oceans from East, West, and South, so the accumulation rate of marine debris along the seashore is very high. So, it is very hard to survive for those marine intertidal faunas with very restricted niches.

Figure 9.1: Collection and isolation of varieties of plastic marine debris from Baguran Jalpai beach, West Bengal.

According to estimates provided by the United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), land-based sources are responsible for as much as 80 percent of marine debris, while activities that take place at sea are accountable for the remaining 20 percent (Pawar et al., 2016).

Table 3.1: Sources of marine debris (Data source: Plastic marine debris: Sources, distribution, and impacts on coastal and ocean biodiversity, 2016)

Sources of marine debris	
Land-based sources	**Ocean-based sources**
1. Storm water discharges 2. Combined sewer overflows 3. Littering 4. Solid waste disposal and landfills 5. Industrial activities	1. Commercial fishing 2. Recreational boaters 3. Merchant, military, and research vessels 4. Offshore oil and gas platforms and exploration

Due to the increasing demand for plastic, its production has increased decade after decade. Plastic production in the year 1950 was approximately 1.5 million tonnes; in 2011, it was approximately 280 million tonnes (Plastics Europe, 2012). Microplastic and Nanoplastic are very harmful to organisms that belong to lower trophic levels in the ocean. Industrial coastal areas have been identified as microplastic hotspot regions. The sediment of a populated coastal area can be contaminated by these micro and nano marine debris (Power et al., 2016; Dandapath et al., 2016). It isn't easy to eliminate plastic because it is non-biodegradable. It is only photodegradable into small pieces and may persist for centuries.

Table 3.2: some common types of plastic wastes [data source: Pawar et al. (2016)].

Acronym	Full name	Common example
PETE/PET	Polyethylene terephthalate	Soda bottles, Films
HDPE	High-density polyethylene	Milk jugs, Packaging, Shampoo bottles, Yogurt containers, Detergent bottles, Shopping Bags
PVC	Polyvinyl chloride	Clear food packaging, Candy wrappers, Some bottles, Water pipes, Curtains, Credit cards, Packaging films, Water films
LDPE	Low-density polyethylene	Plastic bags, Wire cloth, Squeezable bottles, Shopping bags
PP	Polypropylene	Caps, straws, Some bottles, Plastic bags and toys, Drinking straws
PS	Polystyrene	Takeout food containers, Disposable cups & plates, Fast food boxes, CD cases
PC PA Other	Polycarbonate Polyamide/Nylon Acrylonitrile butadiene styrene	Water jugs, DVDs, Sunglasses, Toothbrushes

Impact of plastic marine debris:

The environmental impact of plastic can be classified as physical, chemical, and biological. Marine debris travels throughout the ocean and can cause the degradation of physical habitats, the transportation of chemical contaminants, the endangerment of marine life, and the destruction of the aquatic ecosystem. Marine trash made of plastic has the greatest potential to effect changes in the ecosystem and to have an effect on the biota. Because it is suspended near the surface, it is carried by ocean currents to a great extent and remains in the environment for a considerable amount of time. If it is consumed, it is not easily digested. In light of this, the impact of plastic litter on marine environments is a more significant problem than other environmental problems.

Table 3.3: Environmental impact of plastic marine debris (Pawar et al., 2016).

Physical habitat impacts of plastic marine debris
1. Accumulation of debris (Modified habitat structure) 2. Habitat degradation 3. Damage and degradation of coral reef and soft sediment 4. Smother the benthos (reduce light penetration and oxygen exchange) 5. Decline benthic habitat-forming species. 6. Alien species invasions (free flow of marine debris)
Chemical impacts of plastic marine debris
1. Accumulation and transport of persistent organic pollutants (POPs) 2. Leaching of constituent contaminants from plastics A. Bisphenol A (BPA) B. Phthalates
Biological impacts of plastic marine debris
1. Ingestion by Marine turtles, Pelagic seabirds, Cetaceans, fish 2. Bioaccumulation 3. Mimicry of phytoplankton 4. Add toxic substances to the aquatic food chain 5. Entanglement

Pesticide:

Pesticides are one of the major causes of biodiversity loss nowadays. They affect the ecosystem directly by damaging biotic components and indirectly by contaminating abiotic components. Pesticides can be inserted into the food chain and damage the whole ecosystem. Only a decade after the 'green revolution' it became obvious that large-scale spraying of pesticides was causing serious damage to the environment. Many pesticides are toxic for insects, birds, mammals, amphibians, fishes, and other creatures that play beneficial roles in the environment. Wildlife poisoning depends on the quantity of the pesticide and its nature, including toxicity and other properties. Insecticides, rodenticides, fungicides, and more toxic herbicides threaten exposed wildlife (Bagchi, 2020; Das et al., 2022; Deb et al., 2020). Pesticides accumulate in the food chain, causing serious endocrine abnormalities and other physiological changes. Broad-spectrum use of insecticides and herbicides reduces the food supply for birds and mammals resulting extinction of rare species (Isenring, 2010).

Pesticides enter aquatic bodies like ponds, rivers, lakes, etc., and change the physicochemical parameters, affecting aquatic life forms. It reduces the dissolved oxygen in water bodies and causes behavioral and physiological changes in fishes. The eutrophication rate is also increased due to agricultural run-offs' contamination of water bodies. Killing aquatic plants by herbicides can decrease the amount of oxygen in water bodies, reducing fish productivity. Herbicide glyphosate is known to cause high mortality of tadpoles and juvenile

frogs. Pesticides can enter into the body of aquatic organisms via Dermal absorption (Direct absorption via skin), Breathing (Uptake via gills during breathing), and oral uptake (entry via drinking contaminated water effects of pesticides on the environment) (Arya et al., 2021).

The population of beneficial insects like bees and beetles can decline by the broad spectrum use of insecticides like carbamates, organophosphates, and pyrethroids. Pesticide accumulation in the tissue of insectivorous birds leads to the death of many rare species of birds. The bald eagle population in the USA declined primarily because of overexposure to DDT and its metabolites. Pesticides can kill beneficial microorganisms present in the soil, reducing soil fertility (Arya et al., 2021).

Thermal Power Plant:

Kolaghat thermal power plant in West Bengal releases enormous amounts of fly ash containing Silica, Zinc, Copper, Calcium oxide, Aluminium, etc. that contaminate groundwater and aquatic bodies. These contaminants may harm aquatic biodiversity near Kolaghat thermal power station (Mondal et al., 2016).

Loss of top predator:

Top predators affect biodiversity positively due to their key functional roles in regulating trophic cascades. They can be dominant or keystone species as they strongly affect the ecosystem. Their loss can be a major contributing factor to the biodiversity loss in aquatic and terrestrial ecosystems. Loss of top predators can induce the decline of plant biomass as the herbivores start to dominate (Rajak, 2017; Sarkar, 2017). Without top predators, other mesopredators begin to invade the ecosystem and disrupt the whole balance of the ecosystem (Letnic et al., 2012; DeLa et al., 2012).

Sundarbans is one of the largest reserves for the Bengal tiger (*Panthera tigris tigris* L.), the top predator. The tiger population helps regulate the number and distribution of prey and maintains the forest structure, composition, and regeneration. The tiger-human conflict reveals that if the tiger does not exist, the biodiversity of the Sundarbans will be affected by various human activities like poaching, hunting, overexploitation, etc. The rapid decline of prey populations, such as spotted deer, wild boar, barking deer, rhesus macaque, etc., by cyclones led to the extinction of the tiger population. Loss of tiger gives free access to overexploitation. Therefore, decreased mangrove populations can cause huge biodiversity loss. So, the whole ecosystem of Sundarbans depends on the tiger population (Saha & Sarkar, 2022). Due to a lack of proper understanding and awareness of the value of these ecosystems and wildlife, people living around the Sundarbans ecosystem are careless about the integrity of these ecosystems and their valuable flora and fauna. These people deeply believe that tigers are their enemy When the tiger comes out, the villagers unite and put their maximum effort into killing the tiger. So, the common scenario is that the stray tiger is often killed by Poisoning, shooting, or snaring. The tiger-human conflict is so intense because the poor people of Sundarbans enter the

tiger territory for fishing, honey collection, and Golpata collection. Suitable honey-producing trees in the Sundarbans, such as Kholsi, Baen, Kankra, Goran, Gewa, etc. exist in the forest's interior part, which is considered a tiger risk zone (Haque et al., 2015).

It has been reported that habitats occupied by top predators are more diverse than habitats without top predators (Sergio et al., 2005). Top-down control is regulated by the top predators. Therefore, the abundance of upper trophic level dwellers can affect the abundance of lower trophic level dwellers. Top-down control means that predation by higher trophic levels affects biomass accumulation at lower trophic levels. The higher trophic level always maintains its stability by competition and the next lower trophic level is maintained by predation. For the level system, predators and producers are regulated by competition. In the four-level system, top predators and herbivores are limited by competition, while predators and producers are limited by predation and consumption, respectively (Lawrence, 1991). Now, we can predict how important it is to maintain the existence of top predators to prevent biodiversity loss.

Policies adopted by the Indian government:

India, as a megadiversity nation, has adopted many policies and laws. The major goal of these laws and policies is to educate people about nature and its conservation. It is very important to give the message to the local people about how important role the of biodiversity is playing in our lives (Gogoi et al., 2023). Various countries have taken various strategies to protect biodiversity and India is one of them. Here, we are mainly focusing on the steps taken by India's government. The major steps are-

- The government of India enacted the Wildlife Protection Act in 1972. This act creates protected areas for wild fauna and punishments for hunting wild fauna specified in schedules I to IV thereof.
- Wetland Conservation and Management Rules, 2010 have been applied to protect wetlands in the states.
- The National Plan for Conservation of Aquatic Eco-System scheme has been started to manage wetlands in the states, including Ramsar sites in India.
- The Wildlife Crime Control Bureau has been established to control illegal wildlife trade, including endangered species.
- The Wildlife Institute of India, Bombay Natural History Society, and Salim Ali Centre for Ornithology and Natural History are some research institutes that have researched the conservation of wildlife.
- The Govt. of India banned the veterinary use of diclofenac drug which caused the rapid decline of the Gyps vulture population across India. The Bombay Natural History Society has started a conservation breeding program to conserve these vulture species at Pinjore (Haryana), Buxa (West Bengal), and Rani, Guwahati (Assam).
- An additional component known as "Recovery of Endangered Species" has been

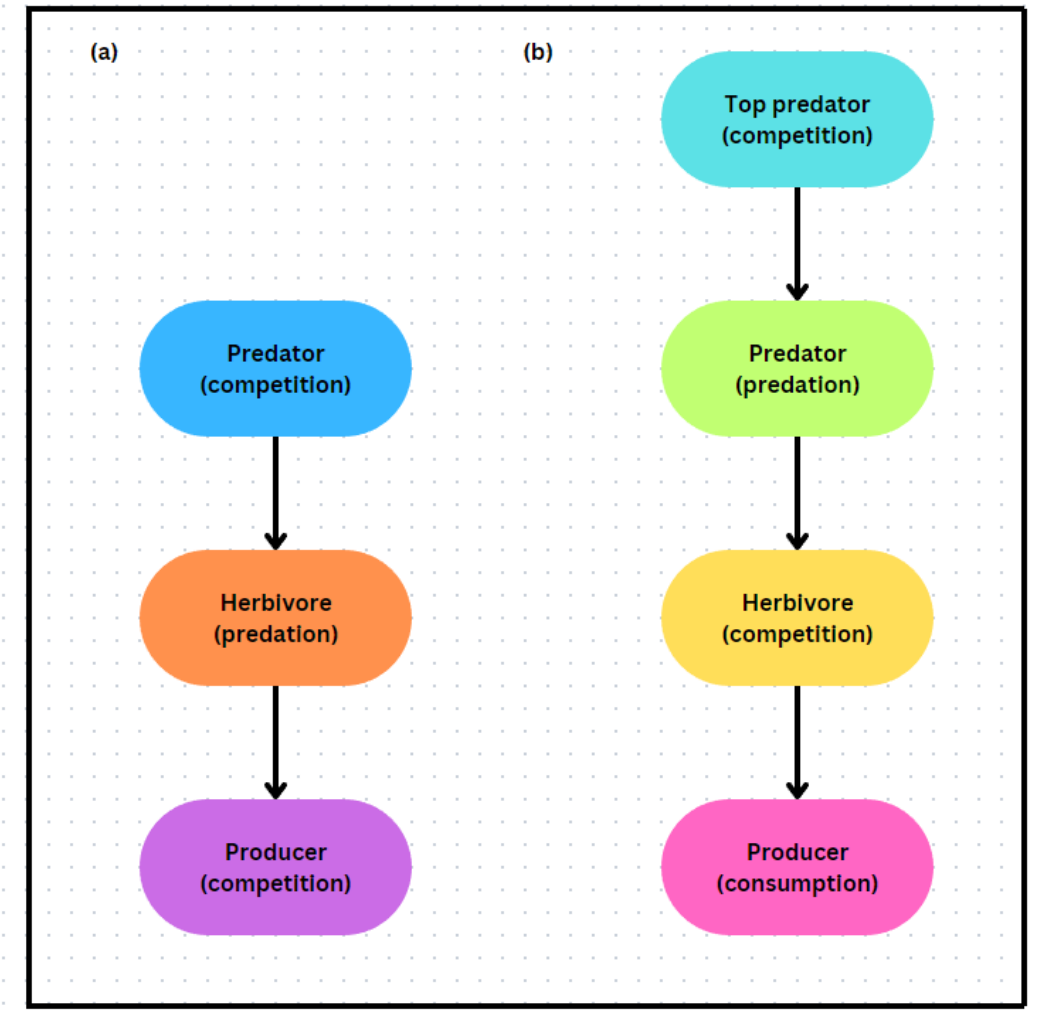


Figure 10: (a) Shows that predators and producers are limited by competition while herbivores are limited by predation. (b) Shows that top predators and herbivores are limited by competition while predators and producers are limited by predation and consumption respectively (Picture courtesy: Encyclopedia of Ecology, 2008).

- incorporated into the plan known as "Integrated Development of Wildlife Habitats," which has been amended. The recovery of sixteen different species has been identified, including the Snow Leopard, the Bustard (including Floricans), the Dolphin, the Hangul, the Nilgiri Tahr, the Marine Turtles, the Dugong, the Edible Nest Swiftlet, the Asian Wild Buffalo, the Nicobar Megapode, the Manipur Brow-antlered Deer, the Vultures, the Malabar Civet, the Indian Rhinoceros, the Swamp Deer, and the Jerdon's Courser.
- Under this ‘Recovery of Endangered Species’ government has spent lakhs of rupees on Hangul in Jammu and Kashmir, Snow Leopard in Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Arunachal Pradesh, Vulture in Punjab, Haryana and

Gujarat, Swiftlet in Andaman and Nicobar Islands, Nilgiri Tahr in Tamil Nadu, Sangai Deer in Manipur.

- As per Wildlife Protection Act in 1972 protected areas like national parks, sanctuaries, conservation reserves, and community reserves have been created to protect important habitats of threatened species.
- The central government initiated 'Integrated Development of Wildlife Habitats', 'Project Tiger', and 'Project Elephant' with states' financial and technical assistance.
- The Central Bureau of Investigation (CBI) has been incorporated under the Wildlife Protection Act, 1972 to apprehend and prosecute wildlife offenders.

Important Acts to protect biodiversity in India:

- Fisheries Act, 1897
- Indian Forests Act, 1927
- Mining and Mineral Development Regulation Act, 1957
- Prevention of cruelty to animals, 1960
- Wildlife Protection Act, 1972
- Water (Prevention and Control of Pollution) Act, 1974
- Forest Conservation Act, 1980
- Air (prevention and control of pollution) Act, 1981
- Environment Protection Act, 1986
- Biological Diversity Act, 2002
- Scheduled Tribes and other traditional forest dwellers (recognition of rights) act 2006

Important policies to protect biodiversity in India:

- National Forest Policy
- National Conservation Strategy and Policy Statement on Environment and Development
- National Policy and macro-level Action Strategy on Biodiversity
- National Biodiversity Action Plan (2009)
- National Agriculture Policy
- National Water Policy
- National Environment Policy (2006)

Other schemes by Govt. of India (George, 1972; Views and Patel, 2021):

- Nagar Van Udyan scheme
- Swachh Bharat Abhiyan in 2014
- Project Tiger in 1973
- Green Skill Development programme in 2017
- National River Conservation Programme

- Green India Mission
- National Coastal Management Programme
- National Afforestation Programme
- National Mission on Himalayan Studies Under Climate Change Programme

Private initiatives:

There are so many companies all over the world that have adopted eco-friendly strategies to develop their companies. The motivation for eco-friendly initiatives is to remain relevant in the future business environment. These companies' production, servicing, and manufacturing can resolve many environmental concerns. Therefore, companies are trying innovative ways to promote a green environment (Saha, 2023). The rapid depletion of natural resources forces companies to go green with sustainable use of natural resources (De et al., 2018; 2019). Here, we will discuss some major reputed companies that have already taken eco-friendly initiatives (Matthews, 2020; Lawson, 2021).

- Coca-Cola and Pepsi (maintenance of water system on which their products depend. Coca-Cola has been working with WWF to conserve key watersheds and improve the efficiency of its use of water in a sustainable way.)
- McDonald’s (company uses energy-efficient appliances, sets up green parking lots, and uses considerate means to obtain their animal products.)
- Dell (promote safe disposal of its products and then recycling.)
- Google (use renewable energy sources, construct the world’s most energy-efficient data center, and support green energy projects.)
- Bank of America (promote a sustainable environment by recycling 30000 tons of paper per year.)
- Tesla Motors (manufactures eco-friendly cars.)
- Wal-Mart (applied a strict policy to cut off suppliers whose manufacturing, processing, and distribution methods contributed to vast carbon emissions and retail stores utilize 100% renewable energy sources.)
- United Airlines (since the year 2000, the airline has managed to reduce Nitrogen Oxide emissions by 75% and spent more than 16 billion US dollars to replace all their airplanes with more fuel-efficient airplanes.)
- Tesco (uses biodiesel trucks for deliveries and estimates its carbon footprint on each item sold.)
- Brooks (introduce a completely biodegradable running shoe.)
- S.C Johnson (reduce 1.8 million pounds of volatile organic compounds from its Windex artifacts and another 1.4 million pounds of polyvinylidene chloride from Saran Wrap.)
- Starbucks (bean-to-coffee approach and use of recycled coffee grounds in making their tables.)

- Toyota (reduced the overall carbon footprint and manufactured the world's first mass-market hybrid vehicle.)
- Pratt & Whitney (managed to lower the number of wasted ingots and reduce factory emissions.)
- HP (open various operational e-waste recycling plants and products are 100% recyclable.)
- Target (introduce eco-clothing line.)
- Ford Motor Company (owns the world's largest green roof and adopted a ten-part environmental policy.)
- Fisher Investments (preservation of Redwood and climate change initiative through cutting down on emissions and gases that threaten their existence.)
- Nike (uses sustainable and eco-friendly materials like recycled polyester and highlights green initiatives through advertisement.)
- Apple (focuses on three main areas – reducing its impact on climate change, preserving precious resources, and using safer product materials.)
- Disney (uses zero net direct greenhouse gas emission policies in all of its facilities and has adopted environmental policies like
- Zero waste (nothing in landfills)
- Net positive environmental impact
- Patagonia (gives 1% of all sales to ecological grants and organizations, involved in regenerative organic agriculture, water conservation, and sustainable material usage.)

Conclusion:

We are an integrated part of biodiversity; as an individual species, we have a key role in the ecosystem. Every species utilizes its niche according to its needs. We are also utilizing the environmental resources according to our needs. Extinction is always associated with evolution. There should be a balance between extinction and diversification. Now the extinction rate is faster than the diversification rate due to anthropogenic activities. If evolution's key is 'survival of the fittest', then we are modifying our environment so that we will probably not be fit to survive against upcoming environmental changes. Five mass extinction events happened during the pre-human era due to volcanic eruption, meteorite impact, long ice age, etc. Scientists predict that we are going through a sixth mass extinction event due to anthropogenic activities. So, this era is better known as the 'Anthropocene'. We must protect biodiversity from anthropogenic activities to sustain the whole ecosystem on Earth. Otherwise, the sixth mass extinction will probably destroy many life forms including us.

Acknowledgements:

We thank all Coastal Ecology Research laboratory members for their support and useful suggestions.

References:

Abbasi, T., & Abbasi, S. A. (2011). Ocean acidification: The newest threat to the global environment. *Crit. Rev. Environ. Sci. Technol*., *41*(18), 1601–1663. http://dx.doi.org/10.1080/10643389.2010.481579.

Alsterberg, C., Roger, F., Sundbäck, K., Juhanson, J., Hulth, S., Hallin, S., & Gamfeldt, L. (2017). Habitat Diversity and Ecosystem Multifunctionality: The Importance of Direct and Indirect Effects. Science Advances, 3(2). http://dx.doi.org/10.1126/sciadv.1601475

Arya, S., Sudhakar, P., & Dwivedi, N. (2021). Pesticides and Its Impact on Biodiversity and Environment. *Iconic Res. Eng. Journals*, *4*(10), 12–15. https://doi.org/10.46505/IJBI.2021.3106

Bagchi, B. (2020). A relative study of diversity of endophytic fungi in a Lianas Butea superba from Belpahari and their seasonal variation. *Int. J. Exp. Res. Rev.*, *23*, 27-34. https://doi.org/10.52756/ijerr.2020.v23.003

Banks, S.C., Cary, G.J., Smith, A.L., Davies, I.D., Driscoll, D.A., Gill, A.M., Lindenmayer, D.B., & Peakall, R. (2013). How Does Ecological Disturbance Influence Genetic Diversity? *Trends in Ecology and Evolution*, *28*(11), 670-679. http://dx.doi.org/10.1016/j.tree.2013.08.005

Barnosky, A.D., Matzke, N., Tomiya, S., Wogan, G., Swartz, B., Quental, T.B., Marshall, C., McGuire, J. L., Lindsey, E.L., Maguire, K.C., Mersey, B., & Ferrer, E A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, *471*(7336), 51–57. http://dx.doi.org/10.1038/nature09678.

Boeck, H. J.D., Bloor, J.M.G., Kreyling, J., Ransijn, J.C.G., Nijs, I., Jentsch, A., & Zeiter, M. (2017). Patterns and Drivers of Biodiversity-Stability Relationships Under Climate Extremes. *Journal of Ecology*, *106*(3), 890-902. https://doi.org/10.1111/1365-2745.12897

Chapin, III. F. S., Zavaleta, E. S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C., & Diaz, S. (2000). Consequences of changing biodiversity. *Nature*, *405*, 234–242. http://dx.doi.org/10.1038/35012241

Dandapath, P., Oraon, G., & Jana, S. (2016). Tourism caused jeopardize of biodiversity: a case study on Mandermoni –Dadanpatrabarh coastal tourist destination in Purba Medinipur district, West Bengal, India. *Int. J. Exp. Res. Rev.*, *4*, 40-44. Retrieved from https://qtanalytics.in/journals/index.php/IJERR/article/view/1359

Das, S. K., Karan, S., & Sen, K. (2022). Biodiversity of avifauna in Chandigarh, Jhargram, West Bengal, India. *World Journal of Environmental Biosciences*, *11*(3), 8–13. https://doi.org/10.51847/jNtkP7dkxS

De, M., Medda, S., & Dey, S. (2018). Ecological Health of Wetland Ecosystem: An overview. *Int. J. Exp. Res. Rev.*, *17*, 20-29. https://doi.org/10.52756/ijerr.2018.v17.005

De, M., Pahari, G., & Das, R. (2019). Creating Urban Green Spaces (UGS) in Educational Institutions: A pilot project in Gurudas College, Kolkata-700054, West Bengal, India. *Int. J. Exp. Res. Rev.*, *19*, 22-30. https://doi.org/10.52756/ijerr.2019.v19.003

Deb, H., Saha, A., Deore, S., & Sanyal, T. (2022). Elephant Corridor loss due to anthropogenic stress – a study of change in forest cover using satellite data in the Sonitpur District, Assam, India. *Journal of Wildlife and Biodiversity*, *7*(2), 21–34. https://doi.org/10.5281/zenodo.6627395

Deb, H., Sanyal, T., Kaviraj, A., & Saha, S. (2020). Hazards of wind turbines on avifauna—A preliminary appraisal within the Indian context. *Journal of Threatened Taxa*, *12*(4), 15414–15425. https://doi.org/10.11609/jott.5165.12.4.15414-15425

Gaston, K.J. (2003). The how and why of biodiversity. *Nature*, *421*(6926), 900–901. http://dx.doi.org/10.1038/421900a.

George A A., (1972). Biodiversity Protection : Steps Taken By Indian Government. pp. 3–5.

Ghosh, S., Nahar, N., Dasgupta, D., Sarkar, B., Biswas, P., Chakraborty, R., Acharya, C.K., Jana, S.K., Madhu, N.R. (2022). Socioeconomic Disparity in Health of Rural Communities in the Himalayan Foothills: Mahananda Wildlife Sanctuary, West Bengal. *Chettinad Health City Medical Journal*, 11(2), 9-18. https://doi.org/10.24321/2278.2044.202215

Gogoi, H., Purkayastha, J., & Roychoudhury, S. (2023). Avian diversity in the paddy field ecosystem surrounding the Assam University campus in Silchar during the rainy season. *Int. J. Exp. Res. Rev.*, *34*(Special Vo), 120-137.

Haldar, S., & Haldar, A. (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. https://doi.org/10.52756/boesd.2022.e01.003

Haque, Z. M., Reza, M. I. H., Rahim, S.A., Abdullah, M.P., Elfithri, R., & BinMokhtar, M. (2015). Behavioral change due to climate change effects accelerate tiger human conflicts: A study on Sundarbans mangrove forests, Bangladesh. *Int. J. Conserv. Sci.*, *6*(4), 669–684.

He H., Ning X., Chen K., Li Q., Li K., Liu Z., & Jeppesen E. (2021). Intraguild Predation Dampens Trophic Cascades in Shallow Aquatic Mesocosms in the Subtropics: Implications for Lake Restoration by Biomanipulation. *Freshwater Biology*, *66*(5), 1-10. http://dx.doi.org/10.1111/fwb.13739

Hens, L., & Boon, E. K. (2005). Causes of Biodiversity Loss: a Human Ecological Analysis. *MultiCiencia*, *1*, 1–29.

Heupel, M.R., Knip, D.M., Simpfendorfer, C.A., & Dulvy, N.K. (2014). Sizing Up the Ecological Role of Sharks as Predators. *Marine Ecology Progress Series*, *495*, 291-298. http://dx.doi.org/10.3354/meps10597

https://doi.org/10.52756/ijerr.2023.v34spl.012

Isenring R. (2010). Pesticides and the loss of biodiversity. Pan-Europe.Info. [Online]. Available:http://www.paneurope.info/Campaigns/chemicals/documents/bees/Pesticides_and_the_loss_of_biodiversity.pdf%5Cnpapers2://publication/uuid/F3785E4C-8439-4916-BA0C-14E7E45A1202

Kundu, K. (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. https://doi.org/10.52756/boesd.2022.e01.009

Lawrence, J.M. (2020). Sea Urchins: Biology and Ecology. *Dev. Aquac. Fish. Sci.*, *38*(1991), 730. https://doi.org/10.1016/B978-0-12-819570-3.00024-X

Lawson E., (2021). 9 Companies with Great Environmental Initiatives | Smart Cities Dive. Smartcitiesdrive. 2021. [Online]. Available: https://www.smartcitiesdive.com/ex/sustainablecitiescollective/9-

Letnic, M., Ritchie, E.G., & Dickman, C.R. (2012). Top predators as biodiversity regulators: The dingo Canis lupus dingo as a case study. *Biol. Rev.*, *87*(2), 390–413. http://dx.doi.org/10.1111/j.1469-185X.2011.00203.x.

Maiti, A., Madhu, N.R., & Manna, C. K. (2010). Ethnomedicine used by the tribal people of the district Purulia, W. B., India in controlling fertility : and experimental study. Pharmacologyonline, 1, 783-802.

Maiti, A., Madhu, N.R., & *Manna, C. K. (2013).* Natural products traditionally used by the tribal people of the Purulia district, West Bengal, India for the abortifacient purpose. *International Journal of Genuine Medicine*, *3*(2), e14:1-4.

Matthews K. (2020). 10 Green Companies With Amazing Environmental Initiatives. Blue and Green. 2020. [Online]. Available: https://blueandgreentomorrow.com/magazines/10-green-companies-with-amazing-environmental-initiatives/

Mondal, I., Maity, S., Das, B., Bandyopadhyay, J., & Mondal, A.K. (2016). Modeling of environmental impact assessment of Kolaghat thermal power plant area, West Bengal, using remote sensing and GIS techniques. *Modeling Earth Systems and Environment*, *2*(3). http://dx.doi.org/10.1007/s40808-016-0186-7.

Mukherjee, P., Saha, A., Sen, K., Erfani, H., Madhu, N. R., & Sanyal, T. (2022). Conservation and prospects of indian lacustrine fisheries to reach the sustainable developmental goals (SDG 17). In N. R. Madhu (Ed.), *A Basic Overview of Environment and Sustainable Development* (1st ed., pp. 98–116). International Academic Publishing House (IAPH). https://doi.org/10.52756/boesd.2022.e01.010

Pawar, P.R., Shirgaonkar, S. S., & Patil, R.B. (2016). Plastic marine debris: Sources, distribution and impacts on coastal and ocean biodiversity. *PENCIL Publ. Biol. Sci.*, *3*(1), 40–54.

Poommouang, A., Kriangwanich,, W., Buddhachat K., Brown, J.L., Piboon, P., Chomdej, S., Kampuansai, J., Mekchay, S., Kaewmong, P., Kittiwattanawong, K., &

Nganvongpanit, K. (2021). Genetic Diversity in a Unique Population of Dugong (Dugong dugon) Along the Sea Coasts of Thailand. *Scientific Reports*, *11*, 11624. http://dx.doi.org/10.1038/s41598-021-90947-4

Purvis, A., & Hector, A. (2000). Getting the measure of biodiversity. *Nature*, *405*(6783), 212–219. http://dx.doi.org/10.1038/35012221.

Raha, S., Mukherjee, P., Saha, A., & Sanyal, T. (2022). Aquatic macrophytes: An untold and valuable panoramic resource of ethnomedicine. In B. Sarkar (Ed.), *The Basic Handbook of Indian Ethnobotany and Traditional Medicine* (1st ed., pp. 46–61). International Academic Publishing House (IAPH). https://doi.org/10.52756/bhietm.2022.e01.004

Rai, P.K., & Singh, J.S. (2020). Invasive alien plant species: Their impact on environment, ecosystem services and human health. *Ecol. Indic*., *111*, 106020. http://dx.doi.org/10.1016/j.ecolind.2019.106020.

Rajak, S. (2017). Bioethics on biotechnology and on conservation of biodiversity. *Int. J. Exp. Res. Rev.*, *11*, 56-65. Retrieved from https://qtanalytics.in/journals/index.php/IJERR/article/view/1288

Saha, A. (2023). Circular Economy Strategies for Sustainable Waste Management in the Food Industry. *Journal of Recycling Economy & Sustainability Policy*, *2*(2), 1–16. Retrieved from https://respjournal.com/index.php/pub/article/view/17

Saha, A., & Sarkar, C. (2022). Protecting The Precious Sundarbans: A Comprehensive Review of Biodiversity, Threats and Conservation Strategies In The Mangrove Ecosystem. *Conscientia*, *10*, 60-80.

Sanyal, T., Saha, A., & Mukherjee, P. (2023). Activities of fisheries co-operative societies in India to boost up and optimise the resources and economy of farmers: a review. *Journal of Fisheries*, *11*(2), 112301. https://doi.org/10.17017/j.fish.487

Sarkar, B. (2017). Traditional use of medicinal plants and its biodiversity in India. *Int. J. Exp. Res. Rev.*, *10*, 23-26. Retrieved from https://qtanalytics.in/journals/index.php/IJERR/article/view/1295

Sarkar, B., C.K., Biswas, P., Acharya, Ghorai, S.K., Nahar, N., Jana, S.K., Ghosh, S., Sarkar, D., Behera, B., & Madhu, N.R. (2021). Knowledge of Traditional Indian Medicinal Plants for the Management of COPD. *Chettinad Health City Medical Journal*,*10*(4), 184 – 189. https://doi.org/10.36503/chcmj10(4)-05

Sergio, F., Newton, I., & Marchesi, L. (2005). Conservation: Top predators and biodiversity. *Nature*, *436*(7048), 192. http://dx.doi.org/10.1038/436192a.

Sharma, D., Biswas, H., & Bandyopadhyay, D. (2022). Simulated ocean acidification altered community composition and growth of a coastal phytoplankton assemblage (South West coast of India, eastern Arabian Sea). *Environmental Science and Pollution Research*, *29*(13), 19244–19261. http://dx.doi.org/10.1007/s11356-021-17141-x.

Sigwart, J.D., Bennett, K.D., Edie, S.M., Mander, L., Okamura, B., Padian, K., Wheeler, Q., Winston, J.E., & Yeung, N.W. (2018). Measuring Biodiversity and Extinction-Present and Past. *Integr. Comp. Biol.*, *58*(6), 1111–1117. http://dx.doi.org/10.1093/icb/icy113.

Soni, D.K., & Ansari, F. (2017). Climate change and biodiversity; impacts, vulnerability and mitigation in Indian perspective : A review. *J. Appl. Nat. Sci.*, *9*(1), 632–638. http://dx.doi.org/10.31018/jans.v9i1.1243.

Steel, Z. L., Fogg, A.M., Burnett, R., Roberts, L.J., & Safford, H.D., (2021). When Bigger Isn't Better- Implications of Large High-Severity Wildfire Patches for Avian Diversity and Community Composition. *Diversity and Distributions*, *28*, 439–453http://dx.doi.org/10.1111/ddi.13281

Stephen, A., Suresh, R., and Livingstone, C. (2015). Indian Biodiversity: Past, Present and Future. *Int. J. Environ. Nat. Sci.*, 7, 13–28. [Online]. Available: www.ijenas.com

Tilman, D. (2000). Causes, consequences and ethics of biodiversity. *Nature*, *405*(6783), 208–211. http://dx.doi.org/10.1038/35012217.

Vega, X.D., Grez, A.A., & Simonetti, J.A. (2012). Is top-down control by predators driving insect abundance and herbivory rates in fragmented forests? *Austral Ecol.*, *37*(7), 836–844. http://dx.doi.org/10.1111/j.1442-9993.2011.02345.x.

Venkataraman, K., Sharma, G., & Banerjee, D. (2020). Faunal Diversity of India. In: Dar, G., Khuroo, A. (eds) Biodiversity of the Himalaya: Jammu and Kashmir State. Topics in Biodiversity and Conservation, *18*, 71–92. http://dx.doi.org/10.1007/978-981-32-9174-4_4.

Views, P.P., & Patel, B.M. (2021). Various schemes and policies for the conservation of nature. pp. 1–11.

Vijeta, S., Shikha, S., & Anamika, S. (2021). The principal factors responsible for biodiversity loss. *Open J. Plant Sci.*, *6*, 011–014. http://dx.doi.org/10.17352/ojps.000026

HOW TO CITE

Sourav Bar, Soumik Dhara, Nithar Ranjan Madhu, Biplab Mandal, Bhanumati Sarkar, Sudipta Kumar Ghorai (2023). Root Causes of Biodiversity Loss with Special Reference to India © International Academic Publishing House (IAPH), Dr. Shubhadeep Roychoudhury, Dr. Tanmay Sanyal, Dr. Koushik Sen & Mrs. Sudipa Mukherjee Sanyal (eds.), *A Basic Overview of Environment and Sustainable Development [Volume: 2]*, pp. 1-34. ISBN: 978-81-962683-8-1. DOI: https://doi.org/10.52756/boesd.2023.e02.001