

**SPATIAL ECOLOGY OF HIMALAYAN
TORRENT FROG *NANORANA VICINA*
(STOLICZKA, 1872) IN RESPONSE TO
HABITAT DYNAMICS**

FINAL REPORT (2017 – 2021)



भारतीय वन्यजीव संस्थान
Wildlife Institute of India



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Habitat Dynamics

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Submitted By

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ABSTRACT

Spatial patterns of stream frogs have crucial implications for population dynamics and distribution that can unveil other key aspects of a species ecology. Movement and associated spatial arrangements can have effect on the fitness of both individuals and populations. Comparatively, less information is available on the ecological traits and life history for most of the streams frogs, thus creating a knowledge gap. To better understand the spatial ecology of *Nanoran vicina* an obligate stream frog endemic to western Himalayas, we conducted three years (2017 - 2020) study in the Himalayan streams nearby Binog wildlife sanctuary (BWLS) for an average of 63 days. We radio tagged and tracked 16 individuals of *N. vicina*. Our study observation suggest that the species show high philopatry and less vagility with the highest average movement ranging from 5.9 m to 5.07 m. We have also found that the individuals moved more during monsoon (4.25 m/day) than pre - monsoon (2.99 m/day) and least during post monsoon (1.06 m/day). Our results also suggested that the individuals are mostly confined to the pool section of the stream over other habitats such as cascade, run and riffle. Our study on tadpole of the same genus also revealed the preference of tadpoles in the pool. Mean overwintering tadpole density showed varying diurnal and seasonal patterns in the study pools. The nocturnal density was higher in the modified pools than natural pools during winter, while no differences were found during daytime. This pattern changed in the post winter with high nocturnal density in natural pools. We explored the seasonal resource utilization patterns of the tadpoles using habitat availability and use analyses and the present the key findings. We have also provided a checklist of herpetofaunal diversity recorded and natural history observation in the study areas. Thus, the study portrays important ecological observations on the selected species which can be followed in future to imply proper conservation measures to protect these streams from modifications.

Key words: Stream frog, movement, ecology, radio telemetry.

1. INTRODUCTION

Amphibians are particularly sensitive to local environmental changes because they possess following traits: ectothermic, moist permeable skin, eggs without any protective cover, gill respiration in larval form, require both aquatic and terrestrial habitat to complete life history, a high degree of philopatry, relatively small home ranges, limited dispersal ability and extremely seasonal in reproduction. Habitat changes thus can modify amphibian community composition or seriously impact fitness in some amphibian species (deMaynadier and Hunter, 1995; Patrick et al., 2006; Werner et al., 2007). However, mechanisms that cause such changes in amphibian population are poorly understood.

Tools to trace the physiology, behavior and energetic status of free ranging animals are termed as Biotelemetry. The technique that involves receiver, sensors and radio-transmitter has enable researchers to know, how a free ranging creature adapt in an environment. Since 1990's this technology was extensively used in case of mammals and birds and some large reptiles such as marine turtles which yielded information that has been challenging to collect historically from animals in their naturally associated environment. Biotelemetry, thus given us tools to know about aspects of life history strategies that could not be gathered in other techniques such as in drift fence, visual encounter surveys (Crump and Scott, 1994).

Large birds and mammals have received much attention from researchers studying home range size and space use. However, with the discovery of really small transmitters (1.5 to <2 gm) and advent of enhanced technology, radio telemetry was found to be suitable tool even for small and secretive species such as reptiles and amphibians. Extensive use of such technology to study movement pattern, home range, hibernation, energetic status in herpetofauna have been conducted in Europe, North America and Australia. Scanty studies so far made in Asia and none so far in South Asia on Amphibians.

So far in India, amphibian research is focused on aspects of systematics justified by the fact that documentation of the basic diversity is yet to be achieved. In this scenario, the use of advance technology such as radio telemetry to understand the spatial ecology of small vertebrates is a nascent development. A deeper understanding of the pattern of habitat use and identifying the factors influencing these patterns are likely to uncover aspects of spatial ecology hitherto unknown for Indian amphibians.

This gap in understanding is increasingly problematic as more species and population face threats of decline and extinction due to global climate change, habitat fragmentation and change in land use. Especially amphibians where at least 43% of species worldwide are experiencing population decline which is highest among all vertebrates (Stuart et al., 2004, Wake and Vredenburg, 2008).

2. BACKGROUND OF THE PROJECT

Streams are important source for sustaining freshwater ecosystem (Vorosmarty et al., 2010) and have great ecological values (Benetti et al., 2012). However, stream and river ecosystems are facing degradation from industrialization, modification and pollution (Carpenter, 2011; Zhang et al., 2018; Kim et al., 2019; Mishra et al., 2020). In such scenario, ecological indicators can be useful to assess the condition of the ecosystem (Cairns et al. 1993, Dale and Beyeler, 2001) and restoration (Waddle, 2006). Amphibians are considered to be good bio indicator (Welsh and Ollivier 1998, Sheridan and Olson 2003) of the stream ecosystem. They have several characteristics that make them useful as indicator species especially with their permeable skin and biphasic life cycle that make them sensitive to environmental stress. Thus, to predict the health of a stream ecosystem a thorough research to assess and monitor the stream amphibians is need of the hour, especially state like Uttarakhand where mountain streams and rivers are facing rampant development due to dam construction.

Thus, a first of its kind project named “Spatial Ecology of Himalayan Torrent Frog *Nanorana vicina* in Response to Habitat dynamics” was initiated to study the movement ecology of *Nanorana vicina* (Stoliczka, 1872) in Binog wildlife sanctuary. We excluded Kedarnath wildlife sanctuary from our radio telemetry study due to inaccessibility of necessary resources. In May, 2020 a no cost extension was taken for conducting further research. The objective of the study was following: 1). Monitoring the movement pattern of *Nanorana vicina* in the stream of protected areas, 2). Identification of the crucial habitat used by the frog and 3). Herpetofaunal inventory to assess species richness of the Selected protected areas.

3. LITERATURE REVIEW

Amphibians are the most threatened group of vertebrates, with approximately one third of global amphibian species are now threatened with extinction (Stuart et al., 2004). Reasons for decline are identified as habitat loss, exploitation for food/medicine, UV-B radiation, introduced species, disease and climate change (Beebee and Griffiths, 2005). Understanding the cause and extent of the declines requires an understanding of ecological and biological factors that might affect the movement and dynamics of a species. Movement is a fundamental aspect of an organisms' ecology (Nathan et al., 2008) that defines spatial and temporal scale of its interaction with other organisms, resource and environment (Clobert et al., 2001, 2009). An animal moves either to disperse to new sites or settle near natal site, which has strong consequences for individual fitness, gene flow, natural selection, adaptation, population persistence, metapopulation dynamics and species distribution (Knowlton & Graham, 2010). Despite the importance of movement to the persistence of species, there are considerable gaps in our understanding of movement processes (e.g., Bonte et al., 2012; Clobert et al., 2009; Ronce, 2007). Funk et al. (2005) studied the dispersal in frogs and related their vulnerability to habitat fragmentation. Huste et al. (2006) studied movement and site fidelity of threatened Natterjack toad and Miaud et al. (2000) studied terrestrial movement of the same species. Series of studies being made to understand the dynamics of fragmented Amphibian population that often represent classical metapopulation in a landscape where they were once widely distributed. Understanding the interaction between such populations is key to understand the dynamics (Waples & Gaggiotti, 2006; Baguett & Van Dyck, 2007) and thus prevent extinction of local population of the species.

Radio telemetry is recently used to study the movement and habitat use of terrestrial and aquatic frogs. Johnson et al. (2007) studied spatial distribution in *Hyla versicolor*. McGarrity and Johnson (2010) recorded microhabitat characteristic and habitat use by invasive *Osteopilus septentrionalis* in Florida. Grafe (2011) has delineated movement pattern and home range size in river frog (*Limnonectes leporinus*) from Sundaland. Sinsch et al. (2012) radio tracked Natterjack toad to determine the connectivity of local amphibian population. Courtois et al. (2013) and Martin (2011) showed effectiveness of visible Implant alpha tags and wire tags in individual identity of anuran tadpoles. This is a plan for the first ever radio-telemetry study on amphibian of India.

1. INTRODUCTION

Stream anurans play important role in the dynamic of stream ecosystem and are considered as good bio indicator (Ruksachat, 2020) due to the susceptibility to absorb substances through permeable skin and gut membrane (Soloneskisi et al., 2015). This characteristic of anurans makes them highly vulnerable to pollution and changing environment which makes them the most threatened vertebrates. Conservation of the declining species needs effective management which relies on the accurate information on an organism's basic ecological requirements. Knowledge on the demography habitat relationship at multiple scales, reproduction and movement lead to more comprehensive conservation and management decisions for endangered species across multiple taxa.

Radio telemetry has enabled researchers to know, how a free ranging creature adapt in an environment. This technology has given us tools to know about aspects of life history strategies that could not be gathered in other techniques such as in drift fence, visual encounter surveys (Crump and Scott, 1994). Studies on the movement ecology and habitat use of amphibians has been done for some species, but knowledge gaps remain (Pittman et al. 2014). Such studies can contribute to provide more accurate models that better predict amphibian population responses to habitat alteration (Semlitsch 2008; Pittman et al. 2014). Whereas the need for such studies on threatened species or those with limited geographic distributions is readily apparent. Investigations on species are also warranted because the consistent or inconsistent use of habitat by these species throughout their ranges may provide insights into how species with greater plasticity will respond to increasingly altered (including by climate change) and fragmented habitats. Radio telemetry thus expected to provide valuable information on life history and ecology of threatened amphibians that are currently facing an escalated worldwide population decline among all other vertebrates (Stuart et al 2004, Wake and Vredenburg, 2008).

2. METHODS

2.1: Study Animal

We selected Stoliczka's Torrent Frog (*Nanorana vicina*, Stoliczka, 1872) (**Photo 1**) which is adapted to a life in mountain streams. Females grow larger than males and are known to attain size up to 110 mm (Vasudevan and Sondhi, 2010). This stream breeding Dicroglossidae frog is endemic to Western Himalaya and uniquely adapted to fast flowing rocky mountain streams at mid elevation. The species is distributed from Pakistan through Kashmir, Himachal Pradesh, and Uttarakhand. The type locality of the species is Murree, Western Himalaya in Pakistan. The species is restricted to mid to upper elevation (~1000m to 2500m) and has a patchy distribution (restricted to torrent streams) many of which are already polluted or developed for hydropower generation. Females are largely associated with riparian habitats while male migration might occur during breeding season. The species thus fulfil the criteria of a *biological indicator* as laid by (Holt and Miller, 2011).



Photo 1: Study animal (*Nanorana vicina*)

2.2: Study Area

2.2.1: Binog Wildlife Sanctuary

Binog Wildlife Sanctuary (**Figure 1**) (**BWLS**) ($28^{\circ} 60' - 31^{\circ}28' N$, $70^{\circ}49' - 80^{\circ}60' E$) holds very unique assemblages of amphibians and reptiles where some of the species are endemic to the Western Himalayan range. Physiographically the area is characterized by undulating topography and elevation varies between 1500 m to 2330 m elevation (Kumar et al., 2012). The forest types found in the sanctuary are Banj oak forests, Chir Pine forests and Grasslands (Champion & Seth, 1968). Some tourist spot, settlement and private lands are located at the vicinity of the beat. Binog Wildlife Sanctuary holds a rich assemblage of reptiles and amphibians with few species endemic to Western Himalayan region. The key herpetofaunal habitat featured in this Protected area (PA) is its perennial stream habitats. Stream habitats are the cornerstone of herpetofaunal conservation in this PA.

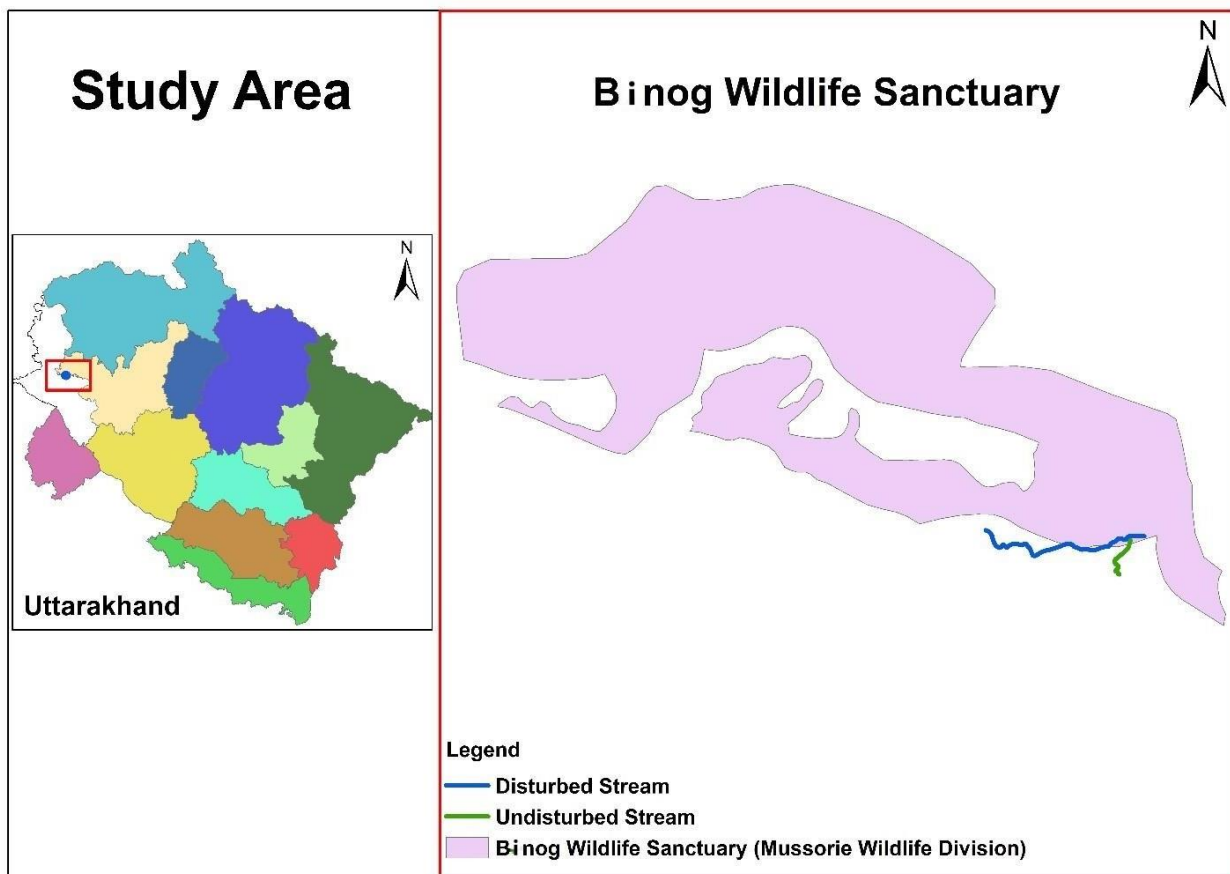


Figure 1: Study area in Binog Wildlife Sanctuary

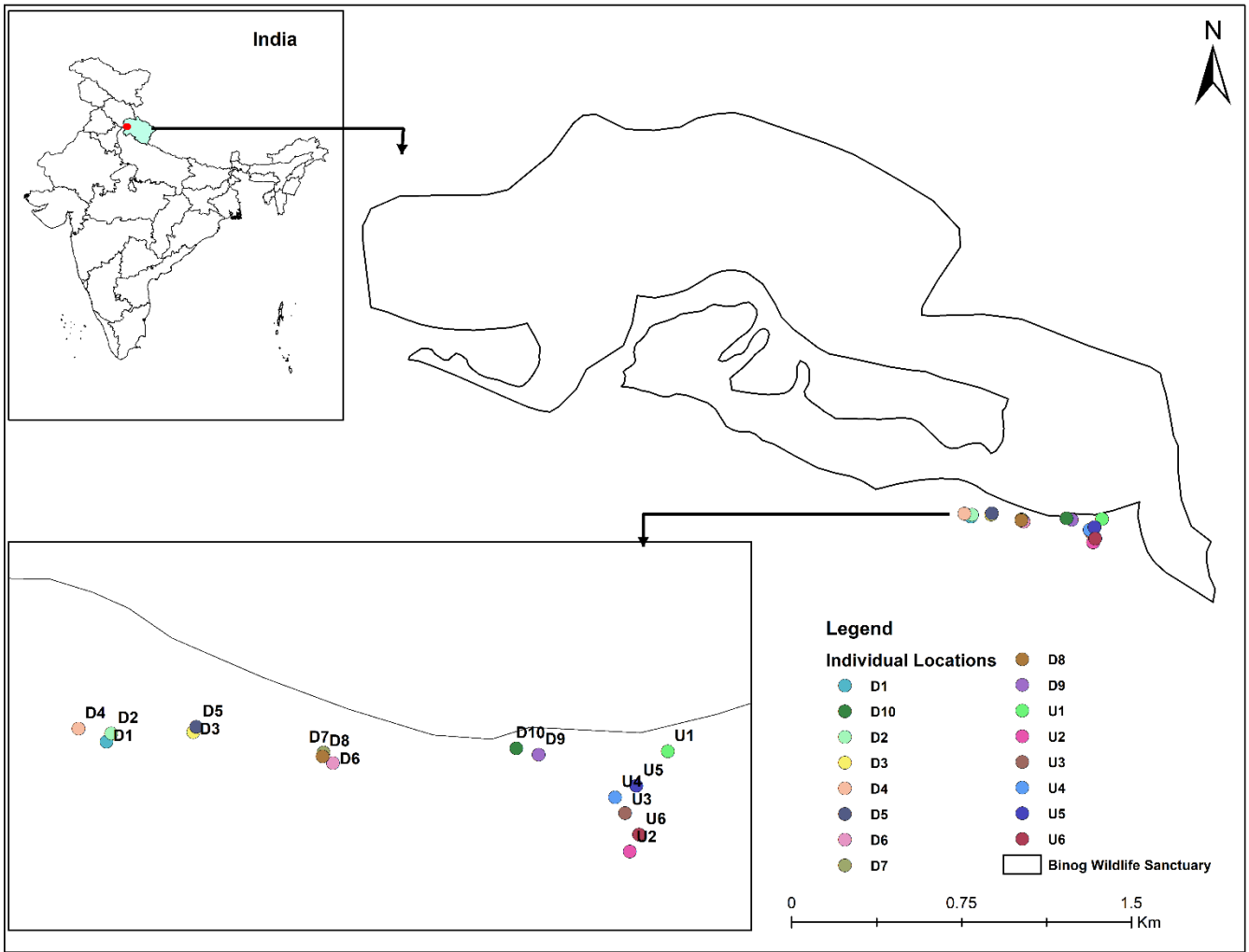


Figure 2: Location of tagged individuals in two streams of Binog wildlife sanctuary.

2.3: Habitat Inventory

We selected two perennial streams on the basis of modification and classified them as Disturbed (**D**) and Undisturbed (**U**) streams (**Figure 1**) in Binog wildlife sanctuary. 10*10-meter grids were laid using Arc GIS. At every 10-meter cross-section of stream was georeferenced and width and depth were taken. Within grid, habitat was identified as pool and non-pool (Cascade, run, riffle). We assumed grid as a rectangle and measured area of pool and non-pool habitat. Streams are spring fed in the sanctuary and is the source of water supply in nearby areas. Both streams at the locality are approximately 1– 4 m wide with moderate flow, primarily rocky with intermittent gravel and pools with detritus, branches and leaf litter. Modification such as artificial pool, check dam and concrete cascade has been made in the disturbed stream.

2.4: Radio tracking and Data analysis

We used very high frequency transmitters (**Wildlife Materials, SOPR-2070**) fitted as external harness to study the movement of 16 individuals of *Nanorana vicina* (**Photo 2, Appendix 2**). We have used external transmitters keeping in view constrain in shape and size of anuran body. The transmitter used is less than 3% of the body weight of the frog as used in earlier studies (Goldberg et al., 2002). We fitted transmitters on the inguinal region of the frog using waist belt harness to avoid movement bias and injury of the tagged frogs. A receiver (**Wildlife Materials TRX -48**) (**Photo 2**) equipped with a three-element Yagi antenna was used to detect the tagged individuals (**Photo 3**). Tagged individuals were given ID as “D” for disturbed streams individuals and “U” for undisturbed stream individuals. Tagged individuals were located using homing-in procedure, usually on a daily basis. After each relocation without disturbing animals, microhabitat and ecological parameters and behavioral activities were noted down in a datasheet. Handheld GPS and meter tape used for recording distance covered. We had run chi square test to predict the habitat preference by the tagged individuals. To check the effect of tags on the weight of individuals we did T test. Data analysis was done using R (3.6.1, 2019/07/05) and Microsoft Excel, 2016. All the maps have been prepared in ArcMap 10.1.



Photo 2: Receiver and Coaxial cable (Left), A transmitter (Right).



Photo 3: *Nanorana vicina* with transmitter attached (Above), Researcher tracking individuals with Yagi Antenna (below).

2.5: Results

Effects of transmitters on individuals.

t- test results suggest that there is no influence on the weight of individuals. Results showed that weight before tagging and after removing tags did not significantly change which means there was not any differences in the means of both ($t = 1.15$, $p \text{ value} = 0.28$) (**Figure 3**).

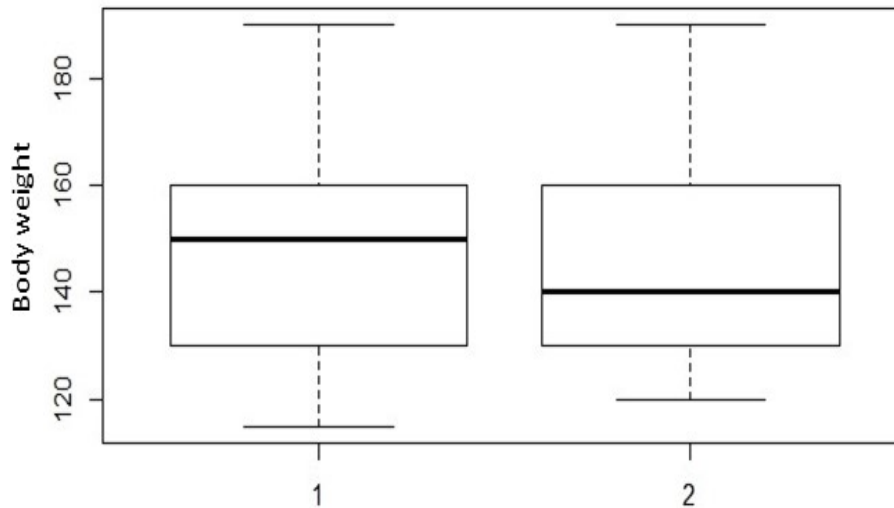


Figure 3: Comparison between weight before tagging (1) and weight after removing tags (2).

Habitat preference

During study period we observed individuals of *N. vicina* were mostly found in pool section of both the stream. This observation has been supported by Chi square value where $X^2(\text{pool}) > X^2(\text{Non-Pool})$ ($177.88 > 111.05$, $p \text{ value} = 8.4513\text{E-}65 \sim 0$), that signifies that pool habitat have been significantly more used than non-pool (**Figure 4 & 5**). To compare our data, we applied VES, which showed that most preferred habitat by the individuals were Pool. However, during rainy season individuals found in land (**Figure 6**).

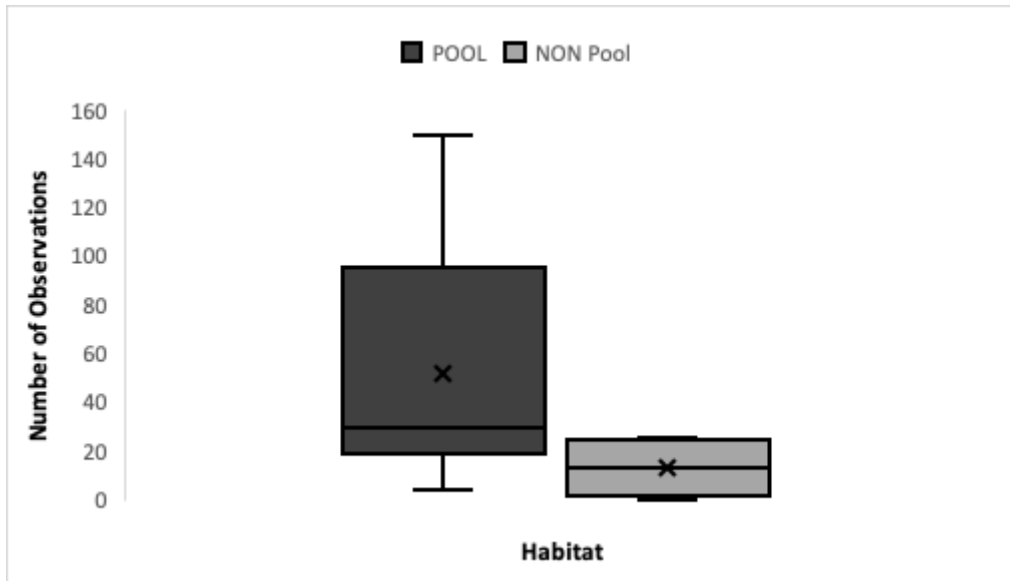


Figure 4: Habitat preference by radio tagged individuals in Disturbed stream.

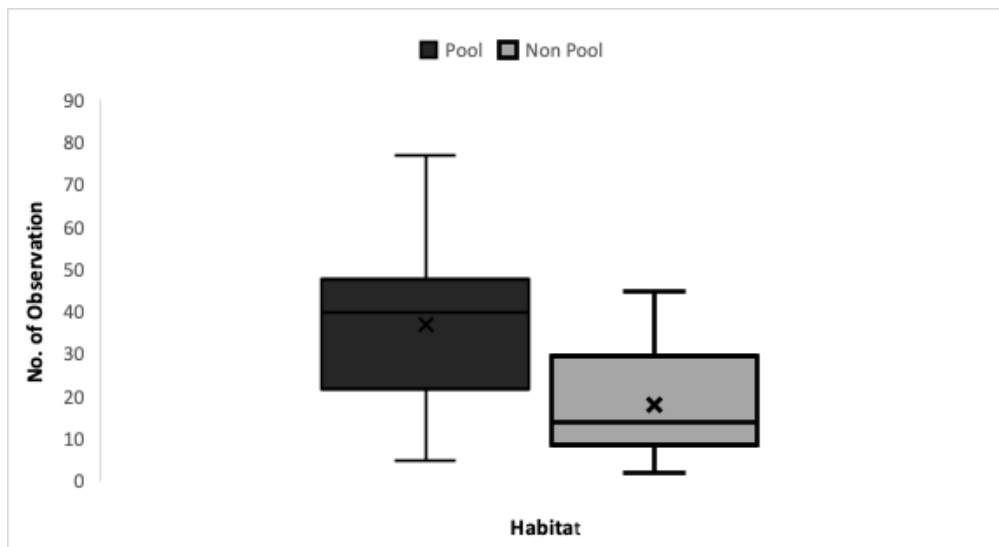


Figure 5: Habitat preference showed by tagged individuals in Undisturbed streams.

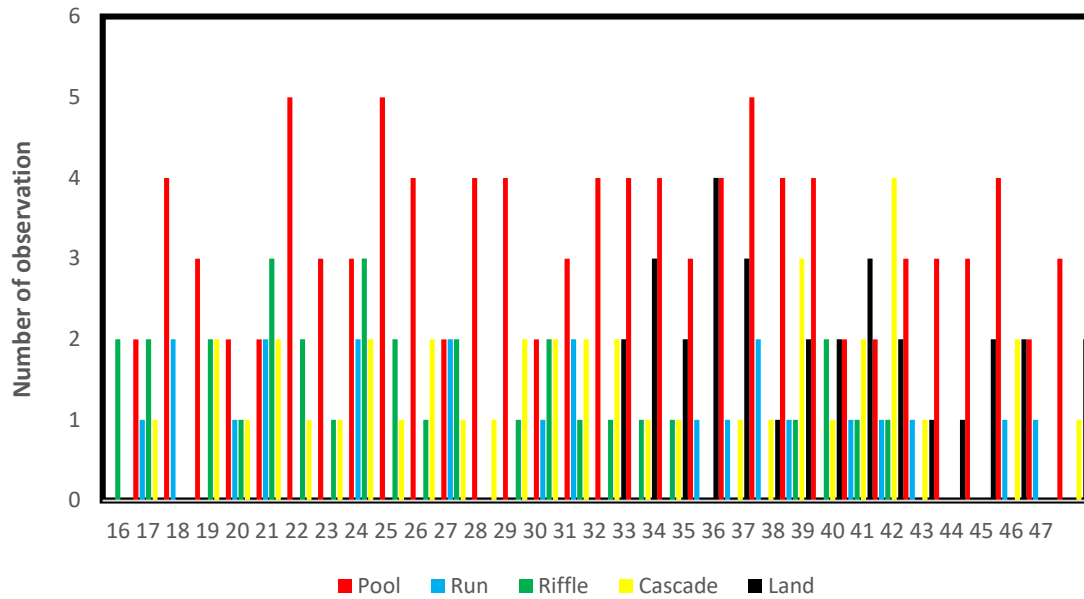


Figure 6: Habitat preference shown by individuals during VES (No. of days = 47) in selected streams.

Movement

Tagged individuals showed less movement during tracking days (Average tracking days = 63). Highest average movement made in disturbed stream was 5.9 m (D5) and the lowest was 0.36 (D8) m during tracking days (**Figure 7**). In undisturbed stream the highest average movement was made by U6 (5.07 m) and the lowest was 0.68 m (U4) (**Figure 8**). However, in an explicit case a single individual (D3) moved 100 m in a day which is the highest movement during the whole study period while the minimum is 0 m in a day. Highest cumulative movement in disturbed stream was 225 m (D2) while in undisturbed stream was 320 m (U1) (**Figure 9, Figure 10**).

Our results also suggested that the individuals moved more during monsoon (4.25 m/day) than pre - monsoon (2.99 m/day) and least in post monsoon (1.06 m/day) (**Figure 11**).

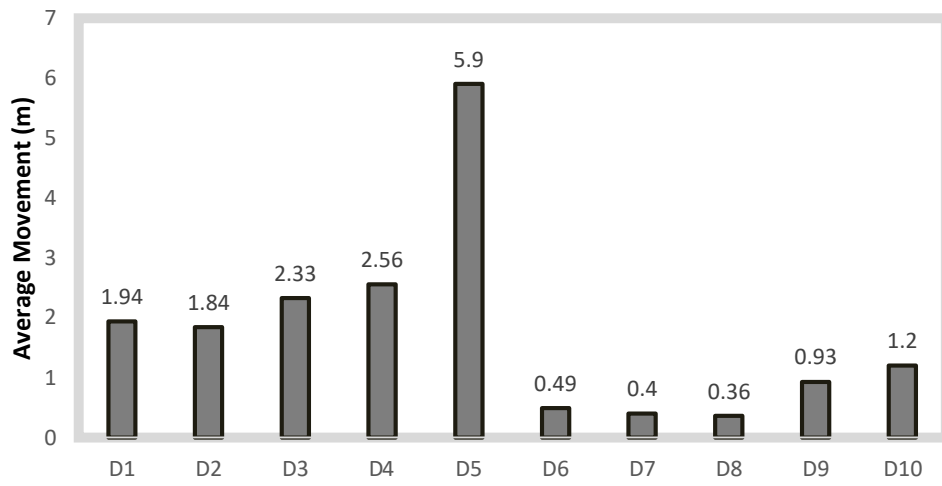


Figure 7: Average movement by individuals in Disturbed stream.

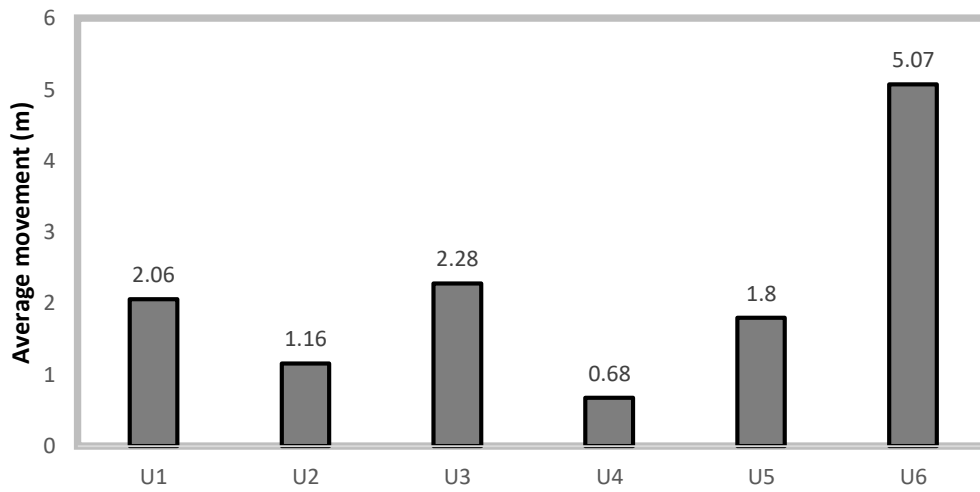


Figure 8: Average movement by individuals in Undisturbed stream.

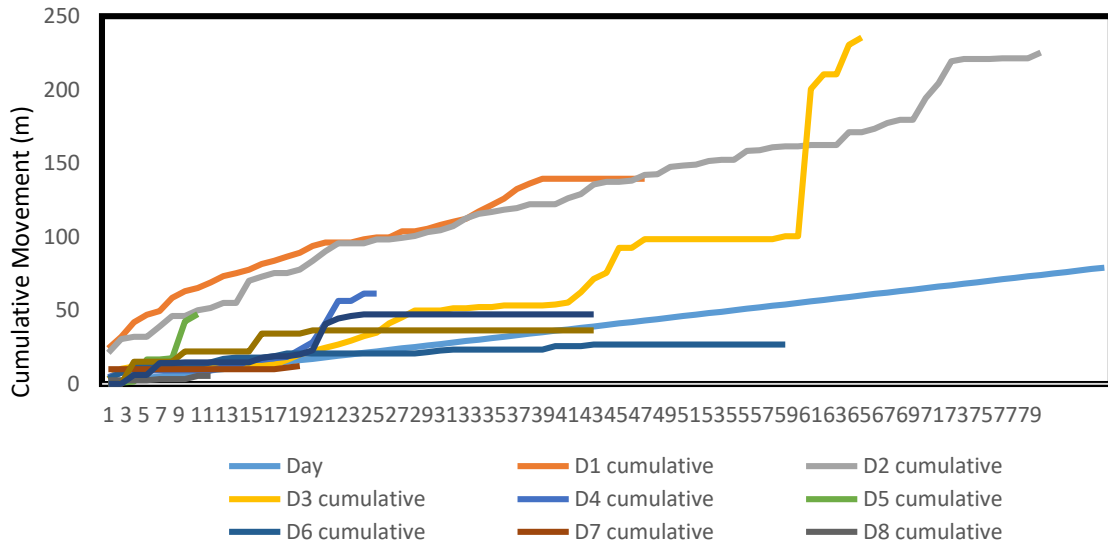


Figure 9: Cumulative movement by individuals in Disturbed stream.

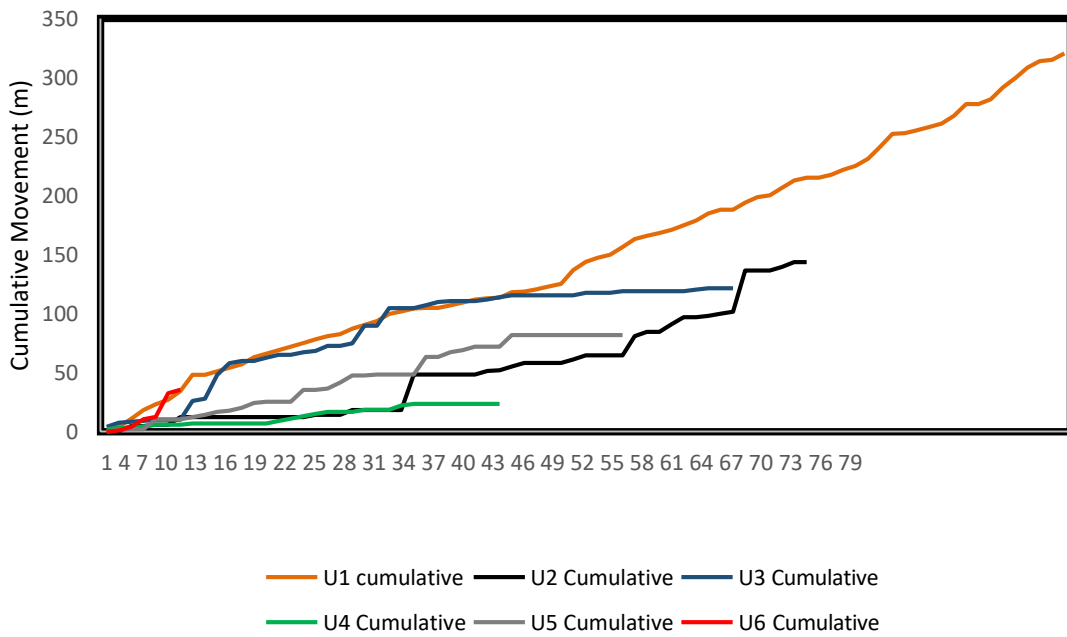


Figure 10: Cumulative movement of individuals in undisturbed stream.

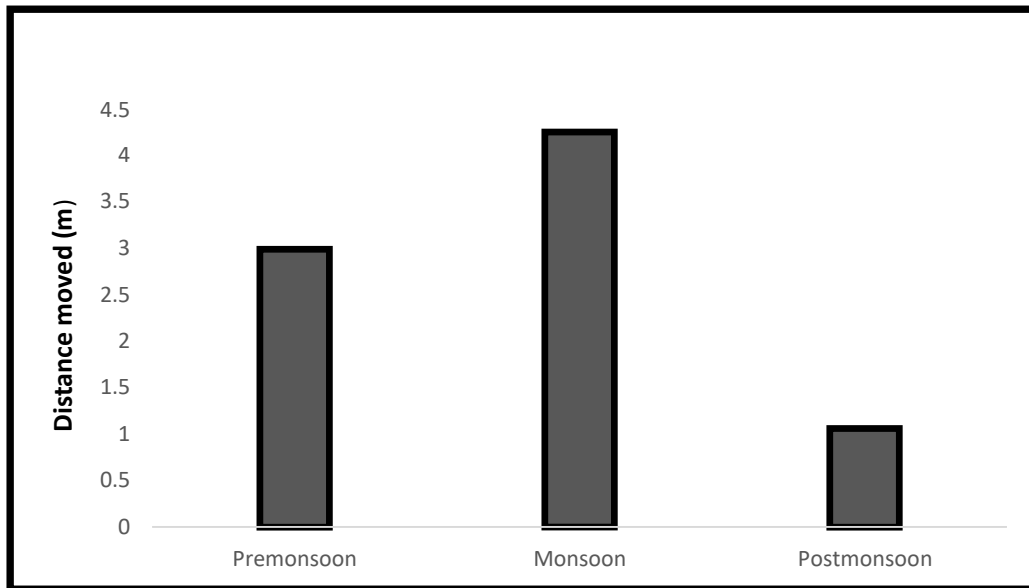


Figure 11: Seasonal movement made by radio tagged individuals.

3. DISCUSSION

Radiotelemetry results suggest that *N. vicina* is a stream dwelling frog which is mostly confined to pool section of the stream and move less. It showed high philopatry, narrow habitat uses and obligate adaptations to torrent stream environment. The trend of individuals to move less has also been observed in other stream frogs support that *N. vicina* is a stream dwelling frog. Inger, 1969; Daugherty and Sheldon, 1982 and Tessier et al. 1991, stated that some tropical and temperate stream-dwelling anurans exhibit philopatry with limited movement. Kam and Chen, 2000 found that mean maximum movement made by *R. swinhoana* was 15.4 ± 30.0 m during the 24-month study period. *N. vicina* being a sedentary animal, shares common characteristic with other anurans such as *L. hochstetteri* and *A. truei* which inhabit permanent streams (Inger 1969, Daugherty et al. 1981, Daugherty and Sheldon 1982, Duellman and Trueb 1986). Sedentary life style was also shown by *Rana (Pelophylax) chosonica* (Ra et al., 2008) and *R. draytonni* (Fellers and Kleeman, 2007). The results of this study suggest that *N. vicina*, like many riparian anurans, is a sedentary animal. Inhabiting riparian zones, animals probably obtain sufficient ecological necessities such that long-distance movements are not required (Kam and Chen, 2000). Our Radiotelemetry results has been supported by Visual encounter survey where they were mostly encountered in the pool section of the stream. Our result corroborates with the findings of Hinderer et al. (2017) which showed that tagged individuals movement triggers by rain. Precipitation has been found to be one of the major contributors for the movement of frogs from aquatic body to the terrestrial habitats (Hinderer et al., 2017).

Previous studies have showed that movement pattern of frogs is correlated with the rain events (Dole, 1971; Kruse and Christman, 2005). However, attaching radio transmitters to amphibians have their own back draws of appearing too heavy on individuals and might have negative impacts on animals (Muths 2003; Rowley and Alford, 2007). Nevertheless, our result showed no effects of tags on the weight of frogs even after removing tags.



Photo 4: Artificial pool (Above), Natural pool (Below)



Photo 5: Types of microhabitats in a Natural stream considered in this study

Chapter 2: Species Richness

1. INTRODUCTION

Herpetofauna represent key components of an ecosystem in terms of biomass and food web. Species richness is a component of the concept of species diversity and used as biodiversity metrics in ecology and conservation planning. Patterns of herpetofaunal species richness on local, regional and global scales have been of perennial interest to biologists. In Indian scenario, studies on herpetofauna are mostly restricted to the biodiversity hot spots in comparison to other parts of India. Study on herpetofauna of Uttarakhand can be traced back to Boulenger (1920). Subsequently few works have carried out by Tilak and Ray (1985), Ray (1992, 1995, 1997, 1999), Husain and Ray (1995, 1997), Ray and Tilak (1995). But information on herpetofauna of Uttarakhand is still remain inadequate. Herein, we provided species richness and relative abundance of two protected areas of Uttarakhand i.e. Binog wildlife sanctuary (Discussed above in spatial ecology of *N. vicina*, **Figure 1**) and Kedarnath wildlife sanctuary (**Figure 12**).

2. METHODS

We applied time constrained visual encounter survey (VES) a method used for measuring and monitoring biological diversity of the amphibians and reptiles (Crump and Scott, 1994). The surveys were executed for one hour at dusk between 1900h and 2200h. Forest trails, hill streams, temporary water pools, marshy lands were actively surveyed to record the presence of individuals. Microhabitat such as leaf litter, dead bark of the trees and fallen logs were also examined. For snake ventral, dorsal and head scales are counted. Data analysis was done in house using Microsoft Excel 2016. Species were identified using the keys of Smith (1935, 1943), Schleich & Kastle (2002), Das (1995) and Dutta (1997)

2.1: Study area

2.1.1: Kedarnath Wildlife Sanctuary

Kedarnath Wildlife Sanctaury (**Figure 12**) (**KWLS**) was established in 1972 and is situated in the north-eastern part of the Garhwal Himalayas between 30°25'-30°41' N, 78°55'-79°22' E. The Sanctuary falls under the IUCN management Category IV (Managed Nature Reserve) in the Biogeographical Province 2.38.12 of Himalayan highlands. KWLS is one of the largest protected areas with 97517.80 ha (25293.70 ha in Chamoli district and 72224.10 ha in Rudraprayag district) in the Western Himalaya. The sanctuary lies in the upper catchment of the Alaknanda and Mandakini Rivers, which are major tributaries of Ganges. The vegetation

of the sanctuary is diverse and most of the forest types are sub-tropical, temperate, sub-alpine and alpine and full of dense forest including oak, pine, birch, rhododendron paddocks with numerous flowering and medicinal plants. The altitudinal ranges vary from 1200 meter to 7068 meters (Syed & Ilyas, 2013). An extreme variation in altitude, aspect and terrain causes diversity in climate. Majority of the area climate is temperate. Most of the streams and rivers are perennial due the thick vegetation.

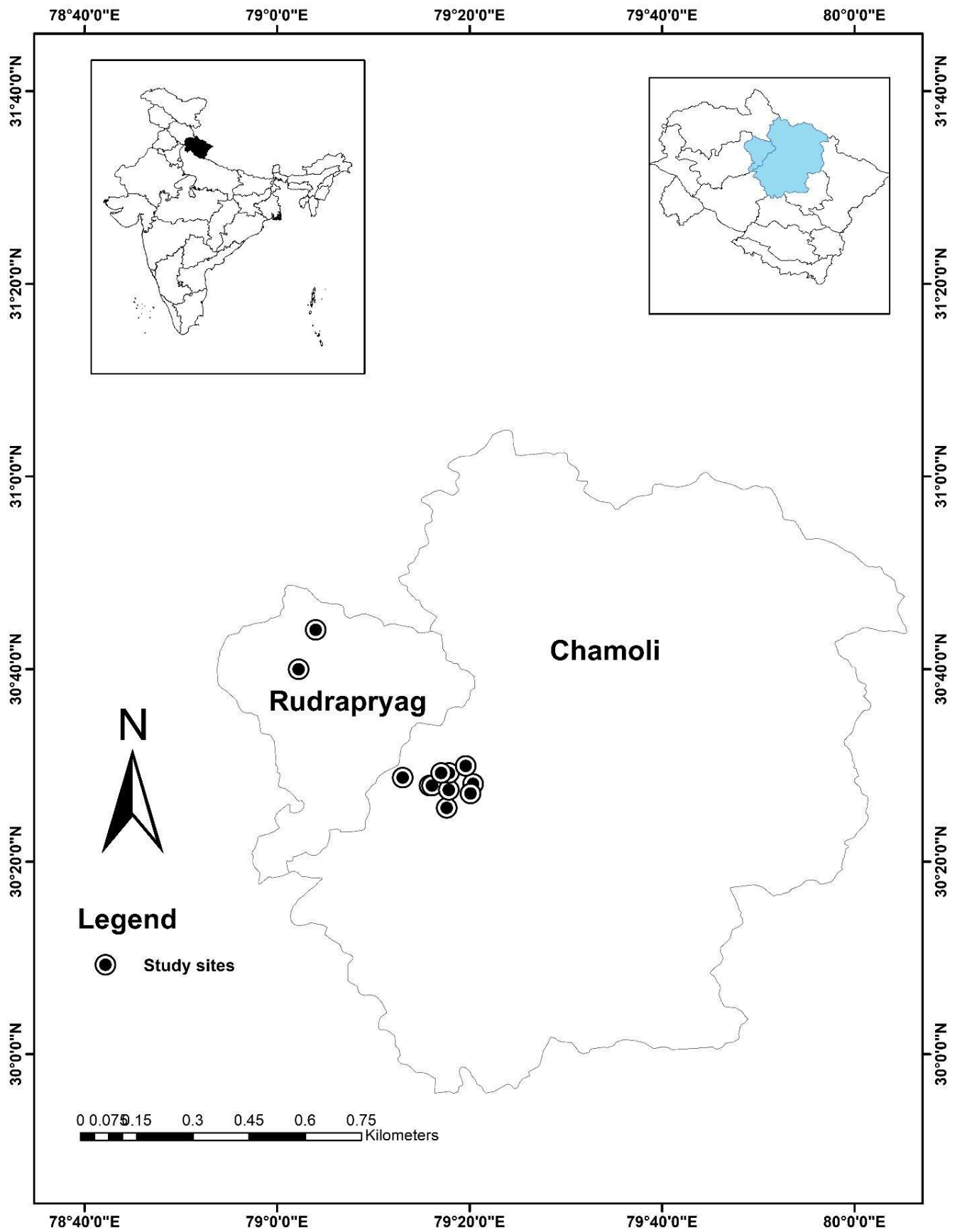


Figure 12: Study sites in Kedarnath Wildlife Sanctuary

2.2: Results

In BWLS, during the study period we recorded 18 species of herpetofauna belonging to 16 genera (**Appendix 1**). Among them amphibian was represented by five species and reptiles were represented by 13 species including eight species of snakes and five species of lizards. Among the recorded species in VES *Nanorana minica* was most abundant species with relative abundance 0.33 and encounter rate 3.5/person hour (**Table 2**). *Asymblepharus himalayanus* has the lowest value of relative abundance (0.04) with an encounter rate 0.4/person hour. VES study also shows that pool section is preferred habitat of the *Nanorana vicina*, while two species *Amolops formosus* and *Amolops jaunsari* are confined to cascade (**Figure 13**). *Nanorana minica* is the most abundant species (**Table 2**) found near the bank of the stream, often calling from under the fallen leaf litters. Only toad species which has been frequently encountered around this place is *Duttaphrynus himalayanus* commonly known as ‘Himalayan Toad’, found in the run section of the stream (**Figure 13**)

In KWLS, we recorded 16 species of herpetofauna belonging to 13 genera and 9 families (**Appendix 1**). Amphibians were represented by nine species of anurans while reptiles were represented by four species of snakes and three species of lizards. Among all recorded species of herpetofauna, *Megophrys cf. parva* has the highest relative abundance value (0.3) during the study period (**Table 1**).

Our study also revealed that KWLS has a greater number of amphibian’s species in comparison to BWLS while BWLS has a greater number of Reptiles species (**Figure 14**).

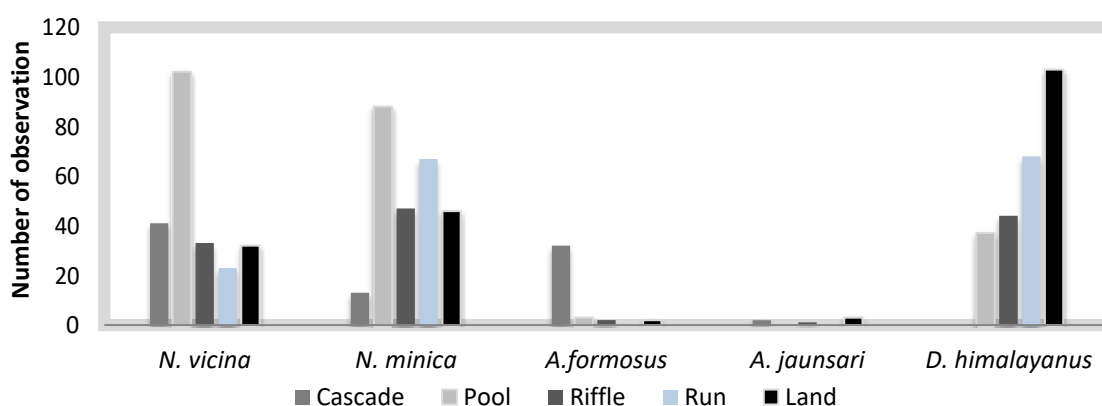


Figure 13: Habitat preference by amphibians in Binog wildlife sanctuary.

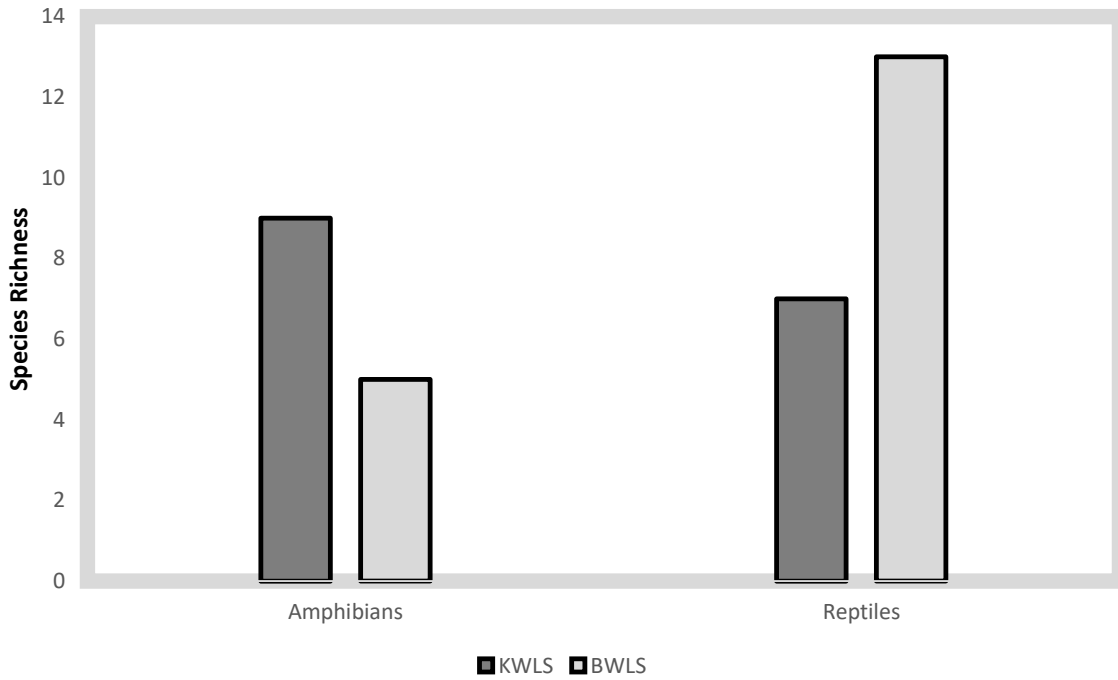


Figure 14: Reptile and amphibians' richness in Study sites.

Table 1: Relative Abundance of the Herpetofaunal Species recorded during VES in KWLS

Name of the species	Relative Abundance
<i>M. cf. parva</i>	0.3
<i>N. minica</i>	0.28
<i>N. vicina</i>	0.04
<i>A. formosus</i>	0.03
<i>D. himalayanus</i>	0.27
<i>D. melanostictus</i>	0.01
<i>H. platyceps</i>	0.01
<i>L. tuberculata</i>	0.01
<i>A. himalayanus</i>	0.03

Table 2: Relative Abundance and Encounter rate of the Herpetofaunal Species recorded during VES in BWLS

Species name	Relative abundance	Encounter Rate
<i>A. formosus</i>	0.06	0.6
<i>A. jaunsari</i>	0.03	0.33
<i>D. himalayanus</i>	0.27	2.93
<i>N. minica</i>	0.33	3.5
<i>N. vicina</i>	0.23	2.53
<i>H. platyceps</i>	0.04	0.47
<i>A. himalaynus</i>	0.04	0.4

2.3: Species Account

2.3.1: Amphibians

***Amolops formosus* (Günther, 1876)**

Body slender and elongated. Pineal body present on forehead. Limbs long and slender. Adhesive disc present on fingers and toes. Webs well developed on toes. Dorsally green with irregular dark brown markings. Cross bands present on limbs and digits. Individuals were seen on cascade boulders near human disturbed areas outside the sanctuary.

***Amolops jaunsari* (Ray, 1992)**

Body stout. Limbs elongated and slender; digits with large adhesive disc. Dorsal skin tubercular. A discontinuous dorsolateral glandular fold present. Webs on toes well developed. An olive-green frog with black or brown spots on dorsum. Under white. Dark bands present on limbs. Discs on fingers white.

***Duttaphrynus himalayanus* (Günther, 1864)**

A large bodied toad with stout limbs. Body dorsally warty and pair of parotid gland present behind eye. Female larger than male. Dorsally olive brown or greyish brown. Belly cream coloured. The species found along the streams and forest floors throughout the study period. Individuals were commonly observed aggregating in the stream pool during breeding period

***Duttaphrynus melanostictus* (Schneider, 1799)**

A large toad having a rough body appearance. Snout is slightly pointed. Interorbital space having black cranial ridges. Frequently encountered from KWLS and BWLS during VES and opportunistic survey. They are quite adaptable to the anthropogenically modified habitats. On handling secreted some fluid having pungent smell. Species is abundant throughout the range. Males are smaller than females.

***Euphlyctis cyanophlyctis* (Schneider, 1799)**

Dorsum light gray, olive-green or light brown, sometimes black, with irregular black spots. Thighs posteriorly dark with one or two yellow or white irregular longitudinal stripes; ventrum white, immaculate or with dark speckling or reticulation; vocal sacs light brown. It is a highly aquatic and littoral frog. It remains permanently resident in different types of habitats with

pooled water

***Fejervarya* sp.**

Gray brown or olive above in color. Snout pointed, projecting beyond mouth. Body with small tubercles, sometimes small longitudinal folds are present. The frog frequents marginal vegetation along canals, streams, torrents, ponds and puddles, when disturbed it leaps in water to swim back at once.

***Megophrys* cf. *parva* (Boulenger, 1893)**

Found in evergreen broadleaf forest alongside streams. Males have been observed calling from bushes and ferns. Call aggregation was heard during June-July.

***Nanorana minica* (Dubois, 1975)**

A small frog with slender ovoid body shape. Call aggregation was recorded during the month of June-July. Male calls from the rocks or under the rocks. Altitudinal range varies from 1000m-2336m. Recorded from both KWLS and BWLS.

***Nanorana vicina* (Stoliczka, 1872)**

Naris a little nearer to the eye, tympanum indistinct, first finger as long as second, toes half webbed; outer metatarsal tubercle reduced, inner narrow, feebly developed and body dorsum tuberculate. Mostly found in the pool section of the streams.

***Sphaerotheca* sp.**

Short, stocky, and toad like, dorsum olive golden, with a light-yellow median line Head broader than long, hind limbs short, tympanum distinct. Species are burrowing in habit and are mostly seen during breeding season

2.3.2: Reptiles

***Asymblepharus himalayanus* (Günther, 1864)**

Body elongated and slender. Head indistinct from neck; snout short. Dorsal scales smooth. Limbs well developed. Dorsally bronze-brown. A broad black stripe present laterally on head and flank. Lips and underside of the body cream coloured.

***Calotes versicolor* (Daudin, 1802)**

A medium to large sized bodied lizard, characterized by the posterodorsal orientation of lateral scales. Dorsal and lateral scales large, more or less distinctly keeled, ventral scales strongly keeled.

***Eurylepis cf. taeniolata* (Blyth, 1854)**

A large bodied skink. Body elongated with long muscular tail. Limbs well developed. Dorsally yellowish brown. Ventrally bright yellow.

***Japalura kumaonensis* (Annandale, 1907)**

Slender body with a long tail. Head distinct from neck. Tympanum exposed. Enlarged mid dorsal scales make a ridge. Dorsal and lateral side of the body brown. “V” shaped dark markings between two yellow stripes present on dorsum. A broad stripe present behind eyes. Dark cross bands present on forehead, limbs and tail. Lips and belly cream coloured.

***Laudakia tuberculata* (Gray, 1827)**

A large bodied lizard with a long tail. Body flattened. Head distinct from neck. Scales strongly keeled and large on tail and limbs. Grayish brown dorsally. Head paler than dorsum. Ventrally cream coloured. In breeding season, the body of male becomes bluish and blue marking appears on throat.

***Boiga multifasciata* (Blyth, 1861)**

Body slender and very long; laterally compressed. Head distinct from neck. Eye large and pupil vertical. Tail long. Dorsal scales smooth. Dorsally grey or light brown. Black broken bands present across the dorsal body. Two black stripes present on posterior head. Lips and throat

whitish. Belly greyish.

***Gloydius himalayanus* (Günther, 1864)**

Body stout with a broad triangular head. Heat sensitive pit present between eye and nostril. Eye pupil vertical. Scales on head and dorsal body strongly keeled. Tail short. Dorsally greyish brown with slightly dark broad bands. A long dark streak present behind eye. Ventrally grey. Individuals were encountered in bushes along stream. One roadkill juvenile was recorded near stream.

***Herpetoreas platyceps* (Blyth, 1854)**

Body slender. Head distinct from the neck. Eye large and pupil rounded. Dorsal scales slightly keeled. Dorsally reddish brown. A black line passes through eye. Upper lip white. Two white, black edged “U” shaped markings present on posterior head. Under white or yellowish. Adults and juveniles were commonly encountered along stream at night. We also observed adult of the species feeding on tadpole of *Nanorana sp.*

***Lycodon mackinnoni* (Wall, 1906)**

Body slender with a slightly broader head. Dorsal scales smooth. Dorsally dark glossy brown with yellow rings along the body. Eyes small and black. Ventrally glossy white. Single individual recorded at night from trail on a hill slope near human habitation.

***Oligodon arnensis* (Shaw, 1802)**

Body slender with slightly broader head. Eyes small. Dorsal scales smooth. Dorsally grayish brown with black transverse bands. Three inverted “V” shaped black markings present on head and neck. Ventrally white.

Individuals were recorded along stream edge near human habitat.

***Fowlea piscator* (Russell, 1796)**

Olive brown snake with black spots along the body. A black line radiating from eye to lip. Single individual was recorded from marshy land in KWLS, which is known as Shamar in local language during opportunistic survey.

***Sibynophis collaris* (Gray, 1853)**

A small snake with slender body. Dorsum brown or greyish brown with Dark crossbar on head

and nape. A line of small black spots along body axis Dorsal scales smooth. enter yellowish with black spot making a dotted line on each side. It is a terrestrial snake.

***Othriophis hogdsonii* (Gunther, 1860)**

An olive brownish color snake with smooth or very lightly keeled dorsal scales. This is a partly arboreal snake and endemic to western Himalayas.

***Ptyas mucosa* (Linnaeus, 1758)**

Very long body with dark color patterns on the whole dorsal surface. Their color varies from pale browns to nearly black. More or less strongly keeled on the posterior part of the body. Snout obtuse, slightly projecting. This snake is diurnal, semi arboreal and fast moving.

3. DISCUSSION

During the study period in both sanctuaries we recorded ten species of amphibians (all anurans) belonging to seven genera. Reptiles were represented by nine species of snakes belonging to nine genera and five species of lizards belonging to five genera. Some of the recorded species such as *Boiga multifasciata* and *Japalura kumaonensis*, *Lycodon mackinnoni*, *Orthriophis hodgsonii*, *Amolops jaunsari*, *Amolops chakrataensis* are restricted to Western Himalaya. Uttarakhand is known for few names bearing herpetofaunal taxa, type localities of which are within the political boundary of the state, such as *A. jaunsari*, *A. chakrataensis*, *J. kumaoensis*, *G. himalayanus* and *L. mackinnoni*. KWLS represents tremendous elevation range, and the climate, vegetation and temperature vary greatly with *elevation*. Distribution of reptiles across the different elevation is very interesting. However, at high elevation the reptilian fauna is less diverse, few of the snake and reptile species are found in these areas. Himalayan pit viper (*Gloydius himalayanus*) is one of the high elevation dwelling species in both sanctuaries as well as India. It thrives in *altitudes* of 1500 to 4887 meters (Husain and Tilak, 1995). Study also reported two rare species of reptiles *Lycodon mackinnoni* and *Eurylepis cf. taeniolata*. Besides, we encountered few species such as *Nanorana sp.*, *Fejervarya sp.*, *Megophrys cf. parva* and *Eurylepis cf. taeniolata* which are either potential new species or conferred to closely related species. Among the recorded species *Nanorana minica* is categorized as vulnerable in IUCN red list while *X. piscator* accorded the highest legal protection status under Schedule II of WL (P) A, 1972. The number of species recorded in our study is low in comparison to other inventories. However, further extensive field survey will add more and hitherto unknown herpetofaunal species to the sanctuaries.

4. HIGHLIGHT OF THE STUDY

Present study recorded a poorly known snake *Lycodon mackinnoni* which is originally described from Mussoorie by Wall in 1906. After that Smith (1943) reported the species from Almora and Muktesar near Nainital in Uttarakhand. Manhas et al. (2015) recorded the species from Doda district of Jammu and Kashmir. Recently Faiz et al. (2018) reported the species from Bagh Azad Kashmir, Pakistan. However, our study rediscovered the species from the type locality after 112 years since its discovery (Nawani et al. 2021).

Another rare species of skink *Eurylepis cf. taeniolata* recorded from the sanctuary. The species is known from Kashmir, Gujarat, Rajasthan, Punjab, Himachal Pradesh in India (Uetz et al., 2021). The present record probably the first record of the species from Uttarakhand. However,

the further study needed on the systematics of the species as also earlier study by Griffith et al. (2000) suggested the *E. taeniolata* is a complex group.

Chapter 3: Natural history of *Duttaphrynus himalayanus*

1. INTRODUCTION

Amphibians breeding at lentic waterbodies are normally distributed across a hydrological gradient, ranging from highly ephemeral ponds to large permanent pools and shallow lakes (Laufer et al., 2015). Selecting a suitable oviposition site might be crucial for oviparous species without parental care behavior (Refsnider & Janzen, 2010). In anurans, two main categories of reproductive behavior are found: explosive breeding and prolonged breeding (Cajade et al., 2020).

The Himalayan toad (*Duttaphrynus himalayanus* (Günther, 1864)) is broadly distributed throughout the Himalayan Mountains in southeastern Tibet (Fei et al., 2009; Sarwar et al., 2016).

2. METHODS

We observed reproductive behavior of Himalayan Toad (*Duttaphrynus himalayanus*) during February and April 2019. We applied ad-libitum survey to observe the breeding behavior of the species. We continuously observed behavioral activities in stream pool both day and night time until the amplexus dislodged. All the events of breeding were observed with the help of red light or low beam torch (at night) from a distance about 1 m. Duration of amplexus, egg laying was recorded with stopwatch and noted down in a standard datasheet. After the completion of spawning, body size (SVL) and body weight of the amplexing pair were taken with digital caliper (Mitutoyo) to nearest 0.1 mm and Pasola spring balance (to nearest 0.1 g) respectively. After dislodged of the amplexant pair we measured the egg clutch with a thread and no. of eggs counted. We measured the diameter of 30 eggs (each clutch) from random section of the clutch.

2.1 : Results

Duttaphrynus himalayanus breeds explosively during the pre-monsoon (March-April). Amplexing pair were observed in pools after 14:00 hr in day time. However, amplexus were frequently observed after 19:00 h emerging under the boulders. Amplexus is axillary (**Photo 6**) and lasts for more than 24 h. The female laid eggs in several clutch preferably in pool edge on gravels or vegetation at an average water depth of $8.89 \text{ cm} \pm 2.82 \text{ cm}$ ($n = 41$). Eggs

laid in gelatinous strings of 1096 ± 385.9 cm ($n= 7$). Eggs black colored (**Photo 6**) with a diameter of 1.64 ± 0.079 mm ($n= 7$). Early morning after 04:00 h individuals and amplexus were observed going or disappearing under boulders. During the study period, no advertisement calls were observed except short aggressive call during male-male combat.

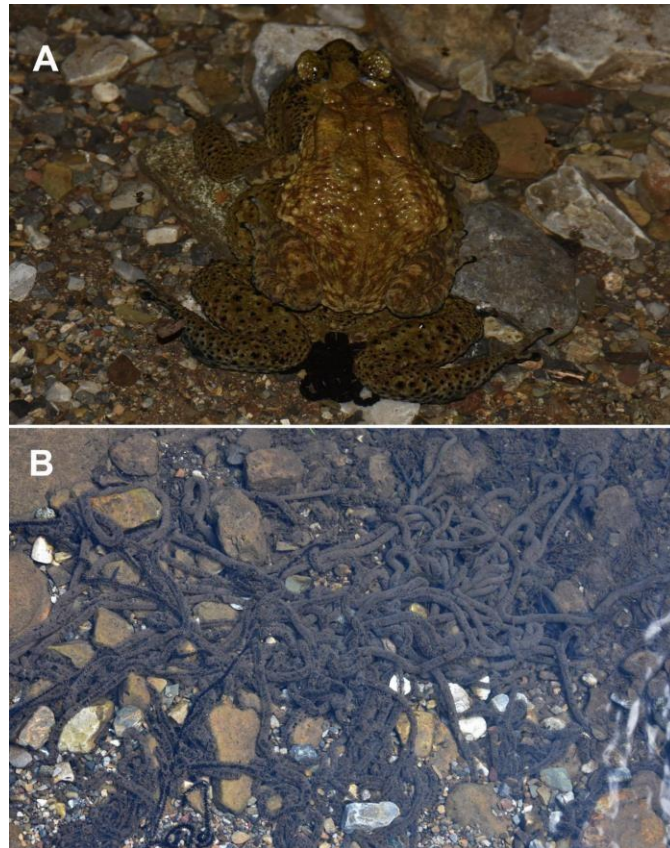


Photo 6: A. *D. himalayanus* amplexing pair laying eggs, B. Egg clutch of *D. himalayanus*



Photo 7: *D. himalayanus* tadpole

3. INTERSPECIFIC AMPLEXUS

Variety of complex mating behaviors has been shown by anurans (Mollov et al., 2010). However, interspecific amplexus is not commonly observed behavior in any animal (Harpalani et al., 2015; Müller, 2016; Beranek, 2017; Mudrek et al., 2017; Groffenet et al., 2019). Amplexus between individuals from different species is termed interspecific amplexus. In Indian perspective some of the documentation has been made on Interspecific amplexus (Sayyed, 2019; Harpalani et al., 2015; Sayyed & Nale, 2017). At 2300 h on 23 March 2021, we documented a male *D. himalayanus* (SVL 73.0 mm) in axillary amplexus (Carvajal-Castro et al. 2020) with an adult *N. vicina* of unknown sex (SVL 91.5 mm) (**Photo 8**).

In earlier studies, absence of species- and sex-recognition in the family Bufonidae has been documented in both natural and laboratory experiment. In lab experiments and in the field, the Asiatic Toad (*Bufo gargarizans*) lacks sex recognition and mate choice in both lab experiments and field (Yu & Lu, 2010; Shin et al., 2020). Heterospecific and multiple amplexus has also

been reported between Smooth-sided Toads (*Rhaebo guttatus*) and Cane Toads (*Rhinella marina*) (Machado & Bernarde, 2011).



Photo 8: Interspecific amplexus between a male Himalayan Toad (*Duttaphrynus himalayanus*) and an adult Himalayan Paa Frog (*Nanorana vicina*) of unknown sex.

Chapter 4: Ecology of tadpoles of Genus *Nanorana*

1. INTRODUCTION

Ectothermic vertebrates have multiple layers of excellent systems to cope with annual, middle-term, or diurnal changes in ambient temperatures as they cannot maintain their bodies at a metabolically favorable temperature (Nakajima et al., 2020). One of such excellencies showed by amphibians is overwintering. Tadpoles of *Nanorana* spp. are known to overwinter (Jithin & Das, 2020). Larval overwintering of the Himalayan stream breeding frogs remains poorly understood despite the fact that it is a survival strategy in the low-temperature environment in the high elevation and latitude. A detailed study was conducted on the larval overwintering ecology with respect to the temperature and disturbance gradients in the pool sections of the Dhobhighat stream in Mussoorie Wildlife Sanctuary during January – July 2021 (Jithin, 2021).

2. METHODS

For assessing the habitat availability and use by tadpoles in the pools, detailed habitat inventory was carried out using multiple transects placed across 2m intervals along the stream. Depth (cm), velocity (m/s), wetted width (m) and substrate composition (bedrock, boulder, small boulder, cobble, gravel, sand, humus, leaf litter, algae, and other substrates) were recorded at every 1m interval (Grant et al., 1990; J. A. Johnson et al., 2020) in these transects. Tadpole densities during the day and night at each pool were calculated visually using a 0.5m² quadrat sampling at random locations in selected pools. Nighttime observations were done with a headtorch. Inflatable boat was used for sampling in pools where access was limited. During the tadpole density estimation, mean depth (cm), substrate and cover types present, water and air temperatures (°C), relative humidity (%), velocity (m/s), leaf litter and humus depth (cm), presence of floating/ submerged algae, fish, and invertebrates (surface or benthic invertebrates) were recorded. Water surface radiant temperature was measured using Extech RH401 digital psychrometer with built-in IR thermometer.

Using Ivlev's electivity index, E_i (Ivlev, 1961) we measured the use of a resource (p_i) compared to its availability (q_i). The index ranges from -1 to 1 , where positive values indicate active selection, negative values for avoidance or inaccessibility and zero showing random selection.

2.1 Results

A clear diurnal variation in mean tadpole density was evident and the degree of this variation was different between winter and post-winter seasons (**Figure 15**). When the diurnal variation analyzed separately for two different pool types, night density in modified pools varied significantly across months (Kruskal-Wallis $X^2(3) = 11.764$, $p = 0.008$), but not in natural pools ($X^2(3) = 4.427$, $p = 0.2189$). Density during day time varied significantly in both natural ($X^2(3) = 18.572$, $p = 0.0003$) and modified pools ($X^2(3) = 19.698$, $p = 0.0002$). Overwintering tadpoles generally avoided both shallow and deeper areas of the pools across seasons and pool types (**Figure 16**). Tadpoles preferred low-velocity areas (0-0.05 m/s) in both modified and natural pools (**Figure 17**) while avoiding the other areas. Tadpoles mostly preferred sand in modified pools during post-winter, and algae in winter. In natural pools, they mostly preferred algae during both winter and post-winter (**Figure 18**). During post-winter, tadpoles preferred submerged and overhanging vegetation as cover in both natural and modified pools. During winter, they mostly preferred log under cuts in modified pools and submerged and overhanging vegetation in natural pools. (**Figure 19**).

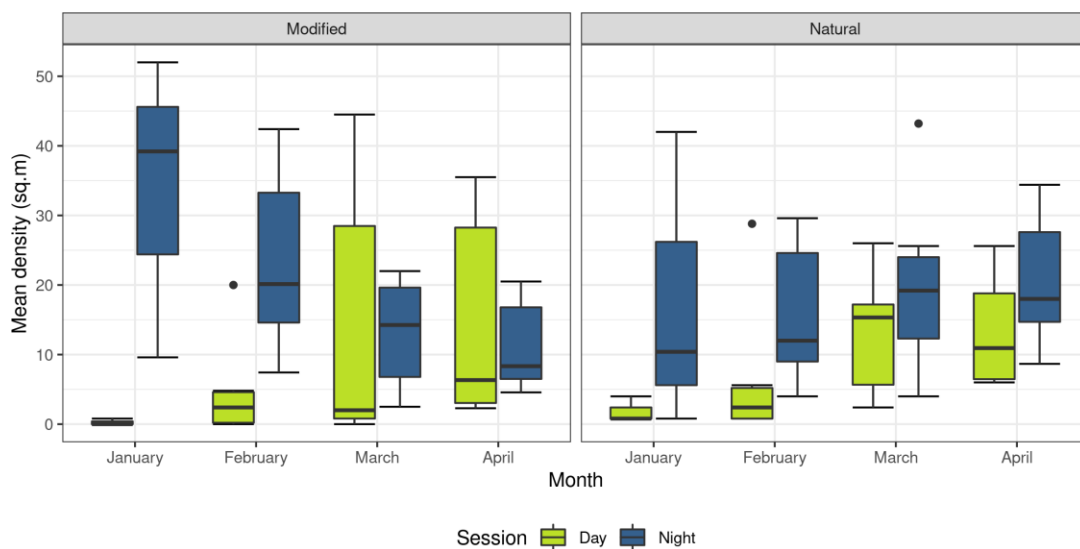


Figure 15: Monthly and diurnal variation in mean tadpole density averaged across sampling sessions.

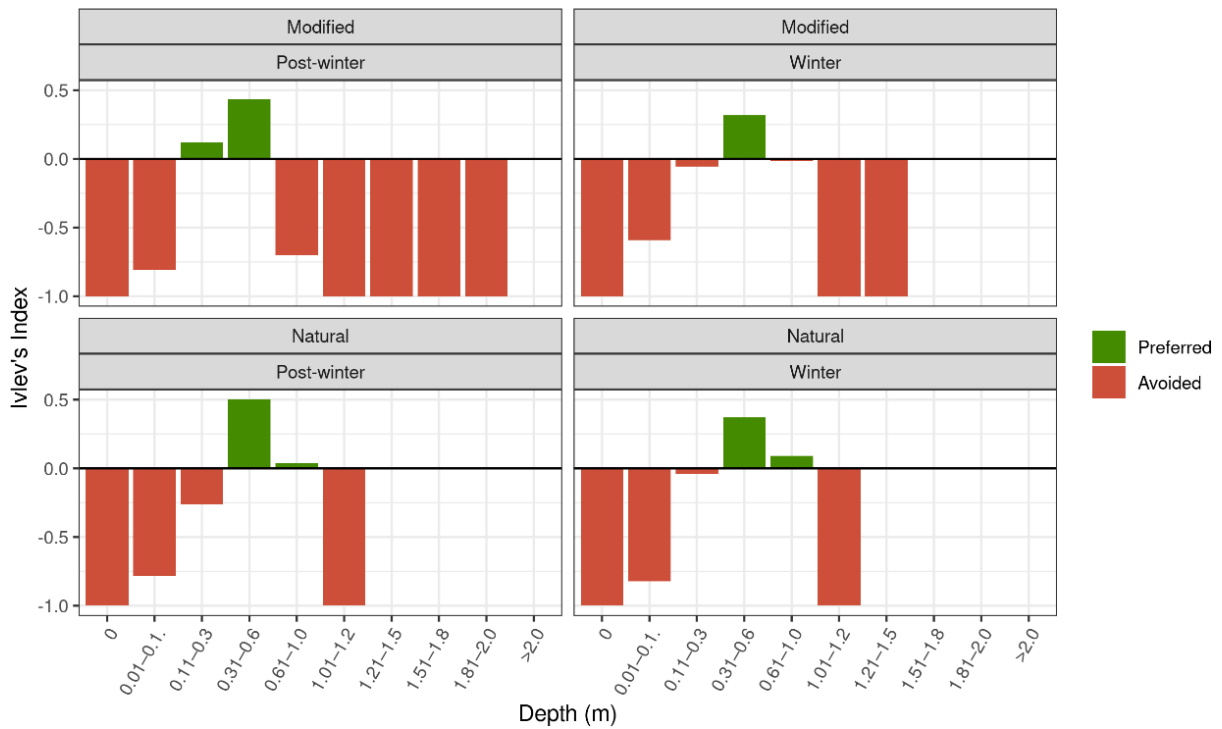


Figure. 16: Avoidance and preference of different classes of water depth by the overwintering tadpoles across seasons and pool types

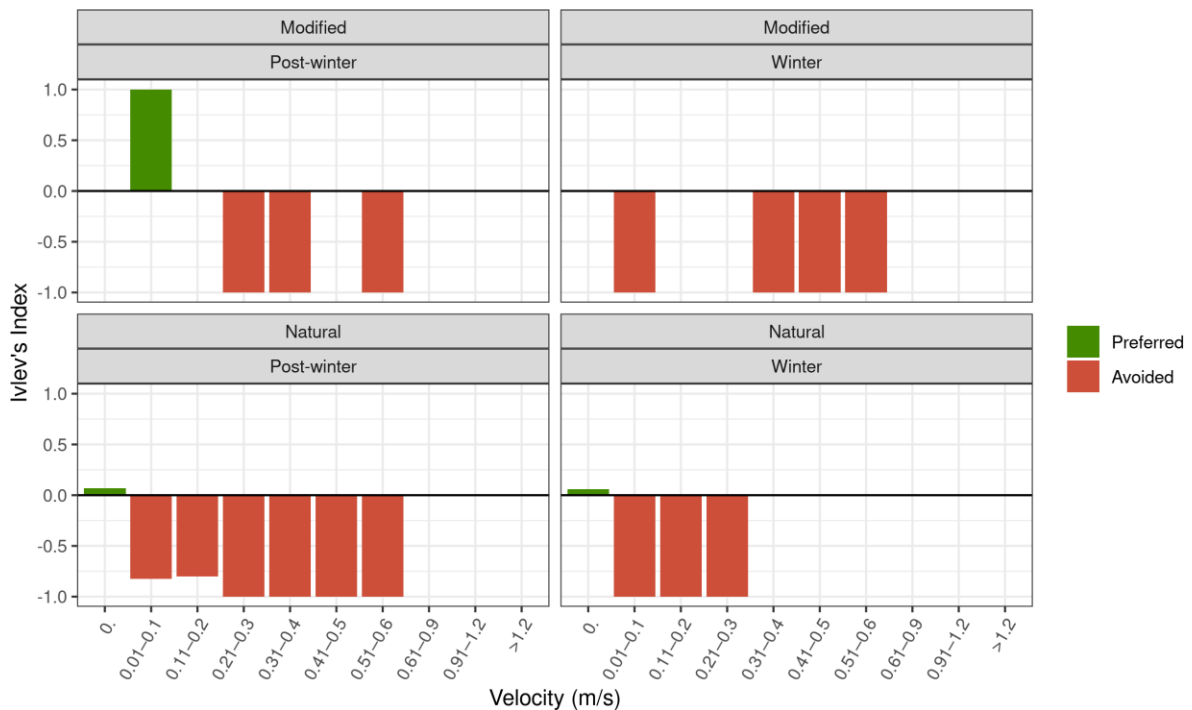


Figure. 17: Avoidance and preference of different classes of water velocity by the overwintering tadpoles across seasons and pool types

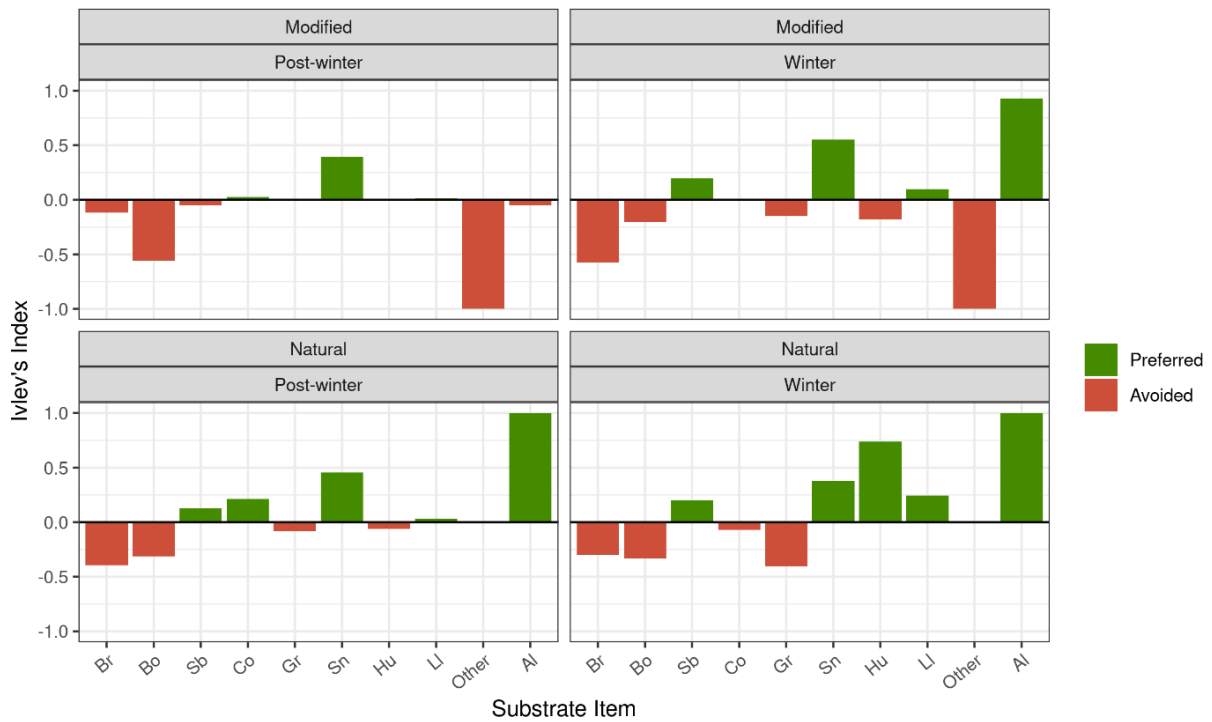


Figure. 18: Avoidance and preference of different types of substrate items by the overwintering tadpoles across seasons and pool types.

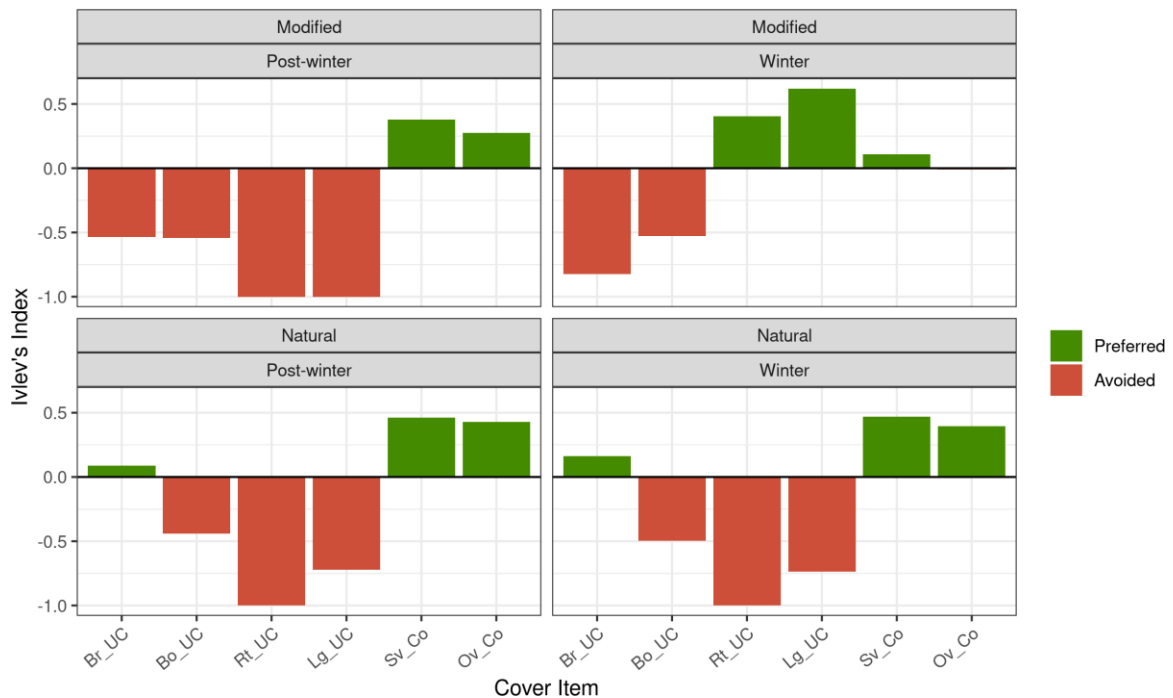


Figure. 19: Avoidance and preference of different types of cover items by the overwintering tadpoles across seasons and pool types



Photo 9: A tadpole of *Nanorana* sp.

3. DISCUSSION

The study showed the variation in tadpole densities at diurnal, and seasonal scales across natural and modified pools. The overwintering tadpole density was best predicted by time of the day, interaction of mean canopy covers with water temperature (negative influence); richness of cover items, mean canopy cover percentage, water temperature, leaf litter depth, velocity and an interaction of day of the time with pool modification (positive influence) (Jithin, 2021). The overwintering tadpoles in the study area can be good models for the assessment of the effect of climate change in the Himalayan region. Long-term research on the breeding biology of the focal species and larval response towards fluctuating temperature will be helpful in understanding the effect of global warming on amphibians in the montane areas. These tadpoles are generally found feeding on the algae grown on the bedrocks, boulders, cobbles, leaf litter surface and walls of modified pools, submerged log in pool. Generally, they are more active in night during winter, but the emergence pattern and activity varies with pool modification and season. The tadpoles are not very active during winter, and can be found resting on the streambed during both day and night. In daytime, they hide under leaf litter, or inside rocky crevices.

Larval ecology of *N. minica* and *N. vicina* are poorly known, and larval descriptions of varying levels of completeness have been reported (Das & Dutta, 2007). Banerjee et al. (2020) communicated *N. vicina* tadpoles feeding on the carrion of Himalayan Toad (*Duttaphrynus himalayanus*) adult. Gill et al. (2020a, b) described the larval morphology of *Nanorana vicina*

4. CONSERVATION PERSPECTIVE

Amphibians are very sensitive to the environment as well as their surroundings and any alterations or modification of their habitat can make them vulnerable to the extinction (Beirne et al. 2013). In the present study area, a significant portion of the amphibian habitat of the stream has been modified to create artificial pools and check dam. Check dams may have direct impact on *N. vicina* as they lay eggs under the tree roots and boulder undercut. Pools are important spawning sites for amphibians like *D. himalayanus*. Creating artificial pool may impact the natural flow of the stream and also likely to impact flow dependent species such as *A. formosus* and *A. jaunsari*. This perhaps a reason we found a smaller number of individuals during our study period (**Figure 13**). Being situated near a popular tourist destination Mussoorie, Binog attracts many tourists throughout the year. People coming for picnics, study tours, trekking groups often leave plastic wrappers, plates and bottles and other wastes in the stream water. These activities may negatively impact the stream ecology. Amphibians being anamniotes (eggs without shell), pollutants readily affect their growth. During our study we have recorded deformities in amphibian around the PA (Banerjee et al., 2020).

From reptile's perspective, their populations are suffering substantial global losses and roads are identified as one of the leading threats to their persistence. Although most road mortality studies have focused on mammals, vehicle collision is an important source of mortality to many species of reptiles (Rosen and Lowe, 1994). For example, in our study area a total of 3 roadkill of 3 species (*Gloydius himalayanus*, *Sibynophis collaris*, and *Boiga multifasciata*) were observed.

Thus, for the conservation of herpetofauna the integrity of their habitat should be maintained. For example, streams habitat should not be modified as amphibians are highly dependent on them and any modification can lead to the local extinction of these indicator species.

Involving local communities and forest department personnel towards the conservation of these lesser known and not-so-charismatic species is of great importance. Awareness and education

of local communities will change the perception of people towards these animals. This can be done through awareness workshops for school children and adults of the villages training workshops of forest personal in the basic identification of common amphibians and reptile species, destigmatizing the negative image associated mainly with snakes through coverage in local newspapers and TV channels.



Photo 10: A check dam in stream of BWLS.

5. MANPOWER TRAINED

5.1: Interns/ Forest personals

Student Name	Workshop / Project Title	Duration
Ayushi Jain	Herpetofaunal Inventory in and around Kedarnath Wildlife Sanctuary	April to June 2018
Swati Nawani	1. Herpetofaunal Inventory in and around Kedarnath Wildlife Sanctuary 2. Breeding Biology of " <i>Duttaphrynus himalayanus</i> "	June to August 2019 and January to June 2020
Deb Shankha Goswami	Spatial Ecology of Himalayan Torrent frog	April to Oct 2019
Aastha Saini	Spatial Ecology of Himalayan Torrent frog	June to Aug 2019
Krishnendu Banerjee	Spatial Ecology of Himalayan Torrent frog	July to September 2019
Shruti Arora	Spatial Ecology of Himalayan Torrent frog	1 sept to 30 sept 2019
Siddharth Rajmohan	Spatial Ecology of Himalayan Torrent frog	Sep to Oct 2019
Jithin Vijayan	Ecology of tadpoles of genus <i>Nanorana</i>	Jan to June 2021
Shanul Nautiyal-	Habitat ecology of tadpoles of <i>Duttaphrynus himalayanus</i> .	Feb to April 2021




Photo 11: MSc batch students during a field training under the project in Binog Wildlife Sanctuary



Photo 12: Forest personals during World forestry day.

6. PUBLICATIONS

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Systematic status of the rare Himalayan wolf snake *Lycodon mackinnoni* Wall, 1906 (Serpentes: Colubridae)

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Abstract

Lycodon mackinnoni is a poorly known Himalayan endemic snake known from Western Himalaya. Since the original description of *L. mackinnoni* almost 112 years ago, this species was not reported from its type locality and its phylogenetic position remain unknown. We herein, provide detail morphological description, comparison with type material, phylogenetic relationship with its congeners and new natural history information.

Key words: Colubrids, DNA, Himalayas, *Lycodon*, rediscovery, taxonomy

Introduction

Lycodon Boie 1826, is a genus of family Colubridae commonly known as “Wolf Snakes” due to their strongly arched maxillary bone (Smith 1943). The genus has a broad distribution from Central Asia, Eastern Iran to Southern and eastern China, Japan, in southwards across the entire Indo-Chinese Peninsula, Indo-Australian Archipelago and Philippines (Lanza 1999, Guo *et al.* 2013). It is one of the most speciose Asiatic snake genera represented by 66 species globally, out of which, 19 species are currently reported from India (Uetz *et al.* 2021).

Mackinnon’s Wolf snake, *Lycodon mackinnoni* was described by Wall (1906) from Mussoorie, Uttarakhand, India, based on a collection by Mr. Philip W. Mackinnon, a plant collector from Mussoorie during the colonial period. Subsequently, the species was also reported from Almora and Mukteshwar (Smith 1943), Doda, Jammu and Kashmir (Manhas *et al.* 2015), Bagh Azad Kashmir, Pakistan (Faiz *et al.* 2018; Jablonski *et al.* 2019; Lal *et al.* 2019).

During our field surveys in Binog Wildlife Sanctuary (BWLS) in 2019 we have come across one topotypic specimen of *L. mackinnoni* after 112 years (Fig. 1). Herein, we provide additional description along with phylogenetic information of the species based on this topotypic material.

Materials and methods

We hereby provide morphological and meristematic data for the freshly collected specimen and compared it with the type specimen (BMNH 1946.1.13.81). The new specimen was formalin fixed, washed and stored in 70% ethanol and housed in the museum of Wildlife Institute of India (WII-ADR197) on 21 May, 2019. Catalogue numbers for voucher specimen bear following prefix; BMNH (The Natural History Museum London, United Kingdom), WII-ADR (Wildlife Institute of India, Dehradun, India; Abhijit Das Reptile collection).

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Black-bellied Coral Snake *Sinomicrurus nigriventer* (Wall, 1908) (Elapidae): an extended distribution in the western Himalaya, India

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The Indian Himalaya region (IHR) is bestowed with rich and endemic biodiversity (Pandit et al. 2007). It is broadly categorized into the western Himalaya, central Himalaya, and northeastern Himalaya (Nautiyal et al. 2005). The western Himalayan region has a unique topography, great variation in altitude and a broad range of vegetational and faunal diversity. The region serves as home for a variety of endemic and threatened fauna (Maikhuri 2018). Nested in the western Himalaya, the state of Uttarakhand possesses a distinct identity of its natural ecosystems, which supports a remarkable diversity of fauna, including at least 72 species of reptiles and amphibians (Vasudevan & Sondhi 2010). Interestingly, several studies on snake ecology have been conducted in the world, but a comprehensive understanding in terms of range distribution and population biology of many snakes is still deficient (Mullin & Seigel 2009).

Coral snakes are a large group of elapid snakes (Döring 2020), which are venomous but commonly less involved in envenomation (Richardson & Little 2012). Generally, elapid snakes are fossorial and show solitary behaviour (Döring 2020). Currently, 107 species

of coral snakes belonging to five genera are recognized in the world, most of them (~76%) being found in the New World (Uetz et al. 2020). India is home to seven coral snake species (Whitaker & Captain 2004; Smith et al. 2012; Mirza et al. 2020), of these *Sinomicrurus maclellandi* (Reinhardt, 1844) was considered to have a wide distribution across the Himalaya, the northeastern hills, and adjoining countries, represented by at least five distinct 'colour forms' (Smith 1943).

The Black-bellied Coral Snake was initially described by British naturalist Col. Frank Wall as a variety of the Maclelland's Coral Snake *Sinomicrurus maclellandi*; however, in a recent study, Mirza et al. (2020) rediscovered this snake from Himachal Pradesh and compared it with existing museum specimens of *Sinomicrurus* spp. Based on morphological and molecular data, the authors concluded that *Sinomicrurus nigriventer* (earlier considered as a variety of *Sinomicrurus maclellandi*) deserves to be considered a distinct species.

Until now, *S. nigriventer* was only known to occur from Solan District (Kasauli and Nairani localities) of Himachal Pradesh, the western Himalaya (Wall 1908; Mirza et al. 2020). The current communication reports

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Short Note

First Record of Carrion Feeding by Tadpoles of *Duttaphrynus himalayanus* and *Nanorana vicina* from Western Himalaya, India

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Scavenging by anuran larvae were documented in some species such as *Bufo cognatus* (on insect remains and dead animal matter)¹, *Rhinella crucifer* (on carcass of an adult *Hypsiboas faber*)², *Osteopilus septentrionalis* (on insect carcasses)³ and *Polypedates megalcephalus* (on an unidentified toad)⁴. Among Indian amphibians, carcass feeding behaviour have been so far documented in tadpoles of *Duttaphrynus melanostictus*⁵, *Minervarya* sp. (on *Duttaphrynus* sp.)⁶ and *Hoplobatrachus tigerinus* (on tadpoles of *Duttaphrynus stomaticus* and *Microhyla ornata*, fishes, earthworms, bugs etc.)^{7,8}. Indirect evidences of scavenging by the tadpoles (i.e. *Duttaphrynus melanostictus*, *Microhyla ornata*, *Fejervarya limnocharis*, *Fejervarya orrissaensis*, *Polypedates maculatus*, *Leptobranchium smithi* and *Euphlyctis cyanophlyctis*) have been also reported from gut content analyses^{9,10,11}. In this communication, we report observations of carrion feeding by tadpoles of *Nanorana vicina* and *Duttaphrynus himalayanus* (Fig. 1) from Benog Wildlife Sanctuary (30.4685°N, 78.0231°E, 1684 m elev., WGS84), Mussoorie, Uttarakhand, India. The voucher photographs (Fig. 1) have been deposited at Zoological Reference Collection of the Lee Kong Chian Natural History Museum, National University of

Singapore (ZRC) and are cataloged as ZRC(IMG) 1.191.

The tadpoles of *N. vicina* were identified by the combination of the characters such as medium sized and dorsoventrally compressed body, snout rounded, eyes dorsally placed, tail tip rounded, dorsum dull greenish-brown, tail greenish-grey^{12,13}. The tadpoles of *D. himalayanus* which is the only toad species occur in the study area¹⁴ and can be easily distinguished by their flattened head, small and sunken eyes, dark brown to black body colour^{13,15}.

First observation on *D. himalayanus* tadpoles feeding on carcass of *D. himalayanus* was carried out on 11th May 2019, at 1230hrs in a pool section of a perennial stream (Fig. 1A). Of our almost 50minutes of observation, we noticed around 10-15 tadpoles were scavenging on the carrion from the large school (spreading over 3m diameter area) gathered over there. While, the second occasion of carcass feeding by *N. vicina* tadpoles feeding on carcass of *D. himalayanus* was observed on 19th July 2019, at 2320hrs in a run section of the same stream approximately 500 m upstream from the previous observation site (Fig. 1B). We observed the tadpoles nibbling on the soft part of the carcass for almost 60 mins. We noticed that around 6-10 tadpoles (of the school spreading over an

A New Item in the Diet of the Kashmir Rock Agama (*Laudakia tuberculata*)

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The Kashmir Rock Agama (*Laudakia tuberculata*) is a saxicolous lizard with a distribution that ranges from eastern Afghanistan across northern Pakistan and India to Nepal and the Tibetan Plateau at elevations of 310 m to at least 5,000 m in the western Himalayas (Minton 1966; Khan 2006). Its diet has been reported to include both plant and animal matter (Waltner 1991; Eremchenko and Kästle 2002). Minton (1966) reported insects taken by juveniles, which is suggestive of an ontogenetic dietary shift as has been reported in many ecologically similar large herbivorous lizards, including congeners (see Waltner 1991).

Bashir et al. (2009) examined the natural diet and reported both animals and plants in the diet of the species; plants included *Brassica oleracea* var. *acephala* (Kale), *B. oleracea* var. *capitata* (Cabbage), *Solanum lycopersicum* (Tomato), *Lactuca serriola* (Prickly Lettuce), *Cynodon dactylon* (Bermuda Grass), *Trifolium repens* (White Clover), *Morus alba* (White

Mulberry), and *Ficus carica* (Common Fig). Additionally, Lal (1991) noted that the species, presumably around cultivated areas, would feed on “tender leaves of pumpkin, squash, bottle gourd, brinjal, tomato, *Zinnia*, *Dahlia* and some forest plants in nurseries”; and Vishwakarma et al. (2019) described individuals of this species feeding on flowers of the naturalized Madagascar Periwinkle (*Catheranthus roseus*) in a tropical moist dry deciduous forest.

At around 1430 h on 29 July 2019, we videographed an adult Kashmir Rock Agama on a rock at the edge of a road (Fig. 1) surrounded by *Eupatorium* sp. (Asteraceae) and Panicked Foldwing (*Dicliptera* aff. *paniculata*) (Acanthaceae). The lizard was feeding on leaves of the latter, a species that had not been recorded in the diet of *L. tuberculata*. The locality is adjacent to human habitations outside Benog Wildlife Sanctuary (30.480126°N, 78.036475°E; WGS84), Uttarakhand, India. The video footage was accessioned into the Zoology Research Collection (ZRC) of the National Museum of Singapore as ZRC [IMG] 2.462.

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Fig. 1. An adult Kashmir Rock Agama (*Laudakia tuberculata*) feeding on the leaves of Panicked Foldwing (*Dicliptera* aff. *paniculata*) (Acanthaceae) outside the Benog Wildlife Sanctuary, Uttarakhand, India. Photograph by Swati Nawani.

Edema in a Himalayan Toad, *Duttaphrynus himalayanus* (Günther 1864) (Anura: Bufonidae)

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Unlike a tumor, which is an abnormal growth of tissue resulting from excessive cell division, an edema is an externally visible disorder characterized by the subcutaneous or intracellular accumulation of fluid or bloating of the body from excessive gas production (Henle et al. 2017a). Edemas, frequently encountered in amphibian tadpoles, are less common in metamorphs (Henle et al. 2017a), although they have been observed in adult Ezo Brown Frogs (*Rana pirica*), Firebellied Toads (*Bombina bombina*), European Green Toads (*Bufo viridis*), Common European Toads (*Bufo bufo*), Moor Frogs (*Rana arvalis*), Pacific Treefrogs (*Pseudacris* [= *Hyla*] *regilla*), and others (Henle et al. 2017b). Temperature shock, high light intensities, and experimental infestations of parasites such as trematodes (e.g., *Ribeiroia ondatrae*) and Blowfly (*Lucilia bufonivora*) maggots also are known to induce edemas in amphibians (Johnson et al. 2001; Kidov 2010; Henle et al. 2017b). In natural conditions, such deformities have been linked to chemical contamination, aberrations at the genetic level, radiation, nutritional deficiencies, and pathogens, such as viruses, bacteria, and fungal infections (Henle et al. 2017b).

At 0822 h on 13 October 2017, we encountered an adult Himalayan Toad (*Duttaphrynus himalayanus*) (SVL 81.6 mm) in the Benog Wildlife Sanctuary, Mussoorie, Uttarakhand, India (30.4685°N, 78.0231°E; WGS84; elev. 1,685 m asl) with an edema emanating from its right flank and extending into the axilla and groin (Fig. 1). The edema was 39.2 mm in length, almost half of the snout–vent length of the toad. The specimen was collected, preserved, and deposited in the laboratory of the Wildlife Institute of India (WII/ADA-731), and a digital voucher was accessioned in the Lee Kong Chian Natural History Museum, National University of Singapore (ZRC[IMG] 1.188). The edema was confirmed by dissection; it was devoid of any tissue growth and contained only extracellular fluid. This toad also exhibited adactyly (congenital lack of digits), a type of ectrodactyly (partial or complete absence of one or all digits or shortening of the digits; Henle and Dubois

2017) on its right forelimb. This is the first report of such an edema in an anuran amphibian from India.

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Fig. 1. Dorsal and ventral views of a Himalayan Toad (*Duttaphrynus himalayanus*) from the Benog Wildlife Sanctuary, Mussoorie, Uttarakhand, India, with an edema on its right flank. Adactyly or ectrodactyly on the right forelimb is indicated by an arrow. Photographs by Abhijit Das.



Cirsium wallichii DC. (Asteraceae): a key nectar source of butterflies

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In general, both larvae and adult butterflies depend on plant resources (Kitahara et al. 2008; Nimbalkar et al. 2011). Adult butterflies forage on a wide variety of plant species for floral nectar (Courtney 1986; Raju et al. 2004). Butterflies, however, do not collect nectar extensively from all the available flowers (Kunte 2000). Thus, the diversity of the butterfly community of a region is associated with the availability of host plants (Murphy & Wilcox 1986; Kitahara et al. 2008). Also, the diversity and abundance of pollinators such as butterflies are crucial for the reproductive success of flowering plants (Mukherjee et al. 2015). Several wild plants considered as weeds serve as important nectar sources for butterflies (Mukherjee et al. 2015; Kapkoti et al. 2016). One such wild weed, *Cirsium* Mill. (Thistle) of the family Asteraceae has been well recognized as a nectar source of butterflies (Robertson 1928; Tooker et al. 2002; Kapkoti et al. 2016). *Cirsium* is a speciose genus of Asteraceae, with about 200 species distributed in Europe, Asia, North & Central America, and northern Africa (Mabberley 2008; Sahli et al. 2017). Among the species of this genus known from India, *Cirsium wallichii* DC. has been extensively used as a traditional medicinal plant in the Himalaya (Uniyal et al. 2011). Interestingly,

owing to a lack of information on *Cirsium wallichii* DC. as a nectar source of butterflies, the current communication aims to address the value of Wallichii's Thistle not only as a weed, but also as a nectar source of butterflies.

The present study was conducted from May to August, 2019 in Benog Wildlife Sanctuary (30.467°N & 78.027°E), Mussoorie, Uttarakhand, India. The sanctuary is characterized by Banj Oak *Quercus leucotrichophora* forests, Chirpine *Pinus roxburghii* forests and grasslands (Champion & Seth 1968) which harbour at least 335 species of vascular plants (Kumar et al. 2012). The survey was done between 08.00h and 11.00h to record the butterfly species visiting *Cirsium wallichii*. We photographed representatives of each butterfly species from the area. Based on the photographs, identification of the species was carried out using Evans (1932) and Kehimkar (2016).

Cirsium wallichii grows along open and modified stream habitats in the sanctuary as well as near human settlements and agricultural lands at the peripheral area (Image 1A). Leaves are stalkless and pinnately lobed with long spines at the margin. The plant blooms from May–July. Capitula are many-flowered, solitary or clustered and borne on leafless stalks. They are 2–3.4cm

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N = 0 14 7 3

that separated the shoreline and floating islands. Reproductively active males were not observed on the shoreline, which is consistent with previous work suggesting that males migrate to deeper water during the reproductive season (Lamb 1984, *op. cit.*).

Males in our study called exclusively from islands of vegetation in the center of the marsh's waterway which corroborated previous observations on the oviposition sites of *L. gryllio* (Wright 1932, *op. cit.*). In other species, male call site occupancy and territory defense is a predictor of oviposition site (Wells 1978, *op. cit.*). Though territoriality has never been directly observed in *L. gryllio*, studies have hypothesized that this species defends call sites (Lamb 1984, *op. cit.*). Our study shows that the call site occupancy of calling male *L. gryllio* mirrors that of other territorial ranids.

In the future, attention should be paid to the behavior of the non-calling males positioned in the open water microhabitats. These males exhibit smaller body size and lower body condition than the calling males in the vegetation (Walkowski et al. 2019, *Copeia* 107:509–516). In other anurans, low body condition is a predictor of alternative reproductive tactics, like satellite or gauntlet behavior (Gerhardt et al. 1987, *Anim. Behav.* 35:1490–1503; Krupa 1989, *Anim. Behav.* 37:1035–1043; Forester and Thompson 1998, *Behaviour* 135:99–119). Both behavioral strategies involve the interception of a gravid female by a non-calling male. Our study did not record an instance of female interception, but microhabitat occupancy suggests that females must travel from the shoreline past non-calling males in the open water to the islands of vegetation where calling males advertise.

All procedures performed in this study were approved by Southeastern Louisiana University's Institutional Animal Care and Use Committee (IACUC Protocol 0027). The Duane and Catherine Shafer Endowment funded parts of this research.

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MINERVARYA SP. PREDATION. At ca. 1500 h on 14 March 2019, we flipped a rock in a dry streambed at the Agumbe Rainforest Research Station (13.5193°N, 75.0956°E; WGS 84) in Agumbe, Karnataka, India, to find a tarantula feeding on a small frog (Fig.

1). The tarantula had already consumed the anterior portion of the frog and only the hind limbs and a portion of the torso were remaining. We took photographs to document the incident and then gently replaced the rock. The spider was identified as belonging to the subfamily Eumenophorinae (Araneae: Theraphosidae) and the frog was identified as belonging to the genus *Minervarya* (synonymous with *Zakerana* and *Fejervarya*; Dinesh et al. 2015, *Zootaxa* 3999:79–94) due to the presence of "fejervaryan lines" on the venter. Many arthropods have been reported to predate small vertebrates such as frogs and lizards (McCormick and Polis 1982, *Biol. Rev.* 57:29–58). Frog predation by mygalomorph spiders has been documented before (Butler and Main 1959, *West Austral. Nat.* 7:52; Kaston 1965, *Amer. Midl. Nat.* 73:336–356; Stewart 1985, *J. Herpetol.* 19:391–401), however, this observation represents the first report of a tarantula feeding on a *Minervarya* sp.

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NANORANA MINICA (Small Paai Frog). **DEFORMITY.** Morphological abnormalities among amphibians are attributed to chemical contamination, UV-B radiation, predation, and parasitic infections such as the trematode *Ribeiroia ondatrae* (Blaustein and Johnson 2003, *Front. Ecol. Environ.* 1:87–94). Several reports on anuran abnormalities such as polymely, ectrodactyly, ectromely, polydactyly, swollen digits, anophthalmia, and edema have been documented in *Limodynastes tasmaniensis*, *Leptodactylus chaquensis*, *Lithobates pipiens*, *L. sylvaticus*, *Pelodytes saharicus*, *Pseudacris regilla* and in many other anuran species from different parts of the world (Henle et al. 2017, *Mertensiella* 25:57–164). Among Indian amphibians several reports of abnormalities have been recorded in frogs like *Hoplobatrachus tigerinus* (Kurulkar and Deshpande 1932, *J. Bombay Nat. Hist. Soc.* 35:462), *Fejervarya* sp., *E. limnocharis*, *Euphylyctis hexadactylus*, *Hyla annectans*, *Amolops gerbillus*, *Polypedates* sp. (Mathew and Sen 2006, *Cobra* 63:6–10), *Indirana beddomii*, *Minervarya rufescens* (Nair and Kumar 2007, *Froglog* 13:10–11). Ectrodactyly has been frequently reported in microglossid frogs (Gurushankara et al. 2007, *Appl. Herpetol.* 4:39–45) mainly from coffee plantations, water bodies near industries, and agricultural paddy fields.

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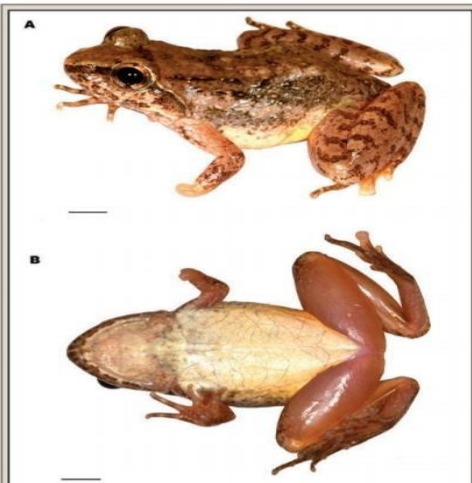


FIG. 1. *Nanorana minica* with adactyly in the left forelimb and swollen fourth toe in the left hindlimb (scale bar = 5 mm).

On 12 September 2019 at 2200 h we photographed one *Nanorana minica* with a deformed left forelimb and swollen fourth digit on the left hindlimb (Lee Kong Chian Natural History Museum, National University of Singapore [ZRC(IMG)] 1.187; 40.79 mm SVL; Fig. 1) in Benog Wildlife Sanctuary, Mussoorie, India (30.4685°N, 78.0232°E; WGS 84; 1660 m elev.). The individual was located in a grass bed 10 m from a natural stream within a forested area. The forelimb deformity, adactyly, is a specific form of ectrodactyly characterized by a partial or complete absence of one or all digits. The hindlimb deformity can be caused by a thickening of the musculature or the epidermis of the digit (Henle et al. 2017, *op. cit.*). This is the first report of limb deformities in *N. minica* and the first report for the genus *Nanorana* from forested habitat.

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ODONTOPHRYNUS MAISUMA. HINDLIMB MALFORMATION. Many records of amphibian malformations in Brazil have been documented (Ferreira et al. 2014, *Herpetol. Rev.* 45:307;

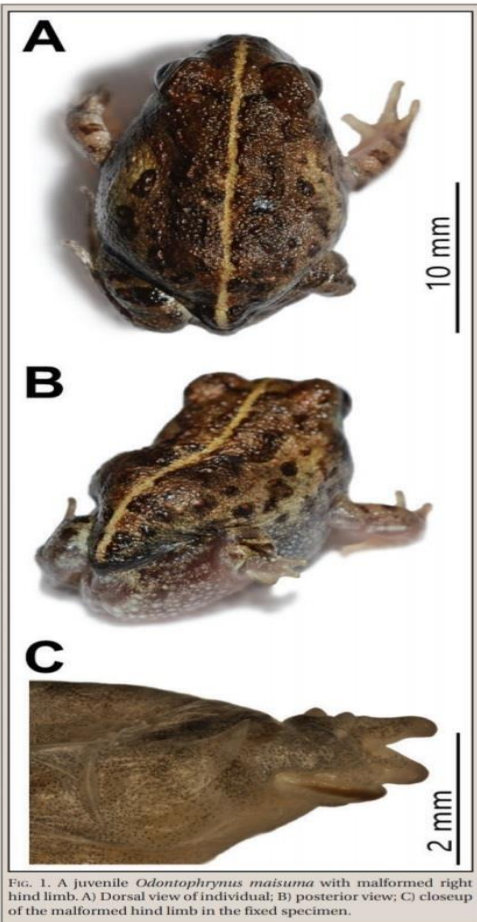


FIG. 1. A juvenile *Odontophrynus maisuma* with malformed right hind limb. A) Dorsal view of individual; B) posterior view; C) closeup of the malformed hind limb in the fixed specimen.

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First Record of Interspecific Amplexus between a Himalayan Toad, *Duttaphrynus himalayanus* (Bufonidae), and a Himalayan Paa Frog, *Nanorana vicina* (Dicroglossidae), from the Western Himalaya of India

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Interspecific amplexus in amphibians has been reported among taxa belonging to different orders (Moldowan et al. 2013; Simović et al. 2014), families (e.g., Sodr  et al. 2014; Theis and Caldart 2015; Melo-Sampaio and Da Silva 2017), and genera (e.g., Groffen et al. 2019; Pedro and Nali 2020). In India, interspecific amplexus has been reported previously between the Nicobar Island Frog (*Indosylvirana nicobariensis*) and Berdmore’s Narrow-mouthed Frog (*Microhyla berdmorei*)

(Decemson et al. 2020); Anamalai Dot Frog (*Uperodon anamalaiensis*), Terrestrial Frog (*Fejervarya* sp.), and Anamallais Indian Frog (*Indirana brachytarsus*) (Harpalani et al. 2015); Malabar Gliding Frog (*Rhacophorus malabaricus*) and Common Indian Treefrog (*Polypedates maculatus*) (Sayyed 2013); Malabar Tree Toad (*Pedostibes tuberculosus*) and Asian Common Toad (*Duttaphrynus melanostictus*) (Sayyed and Nale 2017); Kalakkad Treefrog (*Rhacophorus calcadensis*) and



Fig. 1. Fully (left) and partially submerged (right) interspecific amplexus between a male Himalayan Toad (*Duttaphrynus himalayanus*) and an adult Himalayan Paa Frog (*Nanorana vicina*) of unknown sex in the Binog Mountain Quail Wildlife Sanctuary, Uttarakhand, India. Photographs by V. Jithin.

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Appendix. 1

Herpetofauna recorded during survey in both Protected Areas.

Scientific name	Common Name	IUCN status	KWLS	BWLS
<i>Duttaphrynus melanostictus</i>	Common Asian Toad	LC	✓	✗
<i>Duttaphrynus himalayanus</i>	Himalayan Toad	LC	✓	✓
<i>Amolops formosus</i>	Beautiful Cascade Frog	LC	✓	✓
<i>Amolops jaunsari</i>	Jaunsar cascade frog	DD	✗	✓
<i>Megophrys cf. parva</i>	Mountain Horned Frog	LC	✓	✗
<i>Nanorana minica</i>	Dubois' Frog	VU	✓	✓
<i>Nanorana vicina</i>	Stoliczka's Frog	LC	✓	✓
<i>Sphaerotheca</i> sp.	Burrowing Frog	-	✓	✗
<i>Fejervarya</i> sp.	Cricket Frog	-	✓	✗
<i>Euphlyctis cyanophlyctis</i>	Indian Skipping Frog	LC	✓	✗
<i>Herpetoreas platyceps</i>	Himalayan Mountain Keelback	NA	✓	✓
<i>Boiga multifasciata</i>	Many Banded Cat Snake	DD	✓	✓
<i>Fowlea piscator</i>	Checkered Keelback	NA	✓	✗
<i>Gloydius himalayanus</i>	Himalayan Pit Viper	NA	✓	✓
<i>Sibynophis collaris</i>	Collared black headed snake	LC	✗	✓
<i>Lycodon mackinnoni</i>	Mackinnoni wolf snake	NA	✗	✓
<i>Oligodon arnensis</i>	Common kukri snake	NA	✗	✓
<i>Ptyas mucosa</i>	Common rat snake	NA	✗	✓
<i>Othriophis hodgsonii</i>	Himalayan trinket snake	NA	✗	✓
<i>Asymblepharus himalayanus</i>	Himalayan Rock Skink	NA	✓	✓
<i>Laudakia tuberculata</i>	Himalayan Rock Agama	NA	✓	✓
<i>Japalura kumaonensis</i>	Kumaon Rock Agama	NA	✓	✓
<i>Eurylepis cf. taeniolata</i>	Ribbon sided skink	NA	✗	✓
<i>Calotes versicolor</i>	Common garden lizard	NA	✗	✓

Appendix. 2

Tracking History of Radio telemetry (“*”, tags used on multiple individuals)

Individual ID	Transmitter frequency	Weight	Date of tagging	No. of Tracking days	Tag recover/lost
NVU1	150.435	140	11.05.2019	91	Recovered
NVU2	150.365	145	11.05.2019	86	Recovered
NVU3	150.135	135	16.07.2019	84	Recovered
NVU4	150.215	125	16.07.2019	68	Recovered
NVU5	150.035	125	16.07.2019	92	Recovered
NVU6	150.175*	115	2. 09. 2019	26	Recovered
NVD1	150.406	150	19.05.2019	45	Recovered
NVD2	150.466*	170	19.05.2019	86	Recovered
NVD3	150.394*	160	28.05.2019	68	Recovered
NVD4	150.096*	155	16.07.2019	49	Recovered
NVD5	150.175	190	16.07.2020	13	Recovered
NVD6	150.394	115	08.08.2020	78	Recovered
NVD7	150.295	170	08.08.2020	78	Lost
NVD8	150.175	150	04.09.2019	52	Lost
NVD9	150.096	180	05.09.2019	51	Lost
NVD10	150.466	190	05.09.2020	51	Lost



Photo 13: Amphibians of selected PAs. Top left: *Amolops formosus*, Top right: *Amolops jaunsari*, Middle left: *Nanorana minica*, Middle right: *Megophrys cf. parva*, below left: *Nanorana sp.*, Below right: *Duttaphrynus himalayanus*



Photo 14: Reptiles of selected PAs. Top left: *Othriophis hodgsoni*, Top right: *Herpetoreas platyceps*, Middle left: *Japalura kumaonensis*, Middle right: *Eurylepis cf. taeniolata*, below left: *Boiga multifasciata*, Below right: *Lycodon mackinnoni*



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