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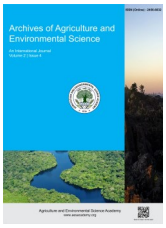

REVIEW ARTICLE

A review on persisting threats to snail's diversity and its conservation approaches

Varun Dhiman[1*], Deepak Pant[2], Dushyant Kumar Sharma[3] and Prem Prakash[4]

[1]Waste Management Laboratory, School of Earth & Environmental Sciences, Central University of Himachal Pradesh, Shahpur - 176206 (Himachal Pradesh), INDIA
[2]School of Chemical Sciences, Central University of Haryana, Jant-Pali, Mahendergarh, Haryana-123031, INDIA
[3]Department of Tree improvement and Genetic resources, College of Horticulture and Forestry, Neri, Hamirpur (Himachal Pradesh) – 177001, INDIA
[4]Department of Silviculture and Agroforestry, College of Horticulture and Forestry, Neri, Hamirpur (Himachal Pradesh) – 177001, INDIA
[*]Corresponding author's E-mail: varundhiman79@gmail.com

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ABSTRACT

Snails are important part of our terrestrial, freshwater and marine ecosystems. They are molluscian members having their effective role in biomonitoring, nutrient cycling and medicinal development. They are integral part of food chain system and have direct or indirect impact in maintaining ecological functioning. Besides their importance, they are documented with largest extinction rate as compared to other existed taxa. This is due to the fact that, unexploration and poor attention has been given in the research and development by the scientific world. Till now, a little information is available related to systematics, life history, population biology, threats and conservation status of these slimy organisms. This paper briefly reviews the diversity of terrestrial, freshwater and marine snails with the existed threats with their conservation approaches which may proved to be fruitful in developing awareness related to the snails in the society.

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INTRODUCTION

Within environmental and ecological studies, the snails have their own place. They are soft, shelled gastropods with unsegmented body of different origin having huge diversification in land, freshwater and marine ecosystem (Vermeij, 2015; Jo *et al.*, 2020). These are known for a coiled shell used for shelter. Animal is completely retracted into it during any physical and chemical change in the near environment. These mollusc members are highly sensitive towards the surrounding activities as they respond accordingly (Dhiman, 2020). Presence of various pollutants, heavy metals affect snails in a manner that one can predict the presence of these contaminants in a better way by analyzing physiological and behavioral changes of these small and slimy creatures (Coeurdassier *et al.*, 2001). Therefore, they act as biological indicators off the environment (Eeva and Suominen, 2010; Baroudi *et al.*, 2020). For the sustenance of life, snails require certain level of moisture content and some sort of other favorable environmental conditions such as suitable temperature range, neutral pH, calcium rich food, decaying organic matter etc. They have significant contribution in ecosystem functioning (Astor, 2014). Snails are on the bottom of food chain and are fundamental part of the ecosystem (Shachak and Steinberger, 1980). These small creatures provide calcium rich diet for many species of marine birds, terrestrial snakes and lizards during their life cycle. Studies confirms the use of snails as a calcium rich food source by wild turkey during egg lying season (Mänd *et al.*, 2000; Dhondt and Hochachka, 2001). They are also used as diet supplements in African countries. Their meat is utilized as a protein rich source in fighting malnutrition in the region (Adeyeye *et al.*, 2020). Snails have significant role in nutrient cycling as they participate in organic matter decompo-

sition and regulating microbial activity in the soil (Moslemi *et al.*, 2012; Ebenso and Isong, 2020). Recently, snail residue of golden apple snails was used to regulate soil acidity and nutrients release in non-irrigated farm lands of South China (Wang *et al.*, 2020). Their eating habits are plants specific and many studies reported their specific food preference for consumption (Kiss, 2017). Recent study on the food choice of *Megalobulimus paranaguensis* shows that this air breathing snail prefers fresh *Malvaviscus* flowers for its feeding (Miranda and Bôas Correia, 2020). Similarly, golden apple snail prefers the consumption of macrophytes having higher nitrogen and calcium level (Pouil *et al.*, 2020). They also affect the distribution pattern of plant communities in terrestrial and aquatic ecosystem. Their habit of selective grazing imposes a greater impact on the distribution of plant species and other macrophytic community. For example, pulmonate snails selectively graze on submerged macrophytes thereby influences their distribution and population abundance in the freshwater ecosystems which in turn negatively affects the distribution of benthivorous fish (Chen *et al.*, 2020). There are little evidences of spore's dispersals by snail species also (Boch *et al.*, 2011). It has been found that snails act as vectors of bryophytes spore dispersal and their propagation (Sabovljević and Sabovljević, 2020). Apart from their essential role in the proper functioning of our ecosystem, the snails disappearing just like other species of flora and fauna due to ignorance and lack of conservation approaches and ecological studies.

DISTRIBUTION AND DIVERSITY

Snails are the members of second largest phylum Mollusca after Arthropoda, constitute 6% of species existed on the earth (Hinegardner, 1974). They are highly diversified in nature. Besides their extensive presence worldwide, the snail species faces endemism because of environmental degradation and habitat loss (Bambaradeniya, 2006; Moreira *et al.*, 2015). Introduction of alien species is another main factor in species extinction of snails (Kay, 1995). According to IUCN red list report on threatened species, in last 400 years nearly about 30% of snail fauna got extinct (Goodfriend *et al.*, 1994). Recently, red list category summary report-2020 for the class gastropoda released by the IUCN (Table1 and Figure 1) reveals that nearly about 267 species got extincted from the earth, 14 are extinct in the wild, 130 are in the category of critically endangered, 592 are critically endangered, 500 are endangered, 962 are vulnerable, 626 are with the tag of near threatened, 1,631 are data deficient and 2,612 gastropod species are in the category of least and lower concern (IUCN, 2020).

Terrestrial snails: Diversity and distribution

The terrestrial snails includes diverse group of approximately 35,000 species with authentic description in the documented literature (Sen *et al.*, 2012). Also, there is huge number (11000-40000) of undescribed terrestrial snail species (Tronstad, 2011). Besides such a large number of diversified species, world of snails is still undescribed and unexplored because taxonomists only considered the outer shell morphology as a special characteristics of these gastropods (Kumar *et al.*, 2017) and also the lack of expert taxonomists to study richness in diversity and distribution of snails is an important factor for their persisting unexploration (Strong *et al.*, 2007). Scientists and explorers mapped many frontiers including tallest mountain ranges, deep underwater ecosystems, subglacial lakes etc. but large part of the earth is still unexplored which may considered to be the natural home for many interesting species of snails (Ficetola *et al.*, 2019). Poor exploration of the snails taxa is also facing the problem of underestimation of diversity richness of the group and region (Oroño and Romero, 2007; III, B. O. S., Batomalaque and Fontanilla, 2014; Miller *et al.*, 2018).

Diversity and distribution of any species depends upon some environmental determinants or variables (Table 2) that influence the richness of species at a particular region. Likewise, many studies and researches carried out to explore the responsible variables for snail's diversity and their distribution across the globe but still not be able to reflect the complexity of snail's diversity. A study by Nunes and Santos on the distribution of land snails across Atlantic rain forest of Brazil reveals that environmental variables like atmospheric temperature, canopy closure, air and soil humidity, litter depth and luminosity influences their distribution (Nunes and Santos, 2012). According to the study by Giovanelli *et al.* (2005), the distribution pattern of *Physa marmorata* and *M. tuberculata* was affected by rainfall and water flow in the region (Giovanelli *et al.*, 2005). In a similar study by Douglas and Pederson (2013) confirms the role of forest disturbance due to anthropogenic activities as one of the important variable that affects snails diversity (Douglas and Pederson, 2013).

Freshwater snails: Diversity and distribution

Presence of freshwater snails is located on every continent of earth except Antarctic region (Strong *et al.*, 2008). They are found in freshwater sources such as lakes, streams, ponds, springs, aquifers and ditches, stones, aquatic vegetation etc. (Strong *et al.*, 2008). Taxonomic review of freshwater snails (Figure 2) reveals authentic description of ~4000 species with 33 to 38 independent lineages of this group (Bouchet and Rocroi, 2005). Similar to terrestrial species, they also face the major concerns of habitat loss and pest infestation. Anthropogenic activities like Dam formation on rivers, industrial water pollution, thermal pollution etc. leads to extinction of freshwater snail species. IUCN placed this group under "Threatened Species". During their evolutionary history, ~20% extinction rate has been observed in whole molluscian taxa (Strong *et al.*, 2008). Richest diversity of fresh water gastropods are found among North American region and contribute in heritage richness of global importance. The diversity and distribution pattern of freshwater snails is affected by anthropogenic activities that cause serious damage to the natural habitats of these snails (Cummings *et al.*, 2004). The destruction of habitat causes decline in species diversity. This problem takes the shape of major environmental concern in the early 20th century.

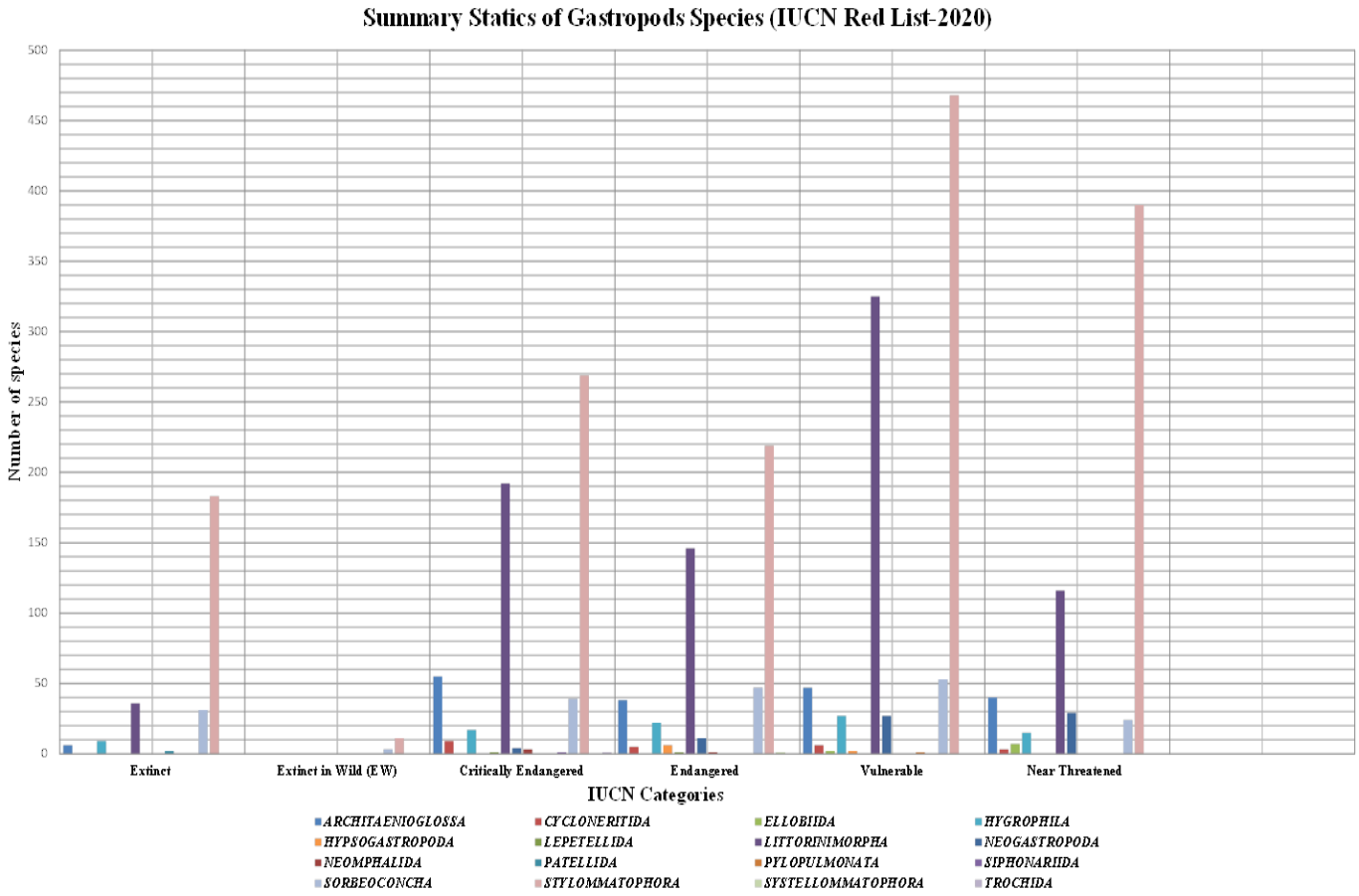

Figure 1. *Conservation status of various gastropod species and orders (IUCN, 2020).*

According to study report by Tennessee Aquarium Research Institute of United States of America on the aquatic biodiversity of North America, this is one the region of the world where the aquatic species including freshwater snails are under serious threat of extinction (Johnson, 2009). It has been reported that nearly about sixty species of freshwater snails became extinct and twenty species are under threat of extinction in last 80 years in North America (Johnson, 2009).

Marine snails: Diversity and distribution

Marine snails are highly diverse with the 52,525 described species all across the globe (Lydeard *et al*., 2004; Bouchet *et al*., 2006). Marine species of snails inhabit sandy shores, coastal areas, deep sea trenches, estuaries, intertidal, subtidal zones etc. Some species are well adapted to extreme environmental conditions like high saline conditions of Caspian Sea and other salty lakes situated in Africa, Australia and central Asia (Finlayson, 2016; Smyth and Elliott, 2020). Marine species are highly diverse in their shell structure and other physiological characteristics such as presence of operculum. Marine snails include the diverse species of cone snails which are known for their magical properties in the field of medicines. These snails secrete venom which is known to contain neurotoxins known as "conotoxins" (Bulaj *et al*., 2003). There are varieties of special kind of protein peptides known as conopeptides in these conotoxins (Gao *et al*., 2017). The genus *conus* is one of the diversified group of marine snails having ~600 species with valid description in the scientific literature (Puillandre and Holford, 2010).

ECOLOGICAL IMPORTANCE

Snails are highly sensitive animals towards any change in its environment and therefore helpful in prediction of climatic variations. In 1839, Charles Darwin proves their usefulness in understanding the ongoing changes in environment (Naggs *et al*., 2006). They emerged as useful research objects in understanding the evolutionary, phylogenetic, biodiversity and conservation studies (Schilthuizen *et al*., 2005; Davison and Chiba, 2008). Snails have unique dispersal pattern which is prominently based upon the past and existing environmental conditions (Naggs *et al*., 2006; Wade *et al*., 2006). Therefore, snails prove to be helpful in studying historical perspective of biogeography and reconstruction of past climatic conditions on the earth (Mayer, 2005; Gümüş, 2009). Their presence in aquatic ecosystem influences the local resident community of particular area.

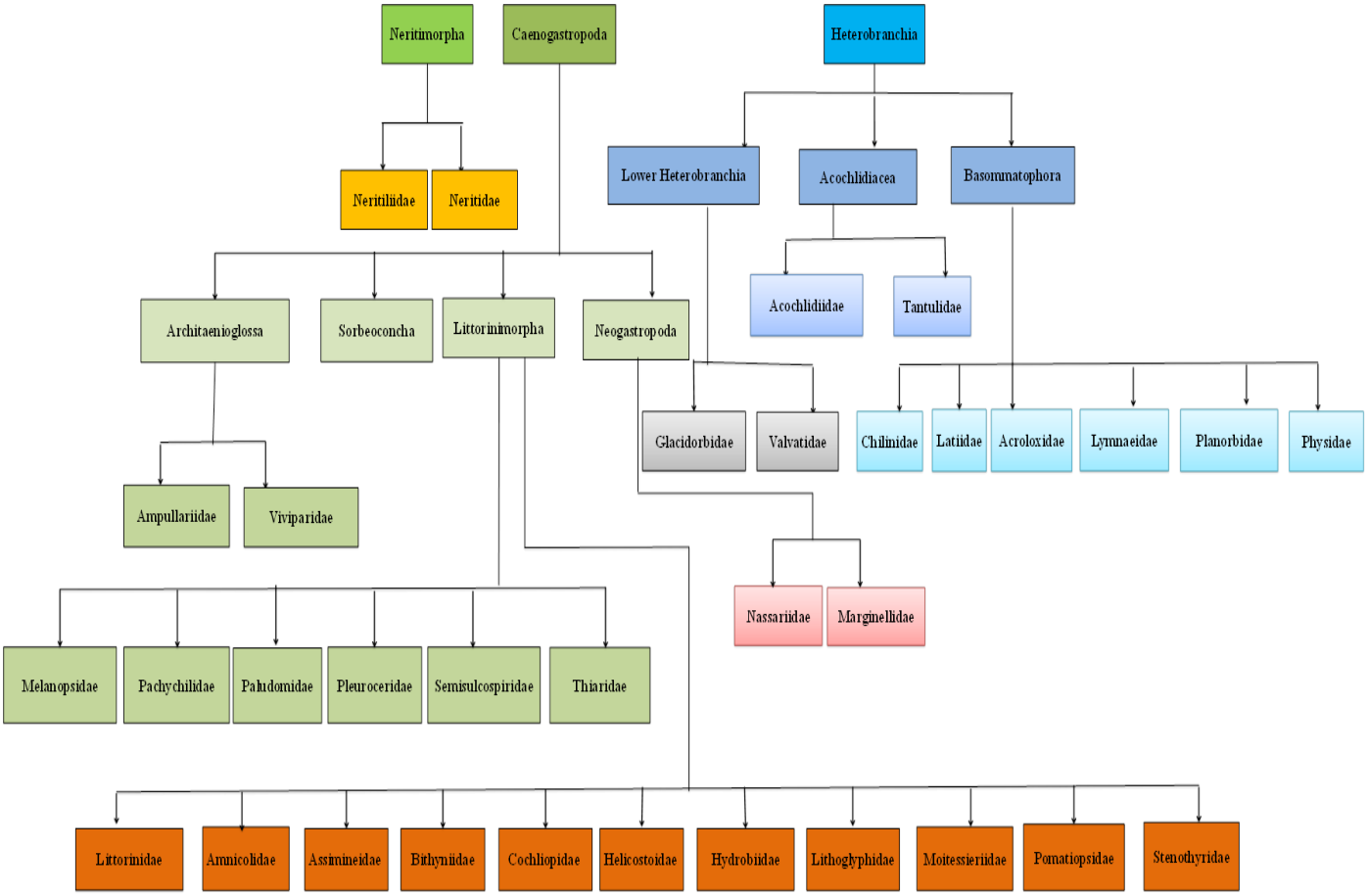

Figure 2. *Overview of Taxonomy of gastropods including families of freshwater Snails (Bouchet et al., 2005; Lysne et al., 2008).*

Studies establish the relationship of sea snails (genus *Ilyanassa*) with the distribution pattern and abundance of resident in fauna community (Cranford, 1988). Ecological importance of snails is discussed below:

Integral part of soil fauna

The terrestrial snails play an important role in soil ecosystem. Other components (e.g. fungi, bacteria, plants and rhizospheric soil) of ecosystem interact with each other and ensure nutrient cycling and other biogeochemical activities for the sustenance of life (Moore *et al.*, 1988). In similar way, molluscs perform intra and extracellular bio-mineralization process for ensuring calcium availability in the soil (Simkiss, 1976). They also play a significant role in organic matter decomposition at initial stages by consuming litter and enhance the biological activity of other actors involved in it (de Oliveira *et al.*, 2010).

Role as crop pests and vectors

Giant African land snail, *Achatina fulica* belongs to the family *Achatinidae* is considered as worst pest worldwide (Fischer *et al.*, 2006). These snails usually prefer mild climates for their growth and development (Raut and Barker, 2009). Recently, their presence is extended to Bhutan (Sarma *et al.*, 2015) and start destroying agricultural crops and flower farming and contribute in extinction of native fauna and hence causes biodiversity loss (Ohlweiler *et al.*, 2010). These snail species are also act as vectors of various diseases and transmit *Angiostrongyliasis* infection in humans because this snail species is the intermediate host of roundworm parasite, *Angiostrongylus cantonensis* responsible for this infectious disease (Thiengo *et al.*, 2010). Some snail's species like *Theba pisana* also act as pest and destroy ornamental and citrus plants.

Food source

Remains of snails have been discovered in sites of Pleistocene and Mid-Holocene ages. They were one of the main source of food during that time (Lubell, 2004). Terrestrial snails were suggested to be the first domesticated animals of humans (Fernández-Armesto, 2003). Various studies confirm the role of snails as food source in prehistoric times and people practicing the snail farming (BAHN, 1983; Lubell, 2004). In African region, some species of snails are used as a meat source and have an equal importance as fish meat. Freshater snails are used as sea food by coastal area residents.

Model organism to study co-evolution and species interactions

The study of fungal growth and interaction of marine snail species *Littoraria irrorata* is very interesting in understanding the complex mechanism of Co-evolution and species interactions (Silliman and Newell, 2003).

Table 1. Red List Category summary of gastropods (IUCN, 2020).

Order	Extinct (EX)	Extinct in Wild (EW)	EX+ EW	Critically Endangered & Possible Extinct CR (PE)	Critically Endangered & Possible Extinct in Wild CR (PEW)	EX+EW+ CR(PE) +CR (PEW)	Critically Endangered (*)	Endangered (**)	Vulnerable (***)	Subtotal	Near Threatened	Lower Risk/ conservation dependent	Data Deficient	Least Concern	Total
ALLOGASTROPODA	00	00	00	00	00	00	01	03	04	08	02	00	09	11	30
ARCHITAENIOGLOSSA	06	00	06	15	00	21	55	38	47	140	40	00	107	167	460
CYCLONERITIDA	00	00	00	01	00	00	09	05	06	20	03	00	32	49	104
ELLOBIIDA	00	00	00	00	00	01	00	00	02	02	07	00	14	48	71
HYGROPHILA	09	00	09	05	00	14	17	22	27	66	15	00	200	220	510
HYPSOGASTROPODA	00	00	00	00	00	00	00	06	02	08	00	00	00	00	08
LEPETELLIDA	00	00	00	00	00	00	01	01	00	02	00	00	00	00	02
LITTORINIMORPHA	36	00	36	50	00	86	192	146	325	663	116	00	576	323	1714
NEOGASTROPODA	00	00	00	00	00	00	04	11	27	42	29	00	113	478	662
NEOMPHALIDA	00	00	00	00	00	00	03	01	00	04	00	00	00	00	04
PATELLIDA	02	00	02	00	00	02	00	00	00	00	00	00	00	00	02
PYLOPULMONATA	00	00	00	00	00	00	00	00	01	01	00	00	09	04	14
SIPHONARIIDA	00	00	00	00	00	00	01	00	00	01	00	00	00	00	01
SORBEOCONCHA	31	03	34	07	00	41	39	47	53	139	24	00	96	138	431
STYLOMMATOPHORA	183	11	194	50	02	246	269	219	468	956	390	00	473	1171	3184
SYSTELLOMMATOPHORA	00	00	00	00	00	00	00	01	00	01	00	00	00	02	03
TROCHIDA	00	00	00	00	00	00	01	00	00	01	00	00	02	01	04
Total	267	14	281	128	02	411	592	500	962	2054	626	00	1631	2612	7204

Where *, **, *** indicated three most important Threatened categories.

Table 2. Environmental variables influence distribution and diversity of terrestrial snails.

Environmental Variables	Impacts	References
Climatic Variables	-Estimation of future displacement of *Megalobulimus sanctipauli* due to increasing temperature from Atlantic forest to new sites. -Growth and reproductive capacity of *Cepaea nemoralis* is altered due to high temperature and low humidity thereby influences its diversity and distribution. -Current climate is helpful in expanding distribution of *Achatina fulica* (Giant African Snail) across the eastern, peninsular India. This snail is under the category of one of the worst alien species. -Due to rise in temperature, elevation shift (164 meter) is observed in land snail species, *Arianta arbustorum* in Swiss National Park.	(Richardson, 1974; Baur and Baur, 2013; Beltramino *et al.*, 2015; Sarma, Munsi and Ananthram, 2015).
Availability of Calcium and other Elements in Soil	-Snail density depends upon Ca and other elements availability in soil. -Ca influences the distribution pattern and species richness of terrestrial snails. -Strong association of distribution of land snails and Ca availability is confirmed by a study conducted in Central Appalachian mountain forest, Maryland. -*Arianta arbustorum* like to eat phosphorus rich *Urtica dioica* plant species. -Studies confirm the role of Mg in Growth and development of snails.	(Pigott and Taylor, 1964; Gomot *et al.*, 1989; Hotopp, 2002; Juřičková *et al.*, 2008).
Soil pH	-Studies established the correlation between snail's population and soil pH.	(Gardenfors, 1992).
Soil Acidification	-Acidification results in lowering pH of soil. -Imposes negative effects on land snail species. -Causes calcium leaching. -Ultimately results in death of snails and therefore affect snail's diversity and distribution.	(Hallbäcken and Tamm, 1986; Falkengren-Grerup, 1986; Falkengren-Grerup *et al.*, 1987).
Moisture and Rainfall	-Population of snails existed near moist places. -*Ovachlamys fulgens* lays its eggs in humid environment. -Rainfall directly affects the diversity of snails. -Studies establish the relationship between rainfall and shell size of snails.	(Barrientos, 2000; Tattersfield *et al.*, 2001; Kadmon and Heller, 1998).
Altitude	-A study confirms the higher abundance of snails at higher altitudes (1000-1500 meter) than at lower altitude. -Slope aspect, angle and elevation are in direct relation with snail's diversity and distribution.	(Peter Tattersfield *et al.*, 2006; Dillon, 1980).
Habitat Conditions	-Distribution of snails is highly dependent on habitat conditions of an area. -Type of vegetation, thickness, canopy height and cover also influence the distribution of snail species.	(Cowie, 1995; Dillon, 1980). (Barrientos, 2000).
Latitudinal variation	-Distribution of small sized snails decreases on increase of latitude. -Decline in snail's diversity along the Western Ghats, India.	(Hausdorf, 2006; Aravind *et al.*, 2005).

Effect on epiphytic communities

Freshwater snails feeds on epiphytic communities (e.g. algal, bryophyte and microbial communities) of freshwater ecosystem, thereby have a positive impact on distribution, density of the these communities (Brönmark, 1989; Yang *et al.*, 2020; Liu, 2020).

Condition and history of site

Terrestrial snails are very suitable biological indicators for determining the condition of particular site and helps in understanding the related past incidents. Due to limited movability of snails, they help in reconstruction of past conditions like soil moisture, forest fire etc. The study of genetic variability among the snails provides an opportunity to understand mechanism of natural selection (Davison, 2002).

Negative interactions

Some species of snails are involved in negative interactions with other organisms (Turner *et al.*, 2007). They carry different parasites that cause diseases in other mammals. Snails eat the fecal matter of white tailed deer, *Odocoileus virginianus* which known to contain larvae of cervid brainworm *Parelaphostrongylus tenuis* responsible for affecting central nervous system of moose, caribou and elk (Baker, 2008).

Table 3. Climate change; Drought; Floods; Strom and Hurricanes; Fire; Habitat Fragmentation; Agricultural Activities; Predator species; Tourism and Developmental activities and Warfare's are some of the main threats that impose threat to snail's biodiversity.

Major Threats	Impacts	References
Climate Change and Temperature Variability	-Climate change causes temperature fluctuations, directly influences the life cycle, reproductive capacity and population dynamics of snails. -Low temperature causes destruction of snail eggs. -Changing temperature modified the future distribution pattern of the species.	(Nicolai *et al.*, 2010; Nicolai and Ansart, 2017).
Drought	-It influences the physiological activities like thermoregulation. -Snails undergo aestivation during this period. -High mortality rate. -Desiccation of snail's body. -Low reproduction due to low sperm viability.	(Nicolai *et al.*, 2011; Heller and Ittiel, 1990; Machin, 1964; Raut and Ghose, 1982).
Floods	-Directly affects the terrestrial fauna. -Drowning and death of snails occurs due to hypoxia. -Migratory behavior of snail species is being observed during flooding situation. -Habitat destruction occurs.	(Plum, 2005; Dahl *et al.*, 1993; Nicolai and Ansart, 2017).
Storms and Hurricanes	-Storms and Hurricanes affect population density including spatial distribution. -Induce desiccation stress on snail individuals, affect eggs and young ones.	(Bloch and Willig, 2006; Nicolai and Ansart, 2017).
Fire	-Fire affects the microclimatic conditions necessary for the survival of gastropods. -It usually modified the source of nutrients, physiochemical properties of top soil. -Reduces the moisture content, litter and organic residue of the soil.	(Bellido, 1987; Seastedt and Ramundo, 1990; Knapp, 2010).
Habitat Fragmentation	-It influences population size, genetic diversity and inbreeding rate of local snail species. -Affect dispersal of Gastropods in direct and indirect ways.	(Fahrig, 2003; Kappes *et al.*, 2009; Wu *et al.*, 2017).
Agricultural Activities	-Land clearance for agricultural purpose and culture of shifting cultivation impose harmful impacts on terrestrial species of snails.	(Pippard, 2012).
Predator species	-The predator species such as *Rattus rattus*, *Herpestes fuscus*, *Gallus gallus*, *Anoplolepis gracilipes*, *Herpestes auropunctatus* and *Sus scrofa domesticus* are the serious concerns that affect their distribution and diversity.	
Tourism and Developmental activities	-Tourism and other developmental activities such as construction of buildings, roads, hotels, dams etc. results in deforestation which in turn cause habitat loss for many species including snails that are the residents of native forests.	
Warfare's	-Bombing of area during any warfare causes serious threats to the living communities by destroying forests and human interference with nature. Snail communities of Koror (Oreor) and Peleliu (Beliliou) islands were found to highly affected during the first and second world war.	

BIODIVERSITY THREAT ASSESSMENT

Biodiversity threat assessment is an essential and fundamental aspect that paves the way forward in understanding the risks associated with the ecosystem biodiversity and helping in development of future strategies needed for its conservation (Keith, 2015). Threat assessment approach of different ecosystems including terrestrial, freshwater and marine ecosystem, allows the scientific community to estimate the state of ecosystem through a time series thereby helps in improving natural biodiversity (Rodríguez *et al.*, 2015). This approach promotes the need of *in-situ* biodiversity conservation (Keith *et al.*, 2015). In 2014, IUCN adopted the risk assessment protocol which involves red list of ecosystem criteria and categories. Their main motive was to describe and explore the applications of threat assessment, strategic ecosystem management and planning (Keith, 2015). In the present scenario, it is the need of hour to access the persisting threats to the biodiversity. Therefore, biodiversity threat assessment is an important tool for biodiversity conservation with its corrective and productive measures.

Biodiversity threat assessment has a number of applications as it provides a detailed diagnostic evaluation and comprehensive assessment of persisting and upcoming threats of an ecosystem. For this purpose, the approach adopts a powerful adaptive management strategy for ecosystem management and its biodiversity conservation. Developments of alternative options for conservation, their targeted monitoring through scientific evaluation are some of the major elements involved in the biodiversity diagnostic evaluation. Similarly, another component known as, strategic ecosystem management act as an essential component of biodiversity threat assessment (Laurila-Pant *et al.*, 2015). It specifically involves the inclusion of supporting structure for the actions taken for the improvement of ecological biodiversity. This component aggregates the integrated biodiversity management system which results in proper regulation of ecosystem functioning (Niesenbaum, 2019). Moreover, strategic management minimizes the biodiversity risks and contributing in biodiversity management. Apart from different aspects, Strategic ecosystem management also considers the important aspect of environmental performance which describes the vitality and health of our ecosystem thereby provide a health bulletin of biodiversity in a time interval (IUCN, 2014). Moreover, it has been observed that, the collected data and observations of biodiversity risk assessment across the globe was varying which lessens the efforts of measuring biodiversity change therefore the transmission of beneficial consequences of the steps taken for the improvement of biodiversity change and its associated impacts on the society were not delivered effectively. To address this problem, biodiversity threat assessment includes the systematic, coordinated and effective global tracking of biodiversity across the globe and constitutes the Group on Earth Observations Biodiversity Observation Network in 2017 which prepares strategies for the scientific monitoring of biodiversity change. It also leads to the development of Essential Biodiversity variables framework and biodiversity observation networks with their specified work of coordination and operational biodiversity monitoring (Navarro *et al.*, 2017; Leidner *et al.*, 2018).

MAJOR THREATS TO SNAILS BIODIVERSITY

The ever increasing human population results in higher demand of natural resources. The overexploitation, unsustainable use, deforestation, construction of dams, roads, buildings by destroying natural habitats of the animals causes serious threat of species extinction. Snail species of terrestrial, freshwater and marine origin are highly affected with these activities. The change in climatic conditions and introduction of invasive alien species in the natural habitat is also an additional factor in biodiversity extinction of snails. IUCN report provides the relevant information on the current conservation status (Table 1) of existed gastropods species which is helpful in understanding the present situation of species biodiversity in particular environment. According to conservation reports and worldwide studies, majority of snail species are under: a) Critically Endangered; b) Endangered and; c) Vulnerable. Table 3 discusses the major threats to the snail's diversity.

CONSERVATION APPROACHES

Conservation approaches involve biodiversity conservation and ecosystem management. These approaches are designed according to the organism's response and its interactions in its specific habitat. These approaches consider the role of ecological integrity in understanding the behavior of snails and other animals with in the natural habitat of these living organisms. The reason behind the declining populations and their persistence are the two major points to be considered in developing any conservation strategy. There is utmost need of studying the various traits including the study of life history, habitat conditions, population biology and threatening process of threatened species before designing and implementation of conservation approaches. However it is the fact that the snails are neglected taxa in scientific world as compared to others and therefore very less attention has been given towards the conservation of these small creatures. Land snails of Australia are one of the prominent examples of threatened species which has not been yet a major research interest among scientific community (Parkyn and Newell, 2013). In the year 2011, IUCN recognized the concerns of threatened snail species and draws the attention of scientific community towards the major issue of snail's extinction. This leads to the development of conservation approaches for snails. Some of them are discussed below:

i. Artificial Culture
ii. Comprehensive Surveys
iii. Habitat Restoration and Niche Protection
iv. Pollution Control
v. Positive Public Perception
vi. Scientific Research and Development
vii. Sustainable Land Use
viii. Watershed Management

i. Artificial culture

Artificial culture, popularly known as Heliciculture involves rising of snail population within artificial environment under controlled conditions. This method is one of the best conservation approach for snails. Fulvius Lippinus in 49 BC mentions about rearing of snail species (Beerden, 2010).

ii. Comprehensive surveys

This method is an important part of conservation approaches of snail species. The extent of snail biodiversity is still unexplored and unknown to scientists and researchers. So, comprehensive surveys are helping in exploring the number of species in wide perspective and provide data regarding the present condition of the species concerned. On the basis of data provided, conservation strategies are designed (Duncan *et al.*, 2003).

iii. Habitat restoration and niche protection

Anthropogenic activities such as deforestation and industrialization lead to habitat loss and interfere with normal activities of species in its niche. Niche is the place of interactions of animals with the different resources necessary for sustenance of life (Wiens, 2011). Any destructive activity in Niche and Habitat of snails proven to be fatal for population growth and hence alter its distribution and biodiversity (Nicolai and Ansart, 2017). For the purpose of conservation, niche protection and habitat restoration is very important. These strategies involve restoration of biotic and abiotic factors thereby helps in restoring natural conditions which are suitable for snail's population.

iv. Pollution control

Variation in physical and chemical conditions of the terrestrial and aquatic ecosystem influences the distribution pattern and normal behavior of the snails. Dumping of variety of toxic waste is the main cause of soil and water pollution which ultimately influences the snails. Toxic metals from electronic waste leach in the soil and water sources and therefore affect the local biodiversity of residing species. Heavy metals such as mercury, lead and copper interfere with reproductive capacity movement, behavior of terrestrial as well as fresh water snail species thereby impose threat on species population (Allah *et al.*, 2003). So, to conserve the population, pollution control measures are taken into consideration.

v. Positive public perception

Positive perception is one of the important aspects for conservation and safety of the concerned species (Bennett, 2016). Unfortunately, due to lack of awareness, people have negative perception about snails. In the eyes of most of the people, snails are slimy, useless creatures that are sluggish and dirty. They are unaware of magical properties of snails in curing a number of human diseases. Therefore, it is must to spread awareness among people related to the snail and its conservation.

vi. Scientific research and development

Scientific R&D plays its crucial role in conservation of snail species. Available literature shows the lack of scientific research and development in the field of gastropods ecology. Snails are not well studied and neglected in scientific world. Due to lack of exploration in world of snails, they are thought to be inferior organisms with no role in ecosystem which is completely wrong. This mindset is against the conservation of these wonderful creatures. Therefore, this is the need of hour to encourage the scientific R&D in this field to increase the pace of biodiversity conservation of snails (Sen *et al.*, 2012).

vii. Sustainable land use

Urbanization in present scenario changes the urban land cover (Mundhe and Jaybhaye, 2014). This directly influences the hydrological and geomorphological characteristics of land, hence affect the flora and fauna of that area. Sustainable land use provides solution to this serious concern. This is one of the major conservation approach involves the integration of natural resources (e.g. land; water, biodiversity) and their distribution in a balanced and fare manner between the living creatures of the terrestrial ecosystem. This practice ensures ample availability of food and other life sustaining resources to the individuals of species.

viii. Watershed management

Freshwater snails require water resources (e.g. lakes, rivers, ponds etc.) for their breeding, physical and various other biological activities. But due to pollution and climate change, these water resources are depleting at a very fast rate. Depletion of these resources ultimately affects the freshwater snail species in terms of their abundance and distribution in the surrounding (Nicolai and Ansart, 2017). So, to improve the land use practices and water quality, watershed management is practiced which ensures the sustainable use of freshwater resources. This method in turn provides suitable habitat and resources for the population growth of snails and hence plays its role in snail's conservation.

Conclusion

Present paper highlighted the status of snail's diversity and focuses on the approaches designed for their conservation. For this purpose, study of systematics, survival strategies and hot spots of snails is very important before going to plan and implement any conservation strategy. The conservation status of snails is poorly known due to the rise of biasness between public and scientific community for snail's extinction. It has been concluded that there is urgent need to conserve natural habitats of the species, so we have to promote the sustainable development. The conservation of snails is going at very slow pace because of the lack of experts in this field. So, it is recommended to raise funds in the field to attract people and to promote research and development in malacology. Awareness should be spread between the general public to change their negative perception about snails by prioritizing the programs of conservation, establishing snailariums and recovery strategies.

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