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Impact of Roads on Indian amphibians - A review

Abstract

Habitat alterations at landscape level impacts small and declining population paradigm in conservation biology. Roads are major cause of fragmentation and degradation of natural habitats and detrimental to wild flora and fauna worldwide. A highly seasonal activity in amphibians that involves adult migration and juvenile dispersal makes them vulnerable to road related mortality. Anamniotic eggs, semi permeable skin and mating strategies that depend on acoustics makes amphibians particularly sensitive to pollution. Direct and indirect impacts of roads on amphibian population may lead to catastrophic decline and extinction. In Indian context such impacts are poorly known. This article reviews the impacts of road on amphibians from Indian perspective and flags the need for effective mitigation strategies to minimize such loss.

Key words: *Roads, Indian amphibians, road mortality, amphibian decline, mitigation*

Introduction

Road system, from the earliest times, is one of the strongest indicators of a society's level of development. With the increase in human population, roads became the back bone of economic growth and social development of any country. India, currently represents the second largest road system in the world (ca 5.2 million km), after the United States of America (National Highways Authority of India, http://www.nhai.org). On the other hand India holds a unique global position in terms of its biodiversity and is counted among 17 megadiverse countires of the world (Myers et al. 2000). Here development comes in conflict with diversity. Studies show that roads promote panoply of negative effects on biodiversity (Forman & Alexander 1998; Forman et al. 2003; van der Ree et al. 2015), continually creating conflicts of disagreement between human well-being and biodiversity and conservation (Laurance & Balmford 2013; Laurance et al. 2014).

India represents almost 5% of total amphibian diversity of the world with 417 species (376 anurans, 2 Salamanders, 39 caecilians (AmphibiaWeb. 2017, http://amphibiaweb.org) 56 % of Indian amphibians are endemic. Most of the Indian amphibian diversity lies in four of the world's biodiversity hotspots (Myers et al. 2000); Western Ghats and Sri Lanka (Western Ghats), Himalaya (Indian Himalaya), Indo-Burma (parts of North east India) and Sundaland (Nicobar Islands) (Pande & Arora 2014). With the increasing discovery of new amphibian species every year, we are contemporaneously facing ecological crisis of amphibian decline. Causes of amphibian decline such as habitat destruction, introduction of exotic predators and competitors, pollution from pesticides, acid precipitation, increased

Fig 1. *Duttaphrynus melanostictus* is one of the most frequently killed amphibian on Indian roads.

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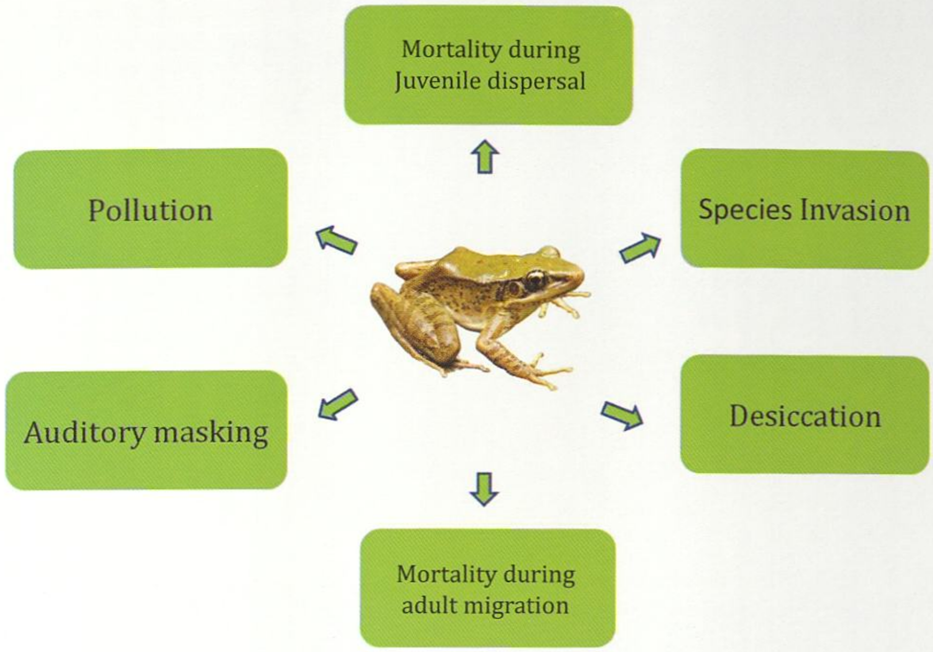


Fig 2. Schematic representation of various threats (direct and indirect) to amphibians caused due to linear barriers.

levels of ultraviolet radiation, consumption by humans, and climate change have been documented (Elmberg1993; Blaustein et al. 1994; Pounds & Crump 1994; Stuart et al. 2004).

Roads are also found to cause decline, local disappearance, unequal sex ratio, growing genetical distance in the vicinity of busy roads and behavioural changes (Oxley et al. 1974; Richardson et al. 1997; Wilkins 1982; DeMaynadier & Hunter 2000; Carr & Fahrig 2001; Vos et al. 2001; Houlahan & Findlay 2003; Andrews & Gibbons 2006) on animal populations.

Amphibians are proved to be the most frequently run over vertebrates on roads in different continents even if their proportion is often underestimated due to low detectability caused by low retention time and small size in comparison with the other taxa (Puky 2006; Puky et al 2007). Vehicular traffic causes negative effects on amphibian density (Fahrig et al. 1995) and the traffic-related mortality is highly detrimental, especially for species with small and declining populations (Spellerberg 1998). Beyond the 'on-road' mortality, the range and severity of indirect impacts of roads far exceed those incurred from direct mortality. Such impacts of linear infrastructures are poorly studied in Indian context and thus, information on impacts of roads on population and species level is hardly known.

Amphibia as a Vulnerable Group

Amphibians are one of the most threatened vertebrate groups on the planet (Hof et al. 2011). Frequently characterized by limited dispersal abilities, strong site fidelity and spatially disjunct breeding habitat, amphibians are suffering massive population decline (Duellman & Trueb 1986; Sinsch 1990; Blaustein et al. 1994; Beebee 1996; Berry 2001; Smith & Green 2005).

In Ecology, movement is a fundamental need for any species be it a plant or an animal (Nathan et al., 2008; Pittman et al., 2014). Population of any biological species can survive only if individuals can disperse (one directional movement) or migrate (going and coming back). Such spatio-temporal movements thus maintain species distribution, gene flow and individual fitness, which in turn advocate a healthy population dynamics (Clobert et al. 2001; Knowlton & Graham 2010; Mueller et al. 2011).

Physical connectivity between amphibian populations (Stevens & Baguette 2008) is crucial as it plays key role in their regional viability (Cushman 2006). Amphibians appears to be the most vulnerable group from road related impacts as roads not only cut through the human land use types but also slice through most of the ecosystem or habitat types in a landscape (Vermeulen & Opdam, 1995; Puky 2006). Thus, impact of roads are both direct (vehicular collision), and indirect (fragmentation) causing direct mortality and/or loss of connectivity between amphibian populations.

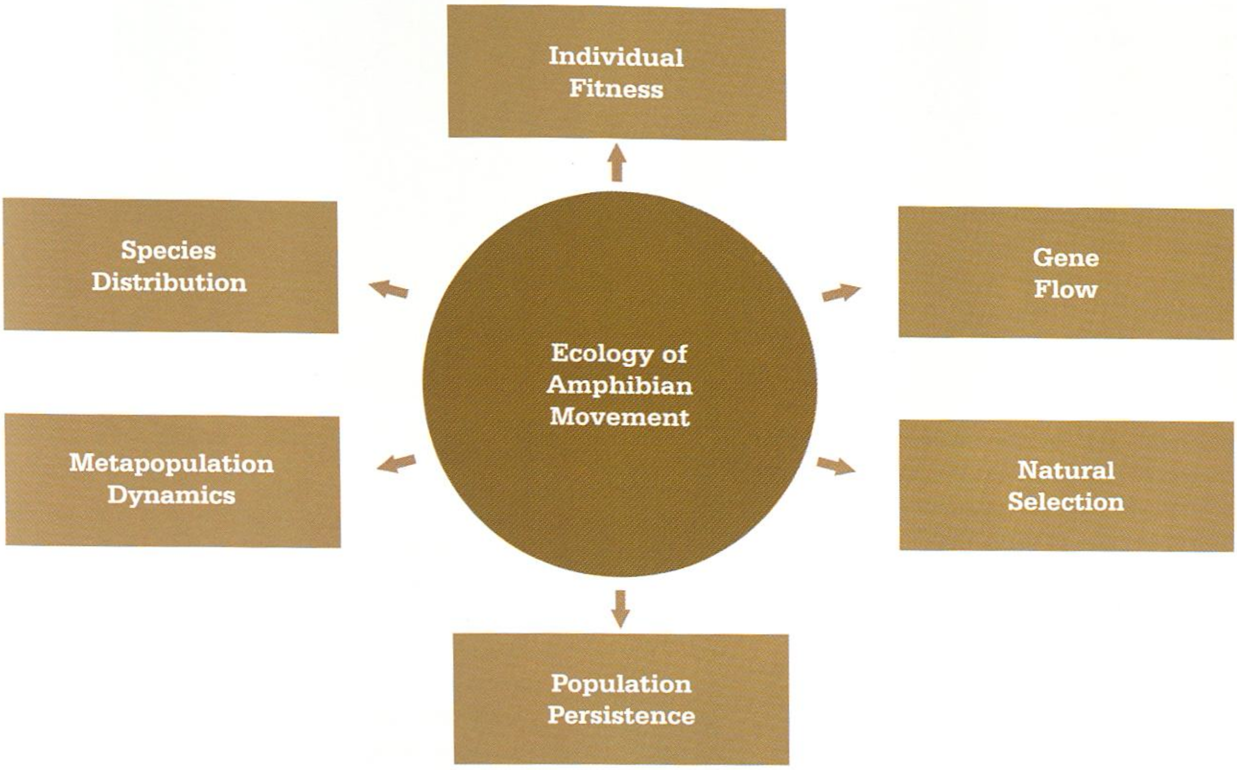


Fig 3. Schematic diagram explaining the importance of amphibian movement in a landscape.

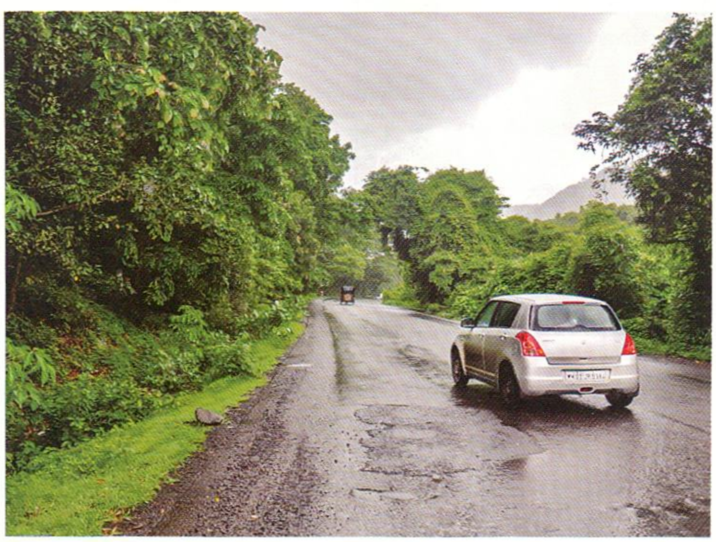
Ecological Effect of Roads on Amphibians

Globally, the studies on the ecological effects of roads on wildlife are quite prevalent and expanding rapidly (Nietvelt 2002). However, in India, the field of road ecology is gearing up and is relatively recent (Baskaran & Boominathan 2010; Gubbi et al. 2012; Joshi & Dixit 2012; Prakash 2012; Krishna et al. 2013; Rajvanshi et al. 2013).

Roads pose severe ecological impacts on individual organisms, populations, species, ecosystems and landscapes (Andrews 1990; Bennett 1993; Forman & Alexander 1998; Spellerberg 1998; Trombulak & Frissell 2000; Seiler 2001; Carr et al. 2002; Forman et al. 2003; Coffin 2007).

Road construction leads to the loss, fragmentation, and degradation of herpetofaunal habitats (Trombulak & Frissell 2000, Andrews et al. 2008), and thus once contiguous panmictic population suddenly converts to smaller isolated subpopulations (Corlatti et al. 2009). Direct mortality from vehicle collisions is the most immediate threat to population persistence (Puky 2006). Amphibian movement in particular is a multi phase process consisting of juvenile dispersal and adult migration (Pittman et al. 2014) which makes them susceptible to higher road mortality. To access spatially separated patches such as breeding site, foraging site and dispersal phase they need

Roads fragmenting wildlife habitat create impacts listed in Fig 2.



to cross roads in fragmented landscapes (Andrews et al. 2008). Their vulnerability is further increased by their relatively slow movement rates (Hels & Buchwald 2001), and many species become immobile in response to approaching vehicles (Mazerolle et al. 2005).

The highest rates of road mortality for amphibians occur where roads are located in the vicinity of a wetland or pond disrupting the spatial connectivity of essential resources and habitats across the landscape (Ashley & Robinson 1996; Dodd & Smith 2003). The studies of amphibian mortality due to roads are highest surveyed in Europe (Puky 2006; Puky 2003; Schmidt & Zumbach 2008). Mass movements triggered by rainfall and warm weather may result in excessive rates of road mortality for salamanders and anurans (Turner 1955; Clevenger et al. 2001)

Amphibian and reptile species often have restricted or patchy distributions and small effective population sizes. Little is known about the long-lasting ecological effects of roads on animal populations in terms of reduced mobility, increased isolation and/or splitting of gene pool. Roads may serve as barriers that restrict gene flow and decrease genetic diversity through a combination of direct mortality and inbreeding. In functionally-small populations, these effects may significantly increase inbreeding depression and increase the probability of local extinction (Rodriguez et al. 1996). Few studies have empirically documented genetic effects on herpetofauna due to roads, and few support the hypothesis that roads reduce gene flow and decrease genetic diversity in amphibians (Reh & Seitz 1990; Hitchings & Beebee 1998; Lesbarrès et al. 2003; Balkenhol & Waits 2009). A study investigated the land use and roads on the genetic structure of common frog (*Rana temporaria*) and found that separation by highways reduced the average amount of heterozygosity (genetic variation) in the population (Reh & Seiz 1990).

Fig 4: *Duttaphrynus melanostictus* killed while in amplexus

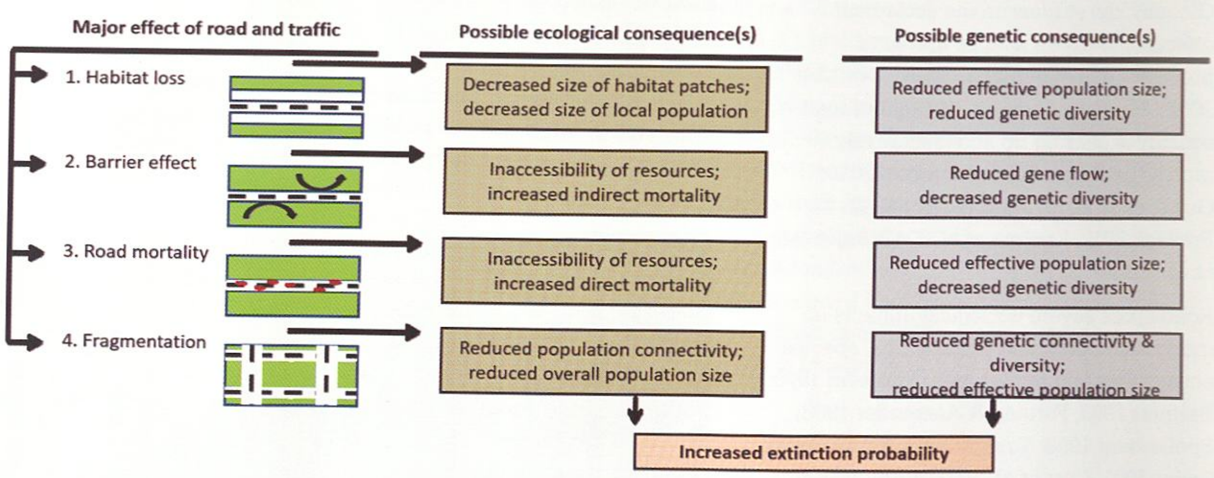


Fig 5: Flowchart explaining road impacts (left), their ecological (centre) and genetic (right) consequences. Adapted from Fahrig (2002) and Jaeger (2014). Modified from Balkenhol & Waits (2009).

Road ecology in Indian perspective

Road ecology is a hot topic in conservation biology. Enormous amount of literature deals with road related mortality on various taxa ranging from macro invertebrate soil fauna (Haskell 2000), herpetofauna (van Gelder 1973; Cooke 1995; Rosen & Lowe 1994; Fahrig et al. 1995; Haxton, 2000; Gibbs & Shriver 2002; von Seckendorff Hoff & Marlow 2002; Andrews & Gibbons 2005, Glista et al. 2008, Elzanowski et al. 2009 and Langen et al. 2009), birds (Mumme et al. 2000) and mammals (Laurance et al.

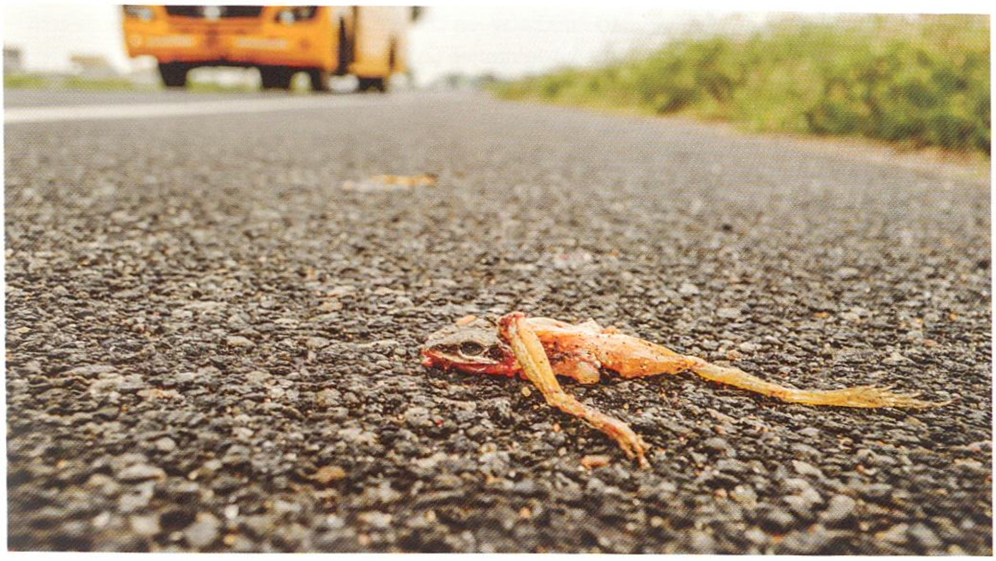


Fig 6. Amphibian road kills are often not detected on road.

2006). Scanty information is available in this regard in Indian context.

Gokula (1997), Vijayakumar et al. (2001), Sundar (2004), Das et al. (2007), Kannan (2007) and Rao & Girish (2007); Baskaran & Boominathan (2010) have studied the effect of vehicular traffic on animal mortality, although the studies are seasonal and for very short duration.

Only handful of studies in India show evidence that amphibians are more susceptible to vehicular traffic (Vijayakumar et al. 2001; Sundar 2004; Bhuphathy et al. 2011; Seshadri & Ganesh 2011; Sharma 2015). However, mortality of animals also depends on other factors such as time of the year, habitat and/or landscape characteristics, behavior of the species and road and traffic characteristics. Andrews and Gibbons (2005) also noticed that presence of breeding habitats near to roads lead to higher amphibian mortality.

In the Anamalai hills of southern India, Western Ghats, Vijaykumar et al. (2001) sampled highway segments passing through rainforest fragments and tea gardens. Their study found 72 reptile and 311 amphibian (5 families and 3 species) road kills including several endemic species. It is interesting to note that the study recorded greater mortality among amphibians (2 individuals/km and 6 individuals/ 10 km) than reptiles (0.43 individuals/Km) due to vehicular movement. In case of reptiles, more than 80% (N=49) of the road kills were that of snakes and in case of amphibians, the family Bufonidae represented half (46.6%, N=144) the total number of individuals recorded. As per the study, an increased activity of amphibians and uropeltids was observed during rainfall, thus making them more vulnerable to road traffic. Conservative extrapolation would suggest that a 100 km stretch of road through forests here witnesses an annual kill of around 10,000 amphibians and reptiles, a large proportion accounting for endemic species to the Western Ghats.

A short study for three months recorded 68 instances of road kill reptiles belonging to 21 species from near Kaziranga National Park in Assam (Das et al 2007). However, similar report from many protected areas fragmented by roads is hitherto missing.

Sheshadri et al. (2009) carried out a survey of amphibian mortality on roads in Sharavathi river basin in the central Western Ghats. Road kill data was recorded in three different land use areas: agricultural fields, water bodies and forests for four days along three 100m stretches in each type of area. A total of 144 individuals belonging to 2 orders, 8 families, 11 genera and 13 species were recorded in the survey. Kills/km was observed for an overall average of 40 kills/km and road kill species compositions varied significantly between land use areas.

A road mortality study of herpetofauna along National Highway 220 in Western Ghats has recorded mortalities of 101 amphibians and 78 reptiles in 24 days. The study showed significant relationship of mortality of amphibians with time of the day and influence of climate on amphibian activity. Overall 3.5 amphibians/ 10 km and

2.7 reptiles/ 10 km were recorded dead during the study. (Bhupathy et al. 2011).

Mortality of herpetofauna has been reported from Western Ghats by Boominathan (1999) in Mudumalai (19 amphibians/ 10 km; 8.3 reptiles/ 10 km) between December 1998 to March 1999 & Mukherjee (2007) in Anaikatti hills (3.49 reptiles/ 10 km) between January 2003 to December 2004. Several other studies by Selvan et al. (2012) and Nagar et al. (2013) show impacts of vehicular traffic

Table 1: Review of Studies on impact of roads and vehicular traffic on Indian Amphibian populations.

S. No	Family	Species	Total mortality	Season of Study
1	Bufonidae	*Duttaphrynus melanostictus*	145	May- June 1988
	Ranidae	-	73	
	Rhacophoridae	-	35	
	Ureotyphilidae	*Ureotyphlus* sp.	19	
	Icthyophidae	*Icthyophis* sp.	8	
	Unidentified	-	31	
2	Bufonidae	*Duttaphrynus melanostictus*	17	June 2008
	Dicroglossidae	*Euphlyctis cyanophlyctis*	3	
	Dicroglossidae	*Fejervarya cf. rufescens*	1	
	Dicroglossidae	*Fejervarya* sp.	22	
	Dicroglossidae	*Hoplobatrachus tigerinus*	1	
	Microhylidae	*Microhyla ornata*	9	
	Microhylidae	*Uperodon cf. montanus*	1	
	Nyctibatrachidae	*Nyctibatrachus* sp.	3	
	Ranidae	*Hylarana malabarica*	1	
	Ranixalidae	*Indirana* sp.	2	
	Rhacophoridae	*Polypedates cf. occidentalis*	1	
	Icthyophiidae	*Ichthyophis* sp.	4	
	Icthyophiidae	*Ichthyophis beddomei*	5	
	Unidentified anurans		74	
3	Bufonidae	*Duttaphrynus melanostictus*	42	December 2006- November 2007
	Ranidae	*Indosylvirana temporalis*	4	
	Ranixalidae	*Indirana* sp.	48	
	Rhacophoridae	*Polypedates pseudocruciger*	1	
	Rhacophoridae	*Rhacophorus malabaricus*	3	
	Dicroglossidae	*Sphaerotheca breviceps*	3	
4	Amphibians	-	211	2008- 2009
5	Amphibians	-	125	January 2007 - June 2007
6	Bufonidae	*Duttaphrynus melanostictus*	11	November 2015
	Dicroglossidae	*Hoplobatrachus* sp.	1	
	Dicroglossidae	*Spherotheca* sp.	1	
	Microhylidae	*Uperodon* sp.	1	
	Rhacophoridae	*Polypedatus* sp	2	
	Unidentified anurans		247	

on herpetofauna mortality.

Most common among the amphibians, is the Bufonidae that is found most in the road kills. This could be due to the foraging nature of Bufonidae, which are very fond of gathering near street lamps and vehicle head lights to feast on insects (Daniels 2005). Their highly eurytopic and human commensally traits (Daniels 2005) could also be the possible reasons for their higher susceptibility of becoming road kill victims.

A brief overview of studies recording the amphibian mortalities in India is given in the table below:

Max. duration (days)	Max. length of road segment (km)	Study Site	Reference
20	3	Valparai, Western Ghats	Vijayakumar et al. (2001)
4	3.6	NH 206, Western Ghats	Seshadri et al. (2009)
24	6	NH 220, Western Ghats	Bhupathy et al. (2011)
2 years	3.5	Kalakad Mundanthurai Tiger Reserve (KMTR), South India	Seshadri & Ganesh (2011)
6 months	-	NH 212 and NH 67, Bandipur National Park, South India	Selvan et al. (2012)
8	3	NH 208, Srivilliputhur, Eastern Ghats	Pers. Comm.2015

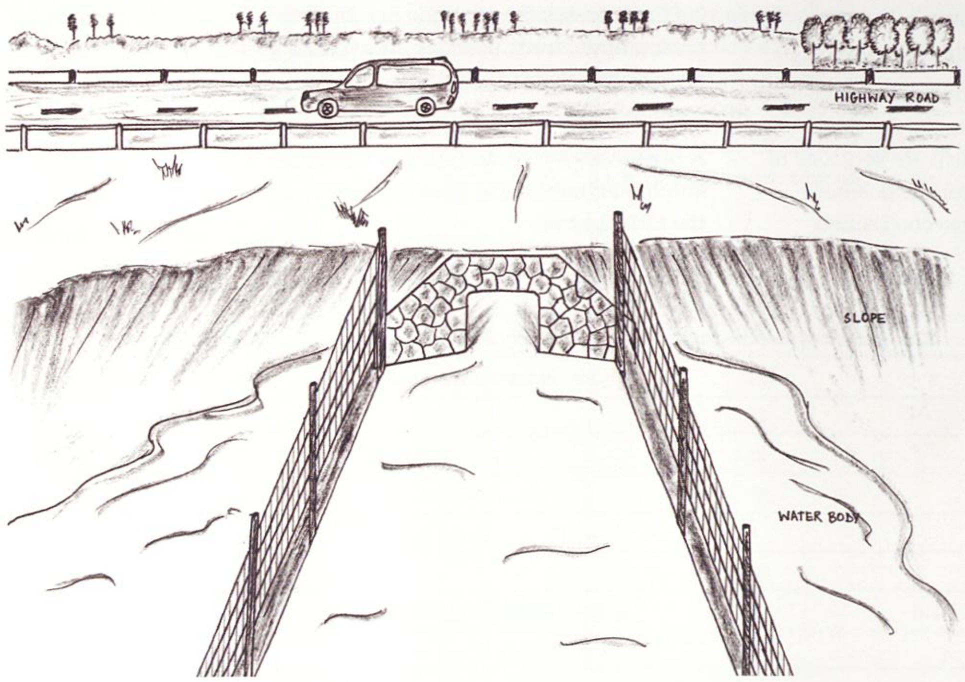


Fig 7: A fenced waterway to guide amphibians through the underpass. Adapted from Gilbert et al. (2015). Illustration by Preeti Sharma.

Mitigation Strategies

Mitigation refers to 'measures to avoid any harm' or 'lessen the gravity of an offence'. Mitigation strategies refers to 'step wise approach to reduce harm', to habitat and wildlife. In present context of development of linear infrastructures such as roads, railway lines, and transmission lines, the adverse impacts on wildlife are well documented (Jalkotzy et al. 1997; Seiler 2002; van der Ree 2015). While the impacts caused due to such linear infrastructures cause direct mortality (Forman et al. 2003) but roads also act as a source of noise, light and chemical pollution, thus creating barriers to amphibian movement (Bee & Swanson 2007; Dorsey et al. 2015).

This brings in the need for wildlife crossing structures popularly known as 'green infrastructure' (Forman et al. 2003) that can be deployed for safe passage of amphibians across the landscape. Role of crossing structures is to provide safe movement for an animal to cross the road and offer connectivity between habitats along the road. Some of the methods mentioned below may be applied to minimize and prevent impacts of roads and check road mortality of lesser vertebrates or group such as amphibians.

The ecological effects of roads get manifested in the regional and local populations and in turn, affect individual behavior. It is, therefore important that while designing mitigation strategies SMART (refers to measures that are specific, measurable, achievable, realistic and timely) approach is recommended for greater effectiveness (Forman et al. 2003).

One of the greatest factors influencing the risk of road mortality in amphibians is their movement or dispersal patterns, species-specific life history traits and behavior (Forman et al. 2003; Andrews & Gibbons 2005). An animal moves either to disperse to new sites or settle near natal sites and often need to cross fragmented landscapes by roads and railway lines in order to select spatially separated breeding and foraging sites (Andrews et al. 2008). The relatively slow movement rate (Hels & Buchwald 2001) and seasonal amphibian movement (juvenile dispersal and adult migration) makes amphibians more susceptible to road mortalities (Pittman et al. 2014). These factors have 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 (Bonte et al. 2012;

Clobert et al. 2009; Ronce 2007). Thus, mitigation measures to reduce mortality due to vehicles involve a combination of approaches: erecting fences and walls to exclude wild animals from moving towards the road and prevent road mortality, constructing of overpasses and underpasses to allow safe movement across the road, erecting signage and warning systems as a regulatory measure to alter human behavior. By incorporating taxa specific designs and choosing the right locations for crossing structures, can keep mortality of wildlife on roads at bay.

Mitigation specific to amphibian population

The road-crossing structures can be installed beneath the road surface (<1.5 m diameter or height) or above the road as fencing or deflectors along the road to direct the movement of amphibians. Potential measures for mitigation of amphibian mortality on roads are listed briefly:

A) **Amphibian tunnels:** Tunnels installed between breeding habitats, or between isolated wetlands known to allow for migration of adult amphibians and emigration of metamorphs from breeding ponds (Podloucky 1989). A tunnel may be designed with a funneling device to the entrance to direct flow of animals entering the tunnel. The closer the tunnels are to the breeding habitats, the more accepted by the amphibians and serve as springboards for amphibians crossing roads (Eriksson et al. 2000).

B) **Pipe Culverts:** These are dry passages, typically round in shape designed to facilitate overland movement of amphibians, made up of smooth metal, or concrete. Single or multiple pipes may be placed at appropriate position and facing the direction of movement of amphibians. Plantation of native vegetation along the sides of the culverts improves the efficacy of the culvert and provides refuge to the amphibians.

C) **Wildlife Culverts:** These are passages up to 120 cm wide located over water channels and are designed for movement of smaller or lesser vertebrates. They may serve as potential amphibian crossing passage provided they are located at the right places.

D) **Modified Culverts/ Drainage Culverts:** These are water passage and drainage which can be modified for wildlife passage. Although the potential of these structures as successful wildlife passage had been overlooked (Forman et al. 2003), yet these non-wildlife-engineered structures can prove best for linkages of species populations (Rodriguez et al. 1996).

E) **Fences:** These are structures designed over the surface of road to prevent movement across roads instead get directed towards wildlife passages. Fences have been practically efficient and effective measure for amphibian crossing. If used in combination with the right crossing structures placed at the right spot, the animals are successfully directed to the tunnels or culverts placed along the fence. Wire, chain link, rail, plastic mesh or concrete can be used for constructing of fencing for amphibians.

Prerequisites for amphibian mitigation

An assessment of species composition (threatened species if any), relative abundance and habitat association along the road stretch is a must in order to design species-specific mitigation measure. Some of the methods to identify zones of animal activity are visual encounter survey, road survey, radiotelemetry, mark recapture using Visual Implant Elastomer (VIE) or Passive Integrated Transponder (PIT) tags (Heyer et al. 1994).

A. Before implementing any linear infrastructure project, it is important to map availability of amphibian breeding (streams, ponds, lakes etc) habitats along proposed road side in a GIS domain. It is better if alignment can be made at least 1km away from amphibian breeding site. With limited data on amphibian movement in Indian context it is difficult to exactly define a distance class, of our native species

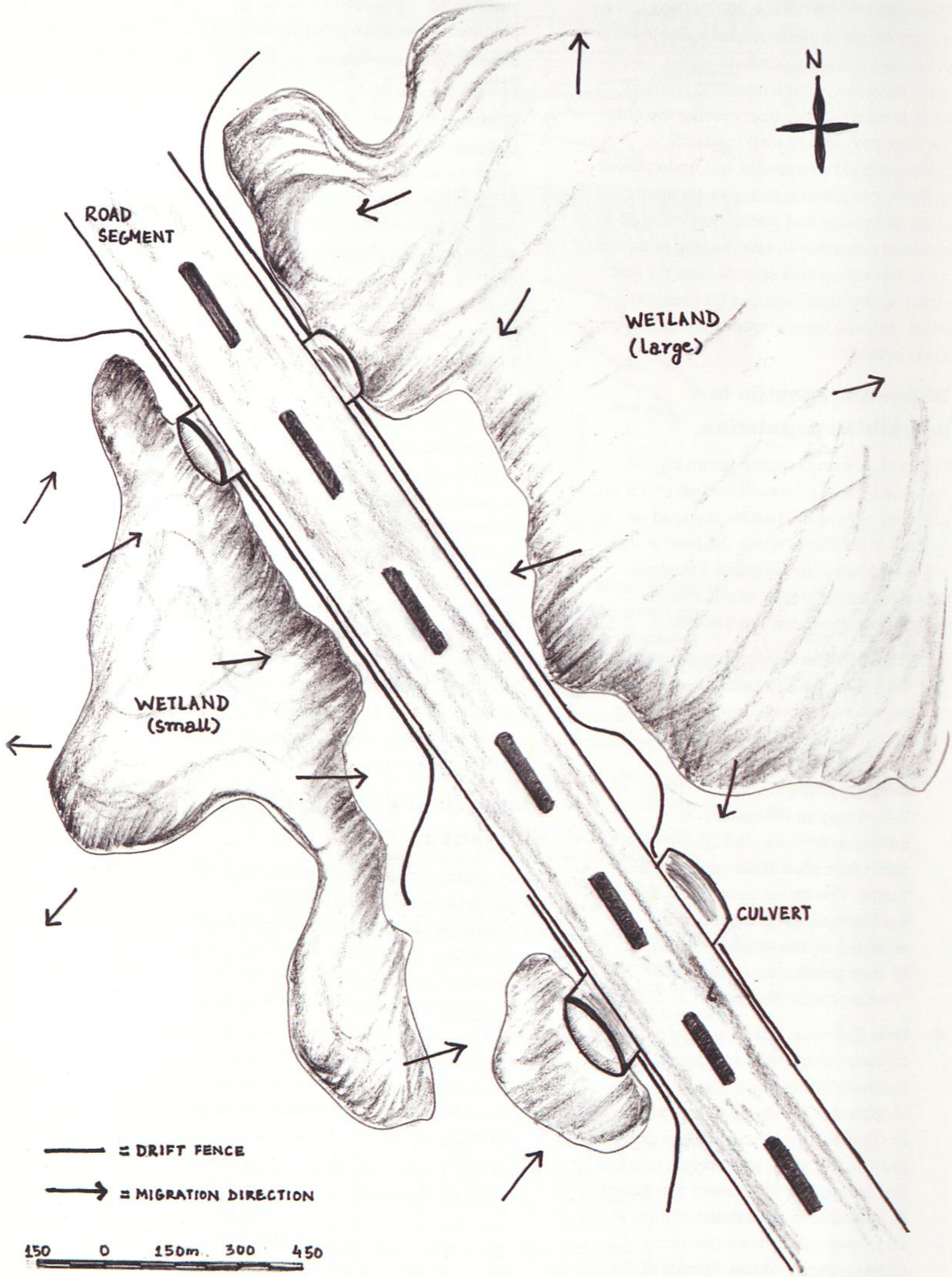


Fig 8: Schematic representation of the use of culverts coupled with fencing to provide safe passage for amphibians. Adapted from Aresco (2005). Illustration by Preeti Sharma

during a particular dispersal/migratory event.

B. If roads bisect amphibian habitat and migration routes, specially designed underpasses need to be established. Such small or large passage if placed across peak activity zone, these structures can significantly help reduce the fragmentation effect. Traditional culverts and minor bridges (built on ditches, streams and rivers) can be modified to facilitate safe movement of amphibians under the highway.

C. The position and size (length and diameter) of these structures, and the angle that they are approached by amphibians are critical factors determining the success of these specialized structures. Amphibians often prefer square shaped tunnels that are buried close to the ground surface, rather than those that are round and set deep into embankments.

D. Passageways should be designed in a way to minimize environmental gradients. Amphibians are particularly sensitive to moisture condition and thus cement flooring of passage may not provide ideal condition for amphibian movement. Cement flooring also likely to limit natural vegetation growth may prove unsuitable for cryptic animals. There should not be gaps or breakage in the fencing. The material should be durable and it should be made sure that the passage ways connects the two sides of the habitat properly.

E. Lack of light within tunnels may deter usage by amphibians (Jackson & Tyning, 1989, Krikowski, 1989). Thus, larger tunnels (such as those in NH) are required to be designed in a way to provide sufficient light to facilitate passage use (Puky 2003). This can be achieved by maximizing diameter to length ratio of passageways to maximize light penetration and airflow.

F. Tunnels fitted with metal grates on the top (on road surface) may act as effective "small passage for amphibians. Metal grates at the top of passageways may be installed to facilitate light and air penetration. Gaps on the metal grates will help amphibians to drop down in the passage.

G. In dry areas, engineering solution for maintaining moisture in passageways needs to be done. In case underpass falls on a waterway or wetland, provision to fence the side of the water channel need to be envisaged.

H. Fencing is necessary where amphibians need to be channeled to use a particular crossing facility. Most fences act as one-way barriers so that the movement of amphibians is only prohibited in a single direction. Top of the fences should curve away from the highway, in order to prevent tree frogs to climb over fences (Puky 2003). Fences should be at least 50 cm high; however, in case of fencing for both reptiles and amphibians they need to be at least 0.8 m high above ground and 0.2 m below ground. In order to direct animals towards passageways to facilitate use, fencing in "Zig-Zag fashion (Jackson & Tyning 1989), is most useful.

I. Traffic noises are known to have auditory masking effect amphibians (Parris et al 2009). If road is passing through forested areas (especially in western Ghats or Northeast India) mitigation measures should include construction of noise barrier of the synthetic fiber of height 1.5m and same may be constructed on the rigid crash barrier on either side of the highway as long as forested corridor section of road.

J. Amphibian translocation as possible mitigation measure is still a controversial topic. However, in certain cases where entire breeding sites or land areas are to be lost and cannot practicably be replaced for technical reasons, amphibian population may be considered for short distance 'in situ' transfers, as a likely mitigation measure. Expert intervention is necessary in this aspect. The new site should be close to the original breeding site and should have same hydrological and ecological conditions as far as possible.

K. Construction of new breeding sites or restoration of earlier breeding site of amphibians may also help maintain native amphibian population and thus can be visualized as possible mitigation measure. Pond designs should take into account measures to assist in their long term management for amphibians. Studies may be undertaken to determine the number, size and type of breeding sites that will be needed to provide effective mitigation. Pond design may vary according to biological requirement of targeted species or amphibian assemblages. If new ponds are close to the road, care should be taken to separate their catchment from the road drainage system, to avoid pollution.

L. Amphibian breeding site management may include the removal of extensive growth of aquatic vegetation or removal of weeds from surrounding areas of the wetland. Care should be taken to remove predatory fish from such breeding habitats.

Follow up

Installation of amphibian fencing, tunnels and underpasses mark the beginning of a mitigation project. Passageways and fencing systems require monitoring for repairs and maintenance. Intensive monitoring and a follow up research may be needed in order to demonstrate effectiveness of passageways and fencing as effective mitigation measure for amphibian road kills. There should be strong research component associated with mitigation measures and funds for that need to be assured. Costs of maintenance and specialist monitoring, should also be included in the provisions for long-term management.

Conclusion

India with an annual economic growth of ca. 7.5 percent for the fiscal year 2016-2017 (Ministry of Finance 2016), the pace of infrastructure development is inevitably set to increase in forth coming years. As is the need of the hour, new contracts have been awarded for 5331 km length of National highways while 3480 km have been already constructed in 2015-16 (Ministry of Road Transport and Highways). The Vehicular densities on Indian roads, that have increased from 0.3 to 30 million in the past 50 years (Raman 2009; Seshadri et al. 2009) are going to go further up in coming days.

As conservationists, we cannot stop progress but we surely can shape it (Rosner 2013). Plenty of studies that support the avoidance of roads by larger mammals like elephants, rhinoceros, lions and tigers. However, scanty knowledge is available for Indian amphibians. Suitable mitigation strategies can be formulated and proposed for implementation if we have scientific evidence that show detrimental effects of roads on Indian amphibians and reptiles. This could help in designing the right mitigation plan at species specific level. Nevertheless, efforts should be made to construct more passages or alter existing structures in the future to lower habitat fragmentation along transportation infrastructure.

Scientific studies surely are important to back up any mitigation plan, but it is also up to the managers to look out for effective conservation strategies to balance the situation. It is high time that we feel the need to have a strategic landscape-level planning in India (Saxena et al. 2016) and practice Strategic environment assessment for developmental projects at landscape level. It is important to incorporate the conservation proponents in the decision making process in order to achieve conservation objectives in Indian transportation system.

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Fig 9. Non-engineered structures can be well utilized for road kill mitigation measures.