Losing time for the tiger *Panthera tigris*: delayed action puts a globally threatened species at risk of local extinction

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Supplementary Material

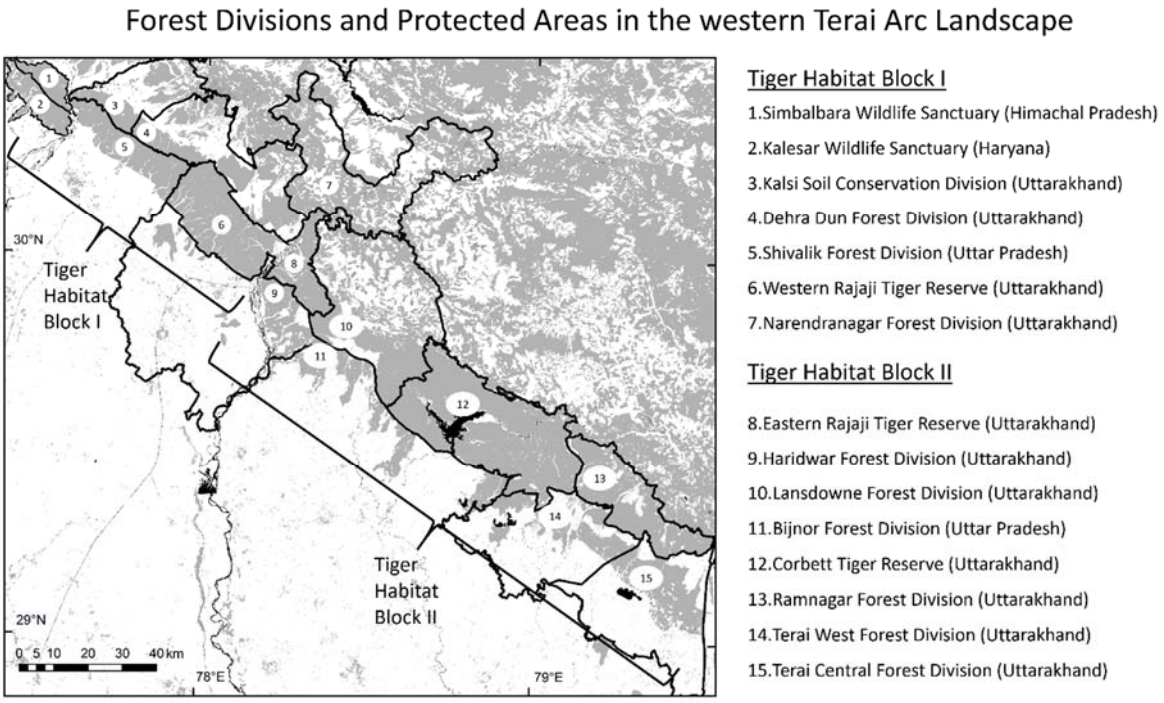

FIG. S1 Protected areas and administrative units within Tiger Habitat Blocks I and II, between the Yamuna and Gola rivers in the western Terai Arc Landscape in India (Fig. 1). Adapted from Harihar & Pandav (2012).

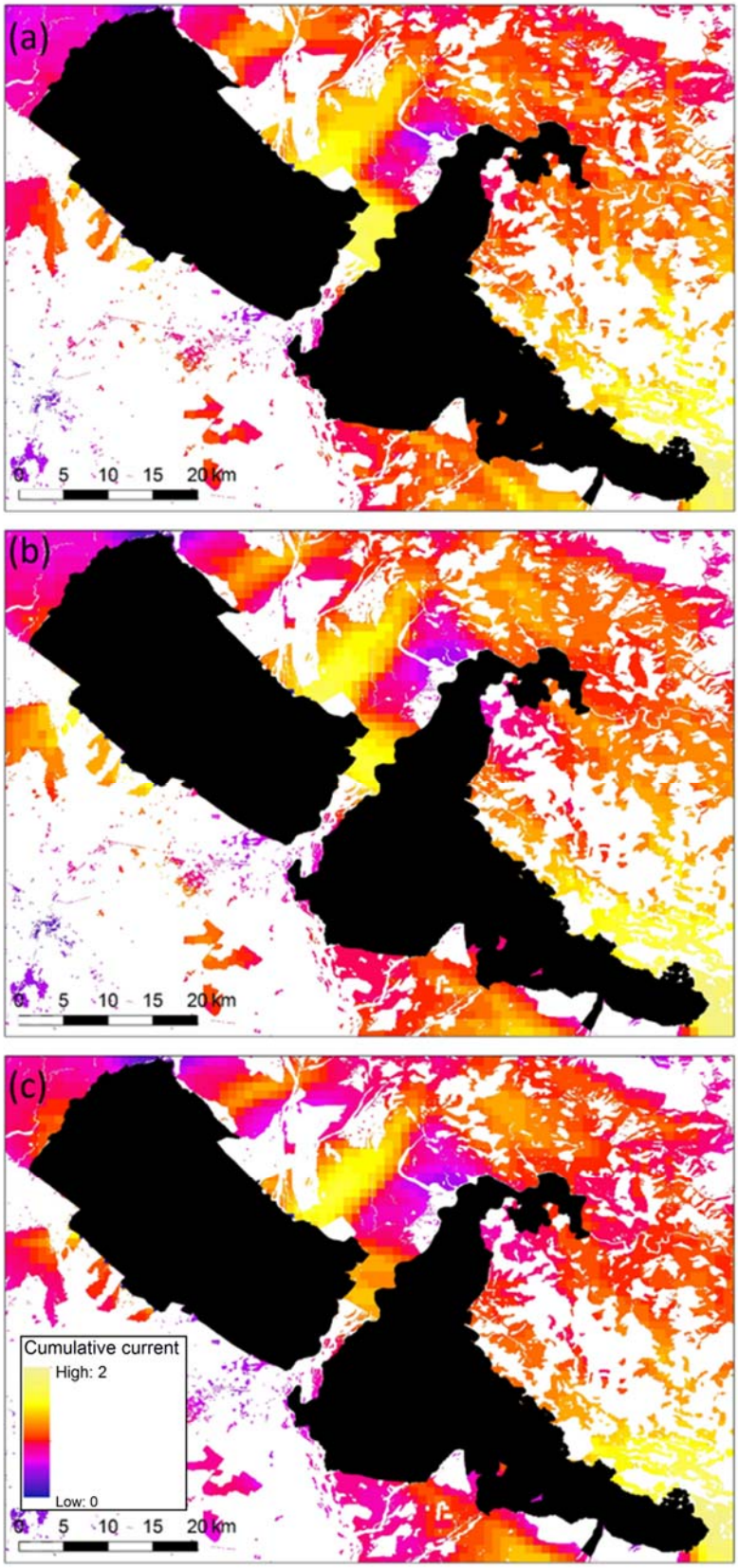

FIG. S2 Modelled cumulative current (connectivity) across the Chilla–Mothichur corridor between the western and eastern sectors of Rajaji Tiger Reserve in the western Terai Arc Landscape of India (Fig. 1) for (a) 1993, (b) 2003 and (c) 2013. The palest shading indicates areas with the maximum movement potential for tigers.

TABLE S1 Models for evaluating the effect of covariates on occupancy ($\hat{\psi}$) based sign survey data collected from the western Terai Arc Landscape, India (Fig. 1), in 2002–2003 (Johnsingh et al., 2004) and 2009–2010 (Harihar & Pandav, 2012) under the single-season occupancy models of MacKenzie et al. (2002), ranked by ΔAIC, with Akaike weight (*w*), number of parameters, and deviance.

Model	ΔAIC	*w*	No. of parameters	Deviance
2002–2003				
ψ (B) *p* (.)	0	0.2679	3	119.02
ψ (WIldP) *p* (.)	0.77	0.1823	3	119.79
ψ (.) *p* (.)	0.84	0.1761	2	121.86
ψ (PrincipP) *p* (.)	1.69	0.1151	3	120.76
ψ (DIst) *p* (.)	2.04	0.0966	3	121.06
ψ (B × Dist) *p* (.)	3.00	0.0598	5	118.02
ψ (B × WildP) *p* (.)	3.12	0.0563	5	118.14
ψ (B × PrincipP) *p* (.)	3.53	0.0459	5	118.55
2009–2010				
ψ (B × WildP) *p* (B)	0	0.301	6	97.43
ψ (B × Dist) *p* (B)	0.04	0.295	6	97.47
ψ (B × PrincipP) *p* (B)	0.70	0.2121	6	98.13
ψ (B) *p* (B)	2.46	0.088	4	103.89
ψ (Dist) *p* (B)	4.14	0.038	4	105.57
ψ (WildP) *p* (B)	4.32	0.0347	4	105.75
ψ (PrincipP) *p* (B)	4.65	0.0294	4	106.08
ψ (.) *p* (B)	5.62	0.0178	3	109.05

TABLE S2 Survey effort and estimates of occupancy ($\hat{\psi}$) from the single-season analysis of the 2002–2003 and 2009–2010 surveys at the level of the administrative units (Fig. S1), in Tiger Habitat Blocks I and II.

Multiple-use forest divisions and protected areas	Effort (km)	$\hat{\psi}_{2002–2003}$ ± SE	$\hat{\psi}_{2009–2010}$ ± SE
Tiger Habitat Block I			
Kalsi Soil Conservation Division	6.1	0.034 ± 0.04	0.025 ± 0.01
Dehradun Forest Division	17	0.052 ± 0.05	0.037 ± 0.01
Shivalik Forest Division	35.5	0.496 ± 0.02	0.03 ± 0.01
Western Rajaji National Park	35.7	0.578 ± 0.02	0.571 ± 0.01
Narendranagar Forest Division	2.7	0.035 ± 0.04	0.033 ± 0.01
Mean		0.239 ± 0.05	0.139 ± 0.03
Tiger Habitat Block II			
Eastern Rajaji National Park	35.5	0.712 ± 0.02	0.977 ± 0.02
Haridwar Forest Division	29	0.686 ± 0.02	0.908 ± 0.02
Lansdowne Forest Division	70.8	0.634 ± 0.02	0.913 ± 0.03
Bijnor Plantation and Forest Division	17.3	0.679 ± 0.02	0.832 ± 0.04
Corbett Tiger Reserve	23.8	0.786 ± 0.02	0.999 ± 0.01
Ramnagar Forest Division	68.4	0.748 ± 0.02	0.901 ± 0.03
Terai West Forest Division	43.4	0.741 ± 0.01	0.963 ± 0.02
Terai Central Forest Division	47.4	0.704 ± 0.02	0.732 ± 0.05
Mean		0.711 ± 0.04	0.903 ± 0.04

TABLE S3 Comparison of model parameters at the scale of the administrative units between the 2002–2003 surveys of Johnsingh et al. (2004) and the 2009–2010 surveys of Harihar & Pandav (2012) across the western Terai Arc Landscape, India (Fig. 1).

Model parameters	2002–2003	2009–2010
$\widehat{\psi} \pm SE$	0.508 ± 0.027	0.548 ± 0.022
$\widehat{\psi}_{THB\ I} \pm SE$	0.239 ± 0.05	0.139 ± 0.03
$\widehat{\psi}_{THB\ I} \pm SE$	0.711 ± 0.04	0.903 ± 0.04
$\hat{p}_{best} \pm SE$	0.657 ± 0.016	
$\hat{p}_{THB\ I} \pm SE$		0.444 ± 0.165
$\hat{p}_{THB\ II} \pm SE$		0.744 ± 0.052

TABLE S4 Estimates of tiger density in western Rajaji Tiger Reserve, India, in 2009, 2011–2012, 2012–2013, and 2014–2015.

	2009[1]	2011–2012	2012–2013	2014–2015[2]
Effort				
No. of trap nights	600	1659	1296	3918
No. of trap locations	20	79	72	164
Captures				
No. of unique individuals identified	2	3	2	2
Total no. of captures	6	12	11	61
Spatially explicit capture–recapture likelihood inference				
$\widehat{D} \pm$ SE	0.4 ± 0.1	0.4 ± 0.2	0.31 ± 0.22	0.28 ± 0.23

[1]Harihar & Pandav (2012)
[2]Rathore (2015)

TABLE S5 Summary of articles spanning 1986–2015 that included the term Chilla–Motichur, Chilla Motichur, or Chilla–Motichur corridor in their title, keywords or abstract, with the conservation recommendations they provided. The following articles included one or more of the search terms but did not provide any conservation recommendations: Badola (1993), Johnsingh & Joshua (1994), Johnsingh & Williams (1999), Singh & Gureja (2001), Williams et al. (2001), Singh et al. (2003b), Ghosh (2003), Joshi & Singh (2008), Williams et al. (2008), Joshi et al. (2009), Joshi (2015), Joshi (2016), and Jumani et al. (2017).

Article	Recommendation													
	Relocate Khand Gaon III	Relocate the army ammunition dump	Secure & protect the islands in the Ganges	Contruct a flyover for vehicular traffic between Raiwala & Haridwar	Translocate tigers from Tiger Habitat Block II into western Rajaji Tiger Reserve	Restrict development between the army camp & western bank of Ganges	Resettle Gangabhogpur & Thalla villages from eastern bank of Ganges	Minimize cattle grazing & anthropogenic disturbances in the corridor	Relocate Chilla Power Colony, Grid & Garhwal Mandal Vikas Nigam Guest House	Build more bridges on the Chilla power canal to facilitate animal movement	Resettle Gujjars from Rajaji Tiger Reserve	Contain disturbances emanating from Haridwar & Raiwala by building a wall along the Motichur *rau* & planting trees	Regulate traffic on National Highway between Haridwar & Raiwala	Regulate daytime traffic & ban night traffic on Chilla canal road
Saxena (1986)	✓	✓	✓			✓								
Khan et al. (1989)	✓	✓	✓			✓								
Johnsingh et al. (1990)	✓	✓					✓							
Johnsingh (2001)	✓	✓	✓	✓		✓	✓				✓	✓	✓	✓
Singh & Sharma (2001)	✓	✓		✓		✓						✓	✓	✓

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Singh (2002)	✓	✓												
Johnsingh & Negi (2003)	✓	✓					✓							
Sinha (2003)	✓	✓		✓										
Singh et al. (2003)	✓	✓												
Johnsingh et al. (2003)	✓	✓	✓	✓		✓	✓				✓			
Johnsingh (2003)	✓	✓	✓	✓		✓	✓					✓	✓	✓
Johnsingh et al. (2004)	✓	✓	✓	✓		✓	✓	✓			✓	✓		✓
Johnsingh (2006)	✓	✓	✓	✓			✓							

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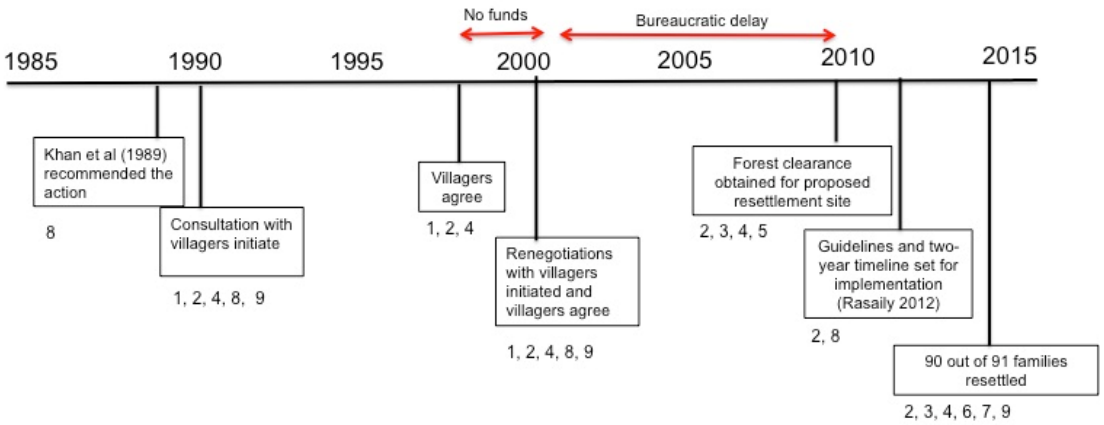
Singh & Chalisgaonkar (2006)				✓										
Nandy et al. (2007)	✓	✓	✓	✓			✓	✓	✓	✓				
Joshi & Singh (2007)		✓	✓	✓										✓
Johnsingh & Madhusudan (2009)					✓									
Harihar et al. (2009)	✓	✓		✓							✓			
Harihar & Goyal (2010)	✓	✓		✓	✓									
Harihar et al. (2014)					✓									

SUPPLEMENTARY MATERIAL 1 Specific timelines of conservation action for the Chilla–Motichur corridor, in India's western Terai Arc Landscape (Fig. 1).

A. Resettlement of Khand Gaon III

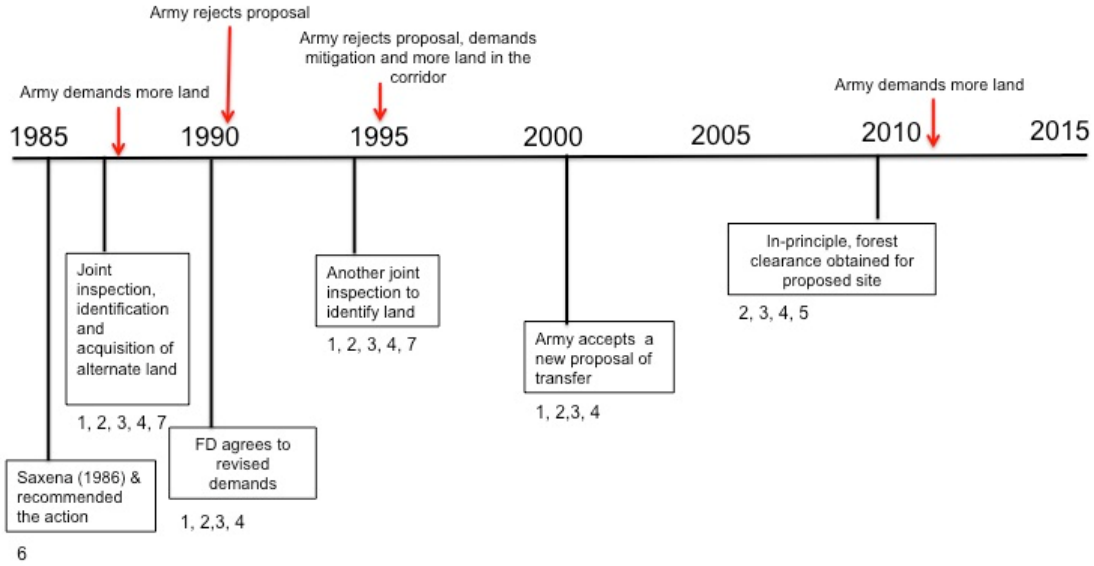


The only recommendation, which was implemented in 2015, was the resettlement of Khandgaon III village, but the process took over 26 years. The first delay was the non-availability of adequate funds, given the parlous nature of state funding at that time, concurrent with the formation of the new state of Uttarakhand (Singh et al., 2003)). Thereafter, obtaining permissions from the federal Ministry of Environment and Forests to clear forested land to resettle families at the new site took several years, reflecting complex bureaucratic structures. Post forest clearance in 2010, resettlement was implemented with support from the district administration for the provision of basic civic necessities, although rights had to be settled for 93 families rather than the initial 32 as a result of the long delay.

Partner organizations/stakeholders (numbered as per the figure above):

1. Khandgaon III residents
2. Management of Rajaji National Park/Tiger Reserve
3. Management of Territorial Forest Division (Resettlement site)
4. State Department of Environment and Forests
5. Ministry of Environment and Forests, Government of India
6. State administrative services
7. District administration
8. Research institutes
9. NGOs

B. Relocation of the army ammunition dump

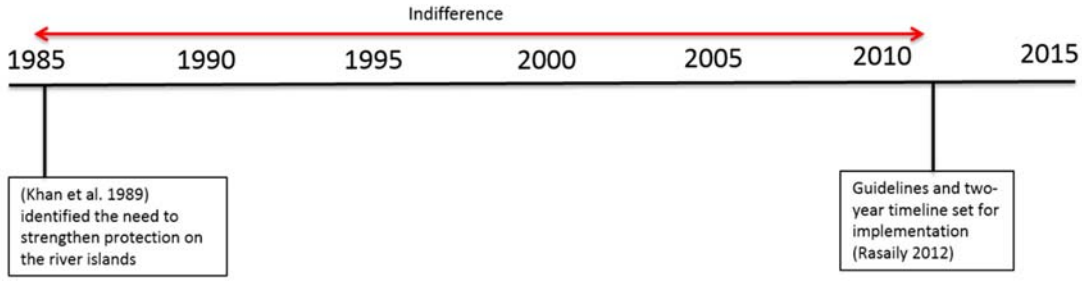


Relocating the army ammunition dump was one of the first recommendations given in 1986 (Saxena, 1986), and its non-implementation primarily reflects excessive bureaucratic structures (within both the Indian Army and State Forest Department) and the hierarchy in departmental organization (the Ministry of Defence being more prominent than the Ministry of Environment and Forests). The defence forces have repeatedly rejected incremental offers of alternative land to relocate the facility and have increased their demands each time, conditioning their relocation on other recommendations concerning the corridor being achieved, the mooted building of additional defence structures in the area, and the payment of financial compensation (Singh et al., 2003).

Partner organizations/stakeholders (numbered as per the figure above):

1. Ministry of Defence, Government of India
2. Management of Rajaji National Park/Tiger Reserve
3. Management of Resettlement Forest Division
4. State Department of Environment and Forests
5. Ministry of Environment of Forests, Government of India
6. Research institutes
7. NGOs

C. Strengthen law enforcement on river islands

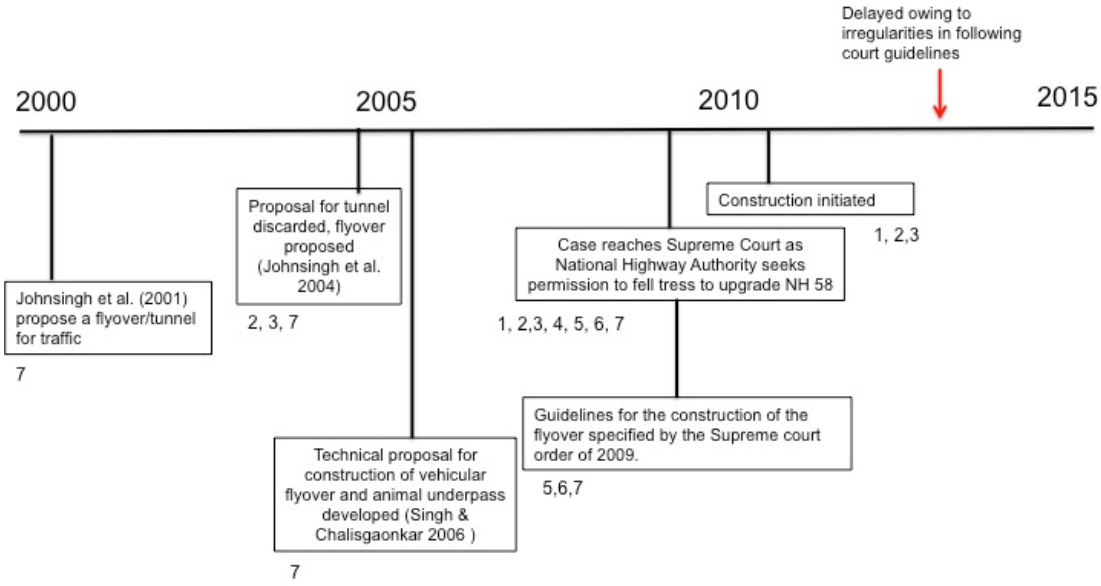


Khan et al. (1989) identified the need to strengthen protection on the river islands across the Chilla–Motichur corridor. Nearly 23 years later, Rasaily (2012) set targets towards strengthening protection in the Rajaji National Park management plan. Guidelines, targets and resources required to establish and strengthen enforcement capacity in the bottleneck were outlined, along with clear timelines and targets for each year. However, the implementation of actions is yet to be initiated and specified targets are yet to be achieved.

Partner organizations/stakeholders:

1. Management of Rajaji National Park/Tiger Reserve

D. Construction of vehicular flyover

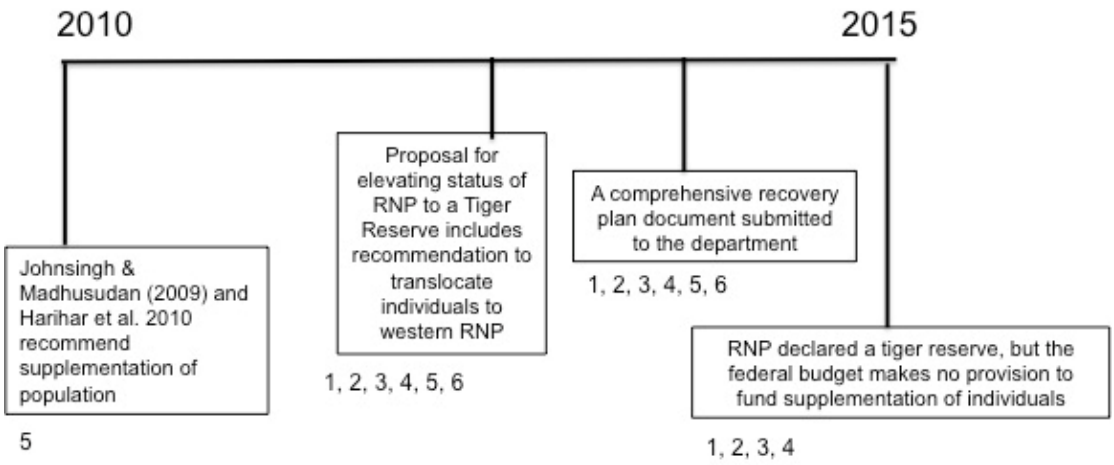


The case of the vehicular flyover illustrates how conflict of inter-departmental interests can delay a conservation action. The National Highway Authority of India (NHAI) proposed to expand the arterial road (National Highway 58) in the bottleneck region given the developmental imperatives of the state. To mitigate the negative effects, Johnsingh et al. (2004) recommended the construction of a vehicular flyover. Given the higher costs involved in building a flyover for traffic, the NHAI contested this suggestion, and the dispute reached the Supreme Court of India in 2009. The proceedings were also delayed because of a lack of a clear prescription (building a vehicular flyover or a wildlife overpass), but eventually the decision was taken in 2009 in favour of building an 800 m long vehicular flyover under the directives of the Central Empowered Committee (under the Supreme Court of India). The construction of the flyover was initiated in 2011 but has yet to be completed (http://www.nhai.org/phase3ui.asp).

Partner organizations/stakeholders (numbered as per the figure above):

1. Ministry of Road Transport and Highways, Government of India
2. Management of Rajaji National Park/Tiger Reserve
3. State Department of Environment and Forests
4. Ministry of Environment and Forests, Government of India
5. Central Empowered Committee, Supreme Court
6. Research institutes
7. NGOs

E. Supplementation of tigers to western Rajaji National Park



The delay in implementation of the above recommendations led to the tiger population in the western part of Rajaji National Park being reduced to three adult females, of which only two remain (Harihar & Pandav, 2012; Harihar et al., 2014). Recognizing the almost imminent extinction of tigers from this patch, translocation of male tigers was recommended in 2009. In 2010 a detailed tiger supplementation plan was submitted to the park management. The National Tiger Conservation Authority, upon declaration of Rajaji Tiger Reserve, endorsed the recommendation in 2013. However, no funds were earmarked for translocation of tigers in the first federal budgetary allocation for this Reserve in 2015. Furthermore, as managers fear that demonstrable population increases post translocation may not happen during their short tenure, they are hesitant to implement such a potentially risky action and take the blame (VanderWerf et al., 2006).

Partner organizations/stakeholders (numbered as per the figure above):

1. Management of Rajaji National Park/Tiger Reserve
2. State Department of Environment and Forests
3. Ministry of Environment of Forests, Government of India
4. National Tiger Conservation Authority
5. Research institutes
6. NGOs