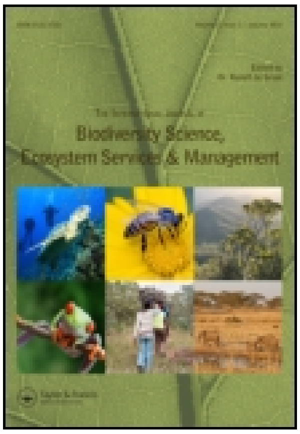

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Impact of anthropogenic disturbances on riparian forest ecology and ecosystem services in Southern India

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This article highlights the impact of anthropogenic disturbance on forest structure and plant diversity in the riparian forest in the Cauvery Wildlife Sanctuary, Karnataka, Southern India. We clustered 11 transects into groups with low and high anthropogenic disturbances. In total, 73 tree species were recorded on 11 transects, of which 57 species were found in less-disturbed sites and 39 species in high-disturbed sites. Shannon–Wiener diversity confirmed higher values for less-disturbed sites (3.2 $\pm$ 0.7) compared with high-disturbed sites (2.7 $\pm$ 0.5). Evenness index suggested no complete evenness in the two sites. Mean species richness and number of individuals in the majority girth classes were found to be higher in less-disturbed sites than in high-disturbed sites. Non-native plants dominated the high-disturbed sites. The occurrence of native and non–native species was correlated with the level of disturbance. Current disturbance intensities may have led to loss of native species such as *Ixora bracheata*, *Madhuca latifolia*, *Syzygium cumini* and *Terminalia arjuna* in riparian forests. This study concludes that species-rich areas in the riparian forests are under threat. Protection of these areas should be prioritized in policy, because anthropogenic disturbance has led to decreasing riparian forest species diversity and structure.

Keywords: wildlife sanctuary; anthropogenic pressures; native and non-native species; riparian forest; species diversity; ecosystem services

Introduction

The word 'riparian' is derived from Latin word *riparius* meaning land adjacent to the water body (Naiman and Decamps 1997). Vegetation in riparian zones is generally characterized by its high species richness (Naiman et al. 1993; Murray and Stauffer 1995) and has unique characters (Amitha 2003) in their life history differing from terrestrial vegetation. Riparian vegetation provides major environmental services through trapping sediments, nutrients and pollutants from agricultural and urban runoff, besides maintaining aquatic biodiversity (Naiman and Decamps 1997). In addition, riparian forests are most diverse and productive in nature (Lovett et al. 2007). They are considered as potentially threatened (Gopal 1988) and endangered ecosystems (Natta et al. 2002) in the world due to abusive and intensive land use. Riparian habitats are more susceptible to exotic species invasion due to the nutrient-rich laden sediments and periodic flooding followed by hydrochory (Pyse and Prach 1994; Gregory and Naiman 2000). World's major river basins Amazon (Nilsson and Jansson 1995) and Mediterranean landscapes (Francisca and Maria 2005) have all witnessed the impact of human activities on riparian ecosystem by losing their originality. Human influences upon tropical Asian rivers are diverse and include degradation of drainage basins (particularly through deforestation and overgrazing), river water regulation and control and river pollution (Johnsingh and Joshua 1989; Dudgeon 1992). River Cauvery, eighth largest river in the tropical Asia passing through the Cauvery Wildlife Sanctuary (CWS), has immense phyto-floristic wealth in its basin, enough to constitute a separate phytogeographic unit (Jayaram 2000). The majority of vegetation in peninsular India is adequately represented in this tract alone (Jayaram 2000). In recent years, increasing rate of population growth and agricultural practices are major threats to the vast native forests in the river basin leading to their disappearance in nearest decades (Cincotta and Engelman 2000). The riparian forest in CWS has been ignored, and there is insufficient knowledge about the tree species present in them, which hinders the planning and conservation steps by all stakeholders.

The CWS is listed as a protected area under section 18 of the Indian Wildlife Protection Act 1973. It is known to harbour a large number of wildlife such as otters, crocodiles, elephants, spotted deer, sambar, Indian guars, wild goats, barking deer, jungle fowl, monitor lizards, giant squirrels, several species of birds and many varieties of fish with famous 'mahsir fish'. The sanctuary area consists of a large stretch of trees growing along the riverbanks (Manjunath 2001) offering various ecosystem services for wildlife. It provides connectivity to Biligiri Rangan hills Temple (BRT) Sanctuary and Mudumalai Tiger Reserve, which is in conjunction with Mysore–Nilgiri corridor (largest population of Asian elephants is found here) (Sukumar 1989). The major portion of the sanctuary is surrounded by dry deciduous patches, and riparian forests here during dry season assumes a very significant place for wildlife (Natta et al. 2003) particularly to

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the otters and wide elephant herds found in the sanctuary. In addition, conservation and management of riparian vegetation in the upper reaches, where CWS is located helps to reduce flood velocities and increase the further flow towards lower reaches, thereby maintaining the river water healthier. In the past few years, the sanctuary is distressed from various kinds of anthropogenic pressures due to the presence of touristic spots, pilgrimage centres, cultivation of crops and human-inhabited places (Manjunath 2001; Kausalya et al. 2006; Sunil et al. 2010). The tourism potential is immense in this protected area due to its proximity to Bangalore city and its natural scenery, mountain hillocks, fishing camp, river rafting and recreational features. Riparian forest in this area has been an integral part of the cultural and traditional parts of landscape. Pilgrims and tourists often camp on the riverbank and use the riparian areas for cooking and other ritual purposes thus increasing the pressure on the riparian forest. The peripheral villagers with substantial livestock population and no adjoining grazing land drive their cattle to the sanctuary. *Lantana* sp. and *Eupatorium* sp. have invaded the sanctuary, suppressed the natural regeneration of the forest and substantially reduced the growth of fodders for herbivores (Manjunath 2001). Kausalya et al., (2006) study on smooth-coated otter (*Lutra perspicillata*) categorized as 'vulnerable' by *2004 IUCN Red List* in the CWS, stating that thinning of bank vegetation has a detrimental effect on these populations, signifies the importance of the riparian forest in the study area. Hence, understanding the human impact on the riparian habitat is essential to the integrated conservation and management of riparian forest in CWS. As there is no comprehensive study on riparian vegetation dynamics in the CWS, our objective was to document the current status of the riparian forest in the study area. The study objective was answered through investigating the response of the vegetation to human-induced activities and the impact of the activities on the structure and diversity of the true riparian/native tree species.

Methodology

Study area

The CWS is situated in the Chamarajanagar district of Karnataka, occupying an area of 526.96 km^2 and set amidst the valleys with the river Cauvery flowing from Shivanasamudra to Hogenakkal falls (Figure 1). The forest is composed of dry deciduous, moist deciduous to semi-evergreen type trees along the riverbank and patches of scrubs. The underlying rocks mainly belong to the metamorphic formation, which includes quartzite, horneblende and schist. Soil along the riverbank varies from red sandy loam to black cotton type. As many as 14 revenue villages are located within the sanctuary supporting a human population of 8000 and a cattle population of 6000 (Manjunath 2001).

Data collection

A preliminary observation was done to document the kind of anthropogenic activities running in riparian forest and the disturbance score obtained for each site following the methods of Mani and Parthasarathy (2006). Disturbance scores given to each site by qualitatively assessing various disturbances (grazing, fire occurrence, encroachment, bridle pathway and tourists intrusion) were ranked into rare (1), occasional (2) and frequent (3) levels of disturbances. By doing so, the sum of all the scores showing high ranks was considered as high disturbance sites and low ranks as low disturbance sites.

Both low- and high-disturbed sites were subjected to tree survey in order to assess the dynamics in riparian vegetation with respect to disturbance sites. For tree documentation, 5000 m^2 (100 m $\times$ 50 m) size belt transect was deployed in less-disturbed sites (six transects) and high-disturbed sites (five transects). Flowering plants ($>$10 cm in size) were sampled in each sampling site excluding grasses, epiphytes, seedlings and herbs. The collected data on trees were analysed for Importance Value Index (IVI) using the Curtis and McIntosh (1951) method.

Shannon and Wiener (H) diversity index and evenness index (J') (Pielou 1977) were calculated at each site as follows:

(1) Shannon–Wiener index (1963) $H = -\sum (p_i \ln p_i) - [(S-1)/2N]$
(2) Evenness $J' = H/H_{\max}$

where H is the Shannon–Wiener index of species diversity; p_i is the proportion of individuals belonging to species i (the ith species); ln is the natural log (2.718); S is the total number of species; and N is the total number of all individuals. The second half of the equation is a correction factor. $H_{\max}$ was calculated as the natural log of the total number of species sampled in each community (Ludwig and Reynolds 1988).

To draw a conclusion for the impact of anthropogenic pressures on native species, disturbance scores given to each site were correlated with the percentages of native and exotic species present in those sites by using statistical software Megastat (7.25) (Orris 2009).

Results

The riparian forest had 73 tree species ($\geq$10 cm gbh) belonging to 44 genera and 20 families distributed in low and high disturbance sites of CWS. Out of 73 tree species, 34 (46.5%) were exclusive to low disturbance sites with high fraction of moist deciduous species and native riparian species. Fourteen species (19.1%) were confined to high disturbance sites with the presence of large number of pioneer species, while 21 (28.7%) species were common to both the areas (Appendix 1). A comparative analysis between the high and low disturbance sites (Table 1) reveals that low disturbance sites harbour more species (26.2 $\pm$ 8.4) than the high-disturbed sites (11.4 $\pm$ 4.3). The result reveals that high disturbance sites concentrate more basal area (10.9 $\pm$ 9.0). The low disturbance sites scored a high value of Shannon–Wiener index (3.2 $\pm$ 0.7) compared

Table 1. Disturbance score (1 = low; 2 = moderate; 3 = high) for 11 study sites in the riparian forest of Cauvery Wildlife Sanctuary (CWS), Karnataka, Southern India.

	Low disturbance sites						High disturbance sites				
Disturbance	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 1	Site 2	Site 3	Site 4	Site 5
Grazing	2	2	2	3	1	3	2	3	3	3	3
Fire	0	0	0	0	2	1	2	2	1	3	2
Encroachment	0	0	0	0	1	0	1	1	1	2	2
Use of bridle pathways	1	1	2	2	2	1	3	2	2	3	2
Tourists/pilgrims and settlements	1	1	2	2	1	1	3	3	3	3	3
Total score	4	4	6	7	7	6	11	11	10	14	12

with the high disturbance sites (2.7 ± 0.5). The Shannon's evenness (*E*) measure for the two categorized sites reveals that there is not much difference in the evenness between the two categorized sites.

A comparison of size class distribution of tree species richness and individuals between the low and high disturbance sites also showed a significant variation (Table 2). The mean species richness in almost all girth classes is found to be more in the low disturbance sites than in the high disturbance sites. The mean tree individuals in lower girth class (10–30 cm) are greater in low disturbance sites (23.3 stems ha$^{-0.5}$). The occurrence rate of species in higher girth class (>181 cm) was 50% greater in low disturbance site. The lower and middle girth classes (10–30 and 151–180) were almost equally represented in all the areas.

Across size class distribution of woody individuals, both sites showed the reverse J-shaped pattern (Figure 2). The extent of non-native individuals among all the girth classes dominated more in the high-disturbed sites compared with the less-disturbed sites. The basal area from lower to middle girth classes is higher in the less-disturbed sites than in the high-disturbed sites (Figure 3). The scatterplot (Figure 4a and b) shows that the disturbance is correlated with invasion by non-native species and the decrease in the proportion of native species in the studied sites. The regeneration status of the native species reveals its inadequate regeneration in the high-disturbed sites compared with less-disturbed sites (Figure 5).

Discussion

Generally, human-induced disturbance in the riparian forest of CWS has led to the decrease in the width of riparian buffer due to its widespread fragmentation in the study sites. The average tree species richness recorded in less-disturbed sites (17.8) and high-disturbed sites (11.4) show similar trends to findings of Francisca and Maria (2005) in the Tagus river basin of Portugal where lower average woody species were recorded (5.7) per site in the disturbed landscape. However, the species recorded in this study can be considered less when compared with the other perennial river 'Chalakudy' in the neighbouring state of Kerala (Amitha 2003). The low disturbance sites had a higher fraction of moist deciduous species and native riparian species compared with the high disturbance sites. The high disturbance site is characterized by the presence of large number of pioneer species as observed by Daniels et al. (1995) in the tropical humid forest of Western Ghats. Increase in the forest fragmentation might have resulted in the loss of valuable fraction of rare and shade tolerant species (Mani and Parthasarathy 2006). A significant difference was obtained for the Shannon–Wiener diversity index, with the less-disturbed sites having more diversity, indicating a general negative effect of human impact on tree species diversity in the high-disturbed sites. Species evenness for the two categorized sites indicates that both the sites had similar evenness with the moderate distribution of species. The tree species richness and number of individuals across girth classes showed significant decrease in the size class category except in size class of 151–180. An insignificant variation among the species richness and number of the individuals was found among the lower girth class indicating that seedlings and saplings establishment was fair among both the sites. Almost 50% reduction in the species richness was noticed in the middle girth class (61–90 cm and 91–120 cm), indicating that some category of species has been futile to the establishment as trees. Species of *Terminalia arjuna* (Figure 7), *Syzygium cumini*, *Madhuca neriifolia*, *Syzygium jambos* and *Syzygium montana* considered as true 'native species' were all unnoticed in the lower girth classes, suggesting that the current disturbance intensities suppressed the regeneration of these native species. Across size class distribution of woody individuals, the occurrence of non-native individuals has greatly contributed to the reverse J-shaped pattern in both sites. Also in high-disturbed sites, the proportion of non-native individuals found to dominate among the lower (10–30 cm) and middle girth classes (30–90 cm) pose a major threat to the native species and a key distress to the riparian forest in the study area. A drastic reduction of voluminous trees (>180 cm gbh) was observed in several sites of both less-disturbed and high-disturbed zones of riparian areas. Although no reason could be attributed from

Table 2. Vegetation characteristics across disturbance gradients of riparian forest in Cauvery Wildlife Sanctuary (CWS), Karnataka, Southern India.

Vegetation characteristics	Low disturbance sites							High disturbance sites					
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Average	Site 1	Site 2	Site 3	Site 4	Site 5	Average
Species richness	8	10	22	24	29	14	17.8 ± 8.4	17	13	8	13	6	11.4 ± 4.3
Number of genera	7	7	15	17	18	14	13.0 ± 4.8	13	10	8	10	5	9.2 ± 2.9
Number of families	5	6	12	12	11	10	9.3 ± 3.0	7	8	4	7	4	6.0 ± 1.8
Density (stems ha^{-1})	50	39	66	81	38	55	54.8 ± 16.5	44	62	40	41	19	41.2 ± 15.2
Basal area (m^2 ha^{-1})	10.8	5.3	17.5	12.3	3.1	2.7	8.6 ± 5.8	1.9	16	23	11.3	2.32	10.9 ± 9.0
Shannon–Wiener diversity index	2.2	2.5	3.8	3.9	4	3.2	3.2 ± 0.7	3.3	2.9	2.4	3	2	2.7 ± 0.5
Evenness index	0.80	0.7	0.80	0.85	0.81	0.82	0.79 ± 0.05	0.73	0.78	0.78	0.80	0.84	0.78 ± 0.03

out of this study, Manjunath (2001) observed that bamboo was growing abundantly all along the riparian area during 1998; part of the bamboo flowered and since then most of its area has become barren due to non-regeneration. This could have been attributed to the absence of voluminous trees in certain sites as bamboo invaded most of the riparian areas earlier. Decreasing basal area among the lower and middle girth classes in the high-disturbed sites reflects the decrease in forest productivity (Sagar et al. 2003) and it is related to the intensity of anthropogenic disturbances including timber harvesting by villagers to meet the demand for fuel wood by the pilgrims and tourists visiting here.

In general, the widespread and dominant non-native species found to replace the native species in the riparian forest in the high-disturbed sites included *Acacia chundra*, *Acacia nilotica*, *Acacia catechu* and *Randia* sp. The said species stand with higher IVI value in the high-disturbed sites (Appendix 1), while the native species such as *T. arjuna* (Figure 7), *S. jambos* and *Ficus hispida* presented in the low disturbance zone exhibited more IVI value in the less-disturbed sites than in the high-disturbed sites. Species having a true riparian value, such as *S. cumini*, *Syzygium caryophyllatum*, *S. montana*, *Homonoia riparia* and *M. neriifolia* have almost gone extinct in the high-disturbed sites of the protected area of CWS. Among these species, *S. cumini*, *S. caryophyllatum*, *S. montana* and *M. neriifolia* have crucial importance for supporting avifauna in the region and also for maintaining the biodiversity of the sanctuary. Moreover, extinction of these native riparian plants naturally affects the source of leaves, twigs, fruit and insects that underpins the aquatic food web (Lovett et al. 2007). Our study confirms that the presence of native and non-native species is related to the intensity of disturbances, increase in the disturbance resulting in the amplification of non-native species and extinction of native species proving that riparian forests are truly sensitive to environmental change (Malanson 1993). Invasion of non-native species in the riparian zone constitutes most serious threats to the biodiversity through the displacement of native plants (Shigenari and Izumi 2004). Despite vast destruction of riparian forest in the study sites, CWS still contains a valuable number of native species, especially in the less human intact sites (Figure 6) safeguarding the minimum width of riparian buffer account for providing habitat to much wildlife existing in the sanctuary. Bavins et al. (2000) suggested a minimum width of 5–106 m of riparian buffer providing the functions of species diversity. Roggeri (1995) observed that riparian forests support a large population of animal species and they play a crucial role in maintaining biodiversity. Therefore, it is recommended that the riparian stretch of CWS needs to be protected and conserved from all kinds of anthropogenic activities. Unregulated and unscientific modes of tourism in and around the riparian zones should be checked and measures should be taken to carry out tourism in a sustainable way by allowing the entry of

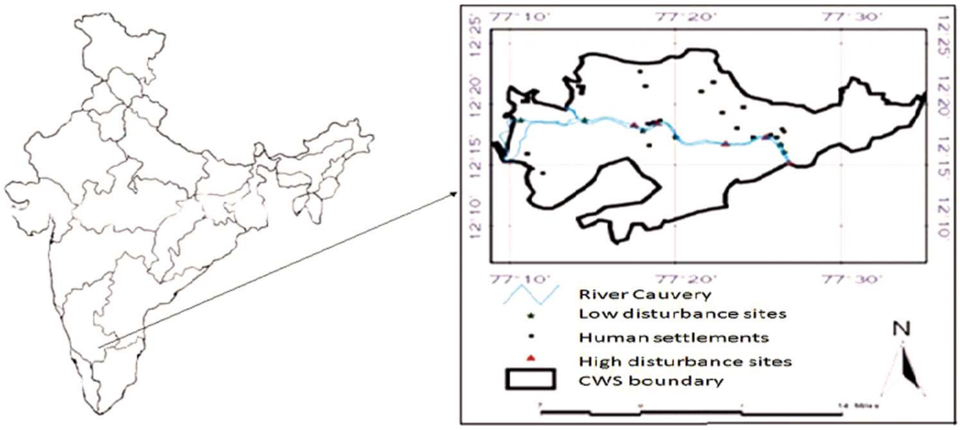

Figure 1. Map of the study area.
Note: CWS, Cauvery Wildlife Sanctuary.

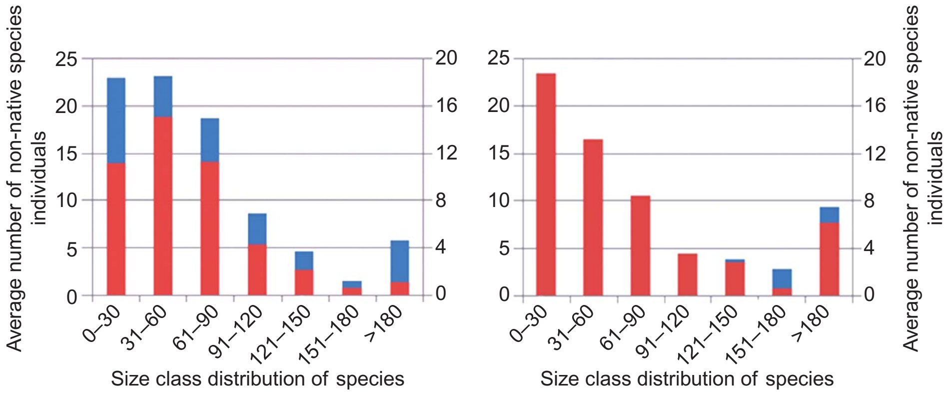

Figure 2. Mean distribution for the size class distribution of woody species in the 11 transects of less-disturbed sites and high-disturbed sites in the riparian forest of Cauvery Wildlife Sanctuary (CWS), Karnataka, Southern India.

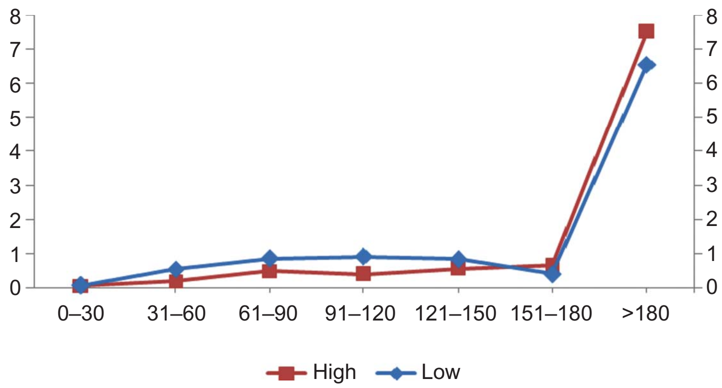

Figure 3. Average distribution of basal area across the sizeclass category in less-disturbed sites (line with squares) and high-disturbed sites (line with cubes) in the riparian forest of Cauvery Wildlife Sanctuary (CWS), Karnataka, Southern India.

tourists into the riparian zone in limited points. Grazing is the common phenomenon noticed in all the selected sampling sites besides fire and unscientific tourism activities (Table 3). Continuous grazing in the riparian zones by the nearby villagers residing inside the sanctuary should be closely managed. Fragmented corridors should be restored with native plantations to avoid soil erosion and bank stability by the forest department with the involvement of key stakeholders such as Shivanasamudra hydroelectric power plant, Atrea power generation, Galibore fishing camp, Bheemeshwari fishing camp and the local communities. Following these strategies will play a vital role in

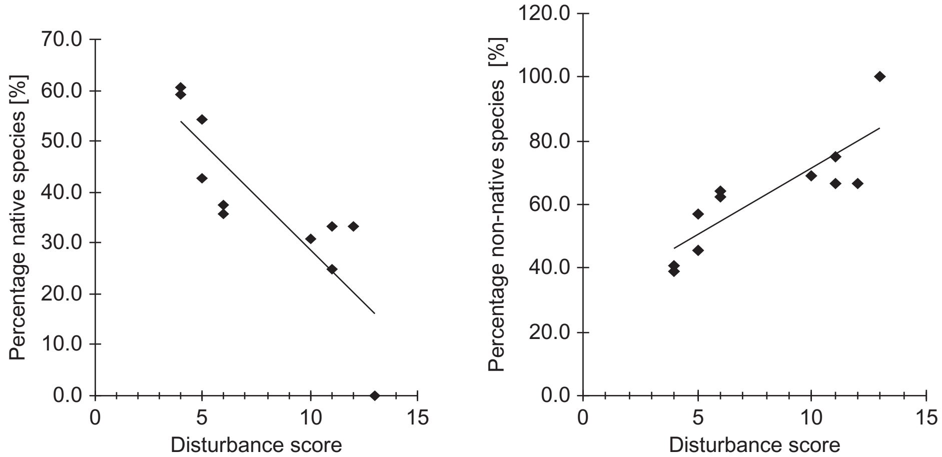

Figure 4. Scatterplot diagram for the relationship between disturbance and the percentage of native species (a), and disturbance and the percentage of non-native species (b) in the studied transects.

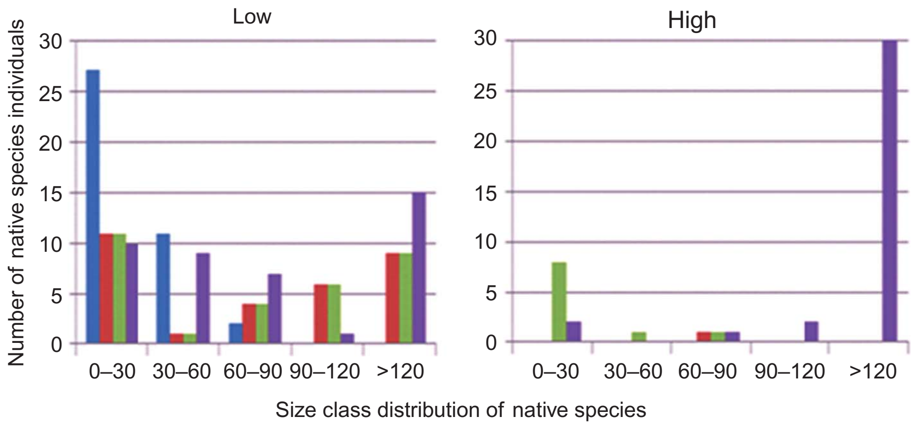

Figure 5. Size class distribution of native tree species in the less-disturbed sites and high-disturbed sites in the riparian forest of Cauvery Wildlife Sanctuary (CWS), Karnataka, Southern India.

Figure 6. Picture of dense riparian forest in the undisturbed areas of Cauvery Wildlife Sanctuary (CWS).

restoring the uniqueness of riparian forest in the study area. The CWS also contains the best habitat and populations for the elephants, as the study area provides connectivity to BRT Sanctuary and Mudumalai Tiger Reserve, which is in conjunction with Mysore–Nilgiri corridor (largest population of Asian elephants is found here) (Sukumar 1989). The major portion of the sanctuary in the present case is surrounded by dry deciduous patches, and riparian forests here during dry season assumes a very significant place for wildlife (Natta et al. 2003) particularly to the otters and wide elephant herds found in the sanctuary. Keeping increasing water scarcity and flood disaster in the lower reaches during monsoon, conservation and management of riparian vegetation in the upper reaches, where CWS is located helps to reduce flood velocities and increase the further flow towards lower reaches, thereby maintaining the river water healthier.

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We thank University Grants Commission (UGC), New Delhi, for financial assistance and Karnataka Forest Department for assistant in field sampling.

Figure 7. Picture of *Terminalia arjuna*, native to riparian areas, displaying its intricate root system, which plays a vital role in mitigating soil erosion in the riparian zone of Cauvery Wildlife Sanctuary (CWS).

Table 3. Species richness, density and occurrence per girth size classwise across the Cauvery Wildlife Sanctuary (CWS), Karnataka, Southern India.

	Species richness		Number of individuals		Species occurrence	
Girth size class (cm)	Low	High	Low	High	Low	High
0–30	8.1 ± 2.3	6.0 ± 0.7	23.3 ± 6.3	21.2 ± 7.2	0.34	0.28
31–60	8.3 ± 4.0	5.6 ± 3.5	23.1 ± 10.7	10.0 ± 7.6	0.35	0.56
61–90	10.0 ± 4.3	5.6 ± 1.5	18.6 ± 6.1	10.6 ± 4.2	0.53	0.52
91–120	5.1 ± 4.2	2.8 ± 2.7	5.6 ± 3.6	4.4 ± 4.7	0.91	0.63
121–150	3.3 ± 2.8	2.8 ± 1.3	4.6 ± 5.3	3.8 ± 2.3	0.71	0.73
151–180	1.3 ± 1.2	1.8 ± 1.4	1.5 ± 1.3	2.8 ± 2.2	0.86	0.64
>180	3.6 ± 2.8	2.8 ± 3	5.8 ± 4.9	9.2 ± 7.8	0.62	0.30

References

Amitha Bachan KH. 2003. Riparian vegetation along the middle and lower zones of the Chalakudy river. Kerala (India): Limnological Association of Kerala, Iringalakkuda. p. 58–63.

Bavins M, Couchman D, Beumer J. 2000. Fisheries guides for fish habitat buffer zones. Queensland (QLD): Department of Primary Industries, Fish Habitat Guide FHG 003: p. 11.

Cincotta RP, Engelman R. 2000. Nature's place: human population and the future of biological diversity. Washington (DC): Population Action International.

Curtis JT, McIntosh RP. 1951. An upland forest continuum in the prairie forest border region of Wisconsin. Ecology. 32(3): 476–496.

Daniels RJR, Madhav G, Joshi NV. 1995. Impact of human extraction on tropical humid forests in the Western Ghats in Uttara kannada, South India. J Appl Ecol. 32(4): 866–874.

Dudgeon D. 1992. Endangered ecosystems: a review of the conservation status of tropical Asian rivers. Hydrobiologia 248(3):167–191.

Francisca CA, Maria TF. 2005. Human disturbed landscapes: effects on composition and integrity of riparian woody vegetation in the Tagus river basin, Portugal. Environ Conserv. 32(1):30–41.

Gopal B. 1988. Wetlands: management and conservation in India. Water Qual Bull. 13:3–6, 29–30.

Gregory HW, Naiman RJ. 2000. Vulnerability of riparian zones to invasion by exotic vascular plants. Plant Ecol. 148(1): 105–114.

Jayaram KC, editor. 2000. Kaveri riverine system: an environmental study. Chennai (India): The Madras Science Foundation. p. 1–6.

Johnsingh AJT, Joshua J. 1989. The threatened gallery forest of the River Thamirabarani, Mundanthurai Wildlife Sanctuary, South India. Biol Conserv. 47(4):273–280.

Kausalya S, Surendra V, Devi Prasad KV. 2006. Factors determining habitat choice of the smooth-coated otter, Lutra perspicillata in a South Indian river system. Curr Sci. 91(5):637–643.

Lovett S, Price P, editors. 2007. Principles for riparian lands management. Canberra (ACT): Land and Water Australia.

Ludwig JA, Reynolds JF. 1988. Statistical ecology: a primer on methods and computing. New York (NY): Wiley.

Malanson GP. 1993. Riparian landscapes. Cambridge studies in ecology. New York (NY): Cambridge University Press.

Mani S, Parthasarathy N. 2006. Tree diversity and structure in inland and coastal tropical dry evergreen forests of peninsular India. Curr Sci. 90(9):1238–1246.

Manjunath 2001. Management plan of Cauvery Wildlife Division. Kanakapura (India): Karnataka Forest Department.

Murray NL, Stauffer DF. 1995. Nongame bird use of habitat in central Appalachian riparian forests. J Wildl Manage. 59(1): 78–89.

Naiman RJ, Decamps H. 1997. The ecology of the interfaces: riparian zones. Annu Rev Ecol Syst. 28:621–658.

Naiman RJ, Décamps H, Pollock M. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecol Appl. 3(2):209–212.

Natta AK, Sinsin B, van der Maesen LJG. 2002. Riparian forests, a unique but endangered ecosystem in Benin. Bot Jahrb Syst. 124(1):59–69.

Natta AK, Sinsin B, van der Maesen LJG. 2003. Riparian forests and biodiversity conservation in Benin (West Africa). Paper submitted to XII World Forestry Congress, 2003, Quebec City, Canada.

Nilsson C, Jansson R. 1995. Floristic differences between riparian corridors of regulated and free-flowing boreal rivers. Regul River Res Manage. 11(1):55–66.

Orris JB. 2009. Megstat statistical software (version 7.25). Indianapolis (IN): Butler University.

Pielou EC. 1977. Mathematical ecology. New York (NY): Wiley.

Pyse P, Prach K. 1994. How important are rivers for supporting plant invasions? In: De Waal L, Child LE, Wade PM, Brock JH, editors. Ecology and management of invasive riverside plants. New York (NY): Wiley. p. 23–31.
Roggeri H. 1995. Zones humides tropicales d'eau douce. Guide des connaissances actuelles et de la gestion durable. WIW, Union Européenne, Université de Leiden/Dordrecht (the Netherlands): Kluwer Academic Publishers.
Sagar R, Raghubanshi AS, Singh JS. 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. For Ecol Manage. 186(1–3):61–71.
Shannon CE, Weiner W. 1963. The mathematical theory of communication. Urbane (IL): University of lllinois Press.
Shigenari M, Izumi W. 2004. Invasive alien plant species in riparian areas of Japan: the contribution of agricultural weeds, revegetation species and aquacultural species. Global Environ Res. 8(1):89–101.
Sukumar R. 1989. Ecology of the Asian Elephant in Southern India. I. Movement and habitat utilization patterns. J Trop Ecol. 5(1):1–18.
Sunil C, Somashekar RK, Nagaraja BC. 2010. Riparian vegetation assessment of Cauvery River Basin of South India. Environ Monit Asses. 170(1–4):545–553.

Appendix 1. List of species found in the riparian zone of the CWS, together with their attributes, RD and IVI.

	Species	Attributes	Low disturbance		High disturbance	
			RD	IVI	RD	IVI
1	*Acacia catechu* Var.	S, P	*	*	5.2	12.4
2	*Acacia chundra* Var.	S, P	3.2	6.6	0.5	2.3
3	*Acacia ferruginea* Dc.	D, P	1.6	4.0	0.5	3.4
4	*Acacia leucophloea* Roxb.	D, P	0.8	3.1	1.4	6.6
5	*Acacia nilotica* L.	S, P	*	*	3.4	11.9
6	*Acacia polyacantha* Willd.	D, P	*	*	1.0	5.5
7	*Adina cordifolia* Cook.	M, P	*	*	4.3	7.1
8	*Aegle marmelos* L.	D, E	0.5	1.7	*	*
9	*Ailanthus excelsa* Roxb.	M, P	1.3	4.1	*	*
10	*Alangium salviforium* Lam.	D, P	3.7	6.7	1.0	3.0
11	*Albizia chinensis* Merr.	M	1.6	4.7	*	*
12	*Albizia lebbeck* Willd.	M	0.8	2.4	*	*
13	*Albizia odoratissima* Benth.	M	*	*	2.4	8.2
14	*Albizia procera* Gam.	M	*	*	2.4	4.5
15	*Atalantia monophylla* Gam.	D, P	*	*	0.5	2.8
16	*Azadirachta indica* A. Juss.	D, P	0.3	1.4	0.5	2.4
17	*Boswellia serrata* Cook.	D	*	*	0.5	2.4
18	*Bridelia scandens* Gam.	M	0.3	1.4	*	*
19	*Canthium dicoccum* Teij.	M, P	1.3	4.6	*	*
20	*Canthium parviflora* shar.	S, P	*	*	0.5	2.4
21	*Canthium* sp.	S, P	*	*	0.5	2.3
22	*Canthium umbellatum* Sant.	M	0.3	1.3	*	*
23	*Cassia siamea* Lam.	D, P	0.3	1.3	*	*
24	*Cassia fistula* L.	D, P	*	*	1.4	3.4
25	*Chloroxylon swietenia* Matt.	D, P	0.3	1.4	1.0	3.0
26	*Citrus medica* Gam.	D, P	0.3	1.3	1.4	3.3
27	*Cleistanthus travencorensis* Gam.	M, D	1.3	2.9	*	*
28	*Commiphora caudata* Gam.	D, P	*	*	2.9	5.2
29	*Cordia wallichii* Don.	D, P	0.3	1.3	1.0	3.1
30	*Dalbergia latifolia* Roxb.	D, P	0.5	1.6	0.5	2.7
31	*Diospyros melanoxylon* Roxb.	D	2.9	8.8	*	*
32	*Diospyros candolleana* Wt.	M	0.3	1.3	0.5	2.3
33	*Diospyros montana* Roxb.	M, P	8.0	14.0	*	*
34	*Erythroxylum monogynum* Roxb.	M	0.5	1.7	*	*
35	*Ficus benghalensis* L.	D, P	1.3	2.6	*	*
36	*Ficus hispida* L.f.	M, R	1.1	3.8	0.5	2.9
37	*Ficus recemosa* Siva.	M	0.3	1.4	*	*
38	*Ficus* sp.		*	*	0.5	2.3
39	*Ficus virens* L.	M	*	*	0.5	2.3
40	*Gliricidia sepium* Sant.	D, P	*	*	1.9	4.2
41	*Hardwickia binata* Gam.	D, P	0.8	2.1	3.8	6.2
42	*Homonoia riparia* Lour.	M, R	0.3	1.3	*	*
43	*Ixora arborea* Roxb.	D	0.8	4.0	*	*
44	*Ixora bracheata* Roxb.	M	3.7	6.5	*	*
45	*Kingiodendron* sp.		2.4	4.0	2.4	4.8
46	*Lagerstroemia lanceolata* Wall.	M, P	1.1	3.3	*	*
47	*Macaranga peltata* Roxb.	M, P	0.3	1.4	*	*
48	*Madhuca latifolia* Var.	M	1.9	6.2	*	*
49	*Madhuca neriifolia.*Lam	M, R	0.5	2.5	*	*
50	*Madhuca* sp.		1.9	8.4	0.5	2.4
51	*Melia dubia* Cav.	M	0.3	1.5	*	*
52	*Melia azadirachta* L.	D	*	*	1.0	3.0
53	*Mitragyna parvifolia* Roxb.	M	1.1	3.4	*	*
54	*Olea dioica* Roxb.	M, R	2.7	7.6	1.9	4.5
55	*Pongamia pinnata* L.	D, P	14.2	24.3	10.1	16.6
56	*Pterocarpus marsupium* Vu.	D	0.3	1.4	*	*

(*Continued*)

Appendix 1. (Continued)

	Species	Attributes	Low disturbance		High disturbance	
			RD	IVI	RD	IVI
57	*Randia regulosa* HK.	D, P	1.6	3.8	*	*
58	*Randia* sp.		0.5	1.7	0.5	2.4
59	*Sapindus emarginatus* Vahl.	M	0.3	1.4	*	*
60	*Schleichera oleosa* Lour.	D, P	1.1	2.4	*	*
61	*Strychnos colubrina* L.	M, P	0.3	1.4	8.2	16.2
62	*Strychnos nux vomica* L.	M, P	3.7	8.8	*	*
63	*Syzygium caryophyllatum* Auct.	M, R	0.3	1.3	*	*
64	*Syzygium cumini* L.	M, R	5.3	16.6	*	*
65	*Syzygium jambos* L.	M, R	0.8	2.8	6.7	16.1
66	*Syzygium montanum* Gam.	M, R	1.1	3.6	*	*
67	*Syzygium zeylanicum* L.	M, R	0.8	4.6	*	*
68	*Tamarindus indica* L.	D, P	4.5	16.1	11.5	31.8
69	*Terminalia arjuna* Roxb.	M, R	8.8	58.3	15.9	79.6
70	*Vitex altissima* L.	M	0.3	1.7	0.5	2.3
71	*Vitex* sp.		0.3	1.3	*	*
72	*Wrigtia tinctoria* En.	D, P	2.4	6.0	0.5	2.3
73	*Zizyphus* sp.		2.7	5.1	*	*

Notes: D, deciduous; M, moist deciduous; S, scrub; P, pioneer; R, native to riparian; IVI, Importance Value Index; CWS, Cauvery Wildlife Sanctuary; RD, relative density.
*Indicates not found in this area.