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Impacts of Dams on Riparian Vegetation: A Case Study in Chalakkudy River, Western Ghats, India

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Abstract

The Chalakkudy river is the fifth longest river in Kerala, originating from the Anamalai part of Western Ghats. Presence of important low-elevation riparian forests and associated biodiversity is the uniqueness of the river, which has been studied in details for heterogenic vegetation composition with systematic sampling. The extent of riparian vegetation was mapped and assessed for its loss due to dams in the River basin. The riparian plot data just downstream to dams, along flow diverted streams, were compared with potential riparian vegetation types. The analysis showed that 60 km riparian forests already submerged due to 6 major dams and 28.8 km riparian forests dried up downstream to dams. Secondary Dry Deciduous Degraded Riparian Forest found downstream to Poringalkuthu and Thunacadavu dams instead of potential Evergreen riparian types indicate the impact of dam diversion of water on the riparian vegetation composition. The dam diversion and alteration decreased the climax species, increased the presence of ruderal species, decreased diversity and degraded the riparian vegetation into secondary degradation types. The compositions were compared with potential vegetation and their phytosociological parameters.

Keywords: Tropical forest, Ecology, Vegetation, River

1. Introduction

The riparian vegetation can be simply defined as the vegetation along the river banks, which has been influenced by the dynamic water table. Naiman *et al.* (1993) define it as "the stream channel between the low- and high-water marks plus the terrestrial landscape above the high-water mark where vegetation may be influenced by elevated water tables or extreme flooding and by the ability of the soils to hold water." Being an ecotone between terrestrial and riverine ecosystems, the riparian vegetation is highly dynamic and unique ecosystem nurture a wide range of biological diversity. The tropical monsoonal climate coupled with mountainous terrains provides a highly dynamic environment where the vegetation within the catchments and that along the riparian areas provides stability to this highly dynamic and vital ecosystem (Bachan, 2010). The riparian vegetation shows heterogenic species composition and can thrive fluvial disturbances occurring throughout the year (Capon and Dowe, 2012).

The riparian vegetation is resilient to calamities occurring in the earth, mainly such as a flood. Over the diversified species and their peculiar adaptations to the divergent climatic conditions, riparian vegetation establishes their dynamic nature. Riparian buffers serve as the filter for the nutrients, and their effectiveness may depend upon several factors. Also, it delineates the flood protection and provides habitat for the organisms in a highly fragmented landscape (Lind *et al.*, 2019). The riparian ecozones perform specialised ecological functions and other services as an output of interactions. Often, they are flourished with biodiversity, and forest canopy regulates the light regime, maintains water quality as well as seasonal nourishment for the betterment of organisms (Robert *et al.*, 1998).

The natural flow of streams and rivers are essential in determining the biodiversity richness of riverine flora and fauna. Several species and their life cycle have evolved following the rhythmic flow of the river (Dynesius and Nilsso, 1994). The riparian vegetation is usually less in extent comparing to other natural vegetation but rich in biodiversity. The riparian vegetation and riparian forests were well understood in many western countries, some part of Asia and poorly understood from the Indian region. The studies of (Bachan, 2003, 2005, 2010; Jobi and George, 2010; Sunil *et al.*, 2016) are some of the pioneering works from the Indian region.

The riparian vegetation along the western slope of Western Ghats are potentially Evergreen Forest formations and characteristically differ from the Riparian Fringing forest of the dry bioclimate as described by (Champion and Seth, 1986). They have been characteristical with heterogeneous composition, and 17 types under four major bioclimate have been reported from the Chalakkudy River Basin (Bachan, 2010; Bachan and Pradeep, 2010; Bachan and Pooja, 2020). They are most predominant with evergreen trees in a moist environment, highly rainfed areas such as Western slopes of Western Ghats. The opening provided by the riverfront brings an exposure of light, which require a good percentage of deciduous and light-demanding species.

The extent of riparian vegetation influences the physical as well as the geomorphological aspects of watersheds in which they serve as the essentials for the riparian forest dynamics (Robert *et al.*, 1998). According to recent statistics, two-thirds of the world's rivers are affected by the development of more than 45,000 large and 80,000 small hydropower stations, almost half of large dams (22,000 out of an estimated 45,000) are located in China (Yu-jun Yi *et al.*, 2018). Dams are affecting riparian

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ecosystems all over the world. Consider the 139 regulated and free-flowing rivers in the United States, Canada, Europe, and former USSR that exceed 350 m^3/s in mean annual discharge. Eighty-five of them, representing 77% of the total water discharge, were strongly or moderately regulated and fragmented by dams (Dynesius and Nilsson, 1994). Studies indicate the flow diversion, alteration, reduction due to dams has a significant impact on the riverine ecosystem, its microhabitats and of flora and fauna (Braatne *et al.*, 2008). Reduced and increased flow of river may severely influence the abundance and reduction in the population rate of the specific species in the riparian vegetation The studies on riparian vegetation as well as impacts of dams on the structure composition, diversity etc. are very rare from our region.

The Chalakkudy River is having different microhabitats nurturing highest diversity of freshwater fishes among the rivers of Kerala. This river has recorded presence of low-elevation riparian forests (Bachan, 2003, 2010) which turned out to be with unique floristic and faunal composition and recognised as a unique ecosystem of high conservation priority (Bachan, 2019). There are six major dams in the Chalakkudy river and 48% of the water is being diverted to Tamil Nadu as part of the Parambikulam Aliyar Project (PAP), an interstate river diversion agreement between Kerala and Tamil Nadu (Ravi *et al.*, 2004). The systematic sampling in the Chalakkudy River revealed the presence of 19 types riparian vegetation types in four major vegetation types (Bachan and Pradeep, 2015) and recorded the highest diversity of riparian vegetation types in the Western Ghats. The impact of dams and water diversions on the Riparian vegetation has not been assessed so far.

This paper compares the vegetation composition and phytosociological parameters of riparian vegetation downstream to the dam diverted and dam-controlled area of Chalakkudy River with potential riparian vegetation. The extent of river stretch submerged under reservoirs and dried up downstream to the dams elucidated from mapping provides an insight into the extent of riparian destroyed due to the dams.

2. Materials and Methods

Study area

Chalakkudy river is the fifth longest river in Kerala, with a length of 144 km and spread of 1704 sq km originating from the Anamalai hills of Western Ghats. The major tributaries are The Karappara originating from Nelliyampathy Hills, Kuriyarkutty from Kuriyarkutty-Topslip area, Parambikulam tributary forms the Karimala-Hills and the Parambikulam Valley and the Sholayar tributary originating from the Akkamalai hills and Sholayar valley. All these tributaries confluence at Orukombankutty at the border of Vazhachal and Parambikulam forest areas then flows down as the main Chalakkudy river through the famous Vazhachal cascades and Athirapilly waterfalls, Chalakkudy town and finally joins with Kodungallur backwaters at Elanthikkara, Puthenvelikkara few kilometres before merges with the Lakshadweep sea at Kodungallur. The Kannakuzhithodu to be considered as tributaries of the Chalakkudy river based on stream characteristics (Bachan and Anitha, 2020).

There are six major dams in the Chalakkudy River, the first one being the Poringalkuthu Dam in the main Chalakkudy river commissioned during 1958, the second hydroelectric project of the state situated 3 km upstream to the Vazhachal bridge. There are two dams in the Sholayar River, the Upper Sholayar in Tamil Nadu and the Lower or Kerala Sholayar. Apart from the Sholayar Dams, the Parmbikulam group dams (Parambikulam, Peruvaripallam and Thunacadvu) were built as part of the PAP and are under the control of Tamil Nadu. The Karapara river originating from the southern slopes of the Nelliyampathi hills is the only undammed tributary of the Chalakkudy River, hence having a perineal flow. The water from the Kerala Sholayar is diverted to Anakkayam watershed finally reaching to Poringalkuthu Reservoir after power generation. Perennial water flows from nearly 100 km evergreen catchment from Karimala region of the Sholayar valley keeps the Sholayar river perineal even after its diversion for power generation in Kerala Sholayar.

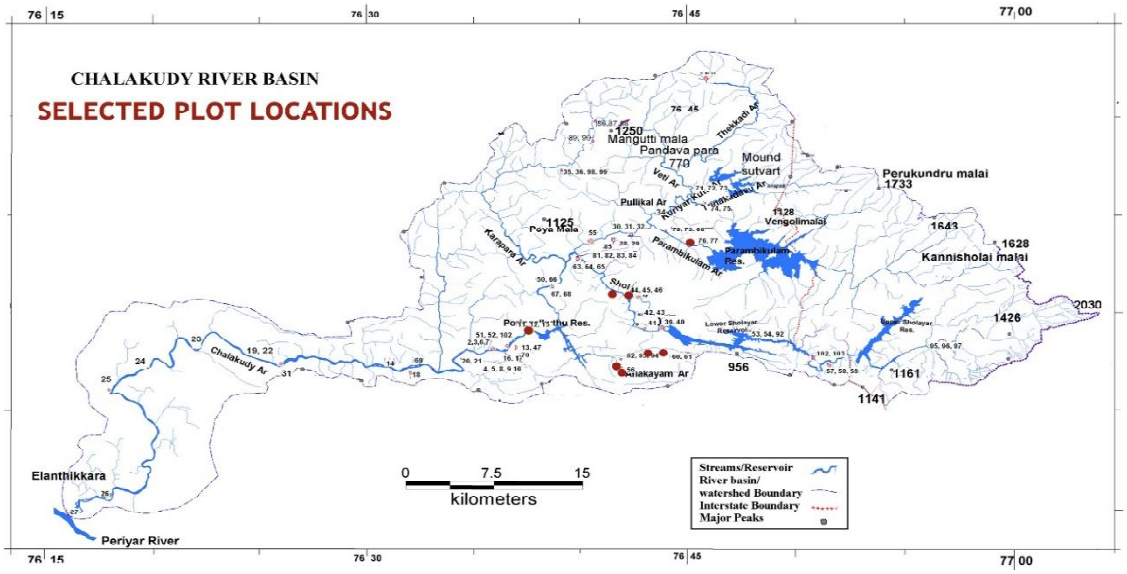


Fig. 1. Selected plot locations in the Chalakkudy river basin

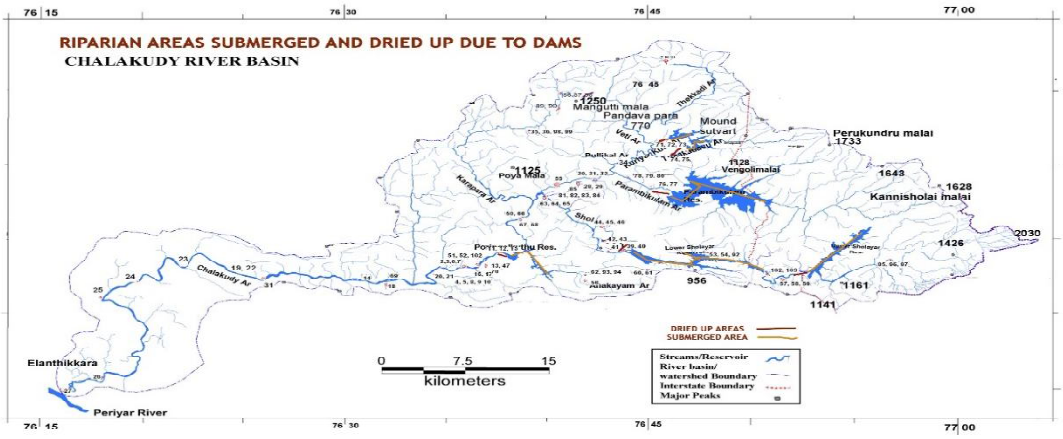


Fig. 2. Riparian areas of Chalakudy river submerged and dried up due to dams

Methodology

Mapping has been done to understand the extent of river stretch submerged underwater and dried up due to total water diversion by dams in the river basin using QGIS Software (Fig. 2).

We selected the following five locations for the comparative study of riparian vegetation: (i) Areas downstream to dams where the flow is wholly diverted: (ia) Downstream to Poringalkuthu Dam, and (ib) Downstream to Parambikulam Dam, (ii) Location along the Anakkayam tributary where the flow is dam controlled, tailrace release from the Kerala Sholayar powerhouse, (iii) Riparian areas of Sholayar River after the confluence of the perennial streams, tributary with a natural flow and (iv) A natural branch of the Anakkayam stream.

All these five locations were sampled with a plot size of 15 x 20 m (300 m^2) 3 each along the riparian areas following the method adopted for the systematic sampling of riparian vegetation in the Chalakkudy river (Bachan, 2010). All the adult trees were enumerated for its identity up to species level and Girth at Breast Height (GBH). All the plants were identified using 'Riparian Flora of Chalakkudy River' (Bachan, 2010; Gamble, 1935; Sasidharan, 2004). Each individual was tallied up to species level to get the number of total individuals per species per plot and the total basal area covered. These plot data were analysed for species similarity clustering the Biodiversity Pro and Past software to understand the heterogenic composition based on specie similarity dissimilarity coefficient. The cluster diagram plotted for the similarity well segregated (Fig. 3) fitting to the hypothesis that the species composition at the four locations separated well and multiple plots in each location clustered together with greater than 50% species similarity. Each vegetation composition was plotted with species and their IVI to understand the composition. True Riparian species (Yellow), Climax species (Green), Ruderal species (Red) and riparian associated species (blue) colour coded separately in the graphs to understand the difference in the composition as a reflection of the impact of flow alterations or diversion due to dams.

Each cluster was pooled together and analysed for phytosociological parameters such as Density, Frequency, Basal area, their Relative values and Importance Value Index (IVI). The IVI provided overall dominance of each species in vegetation and ultimately provided the composition of present riparian vegetation (Bachan 2010).

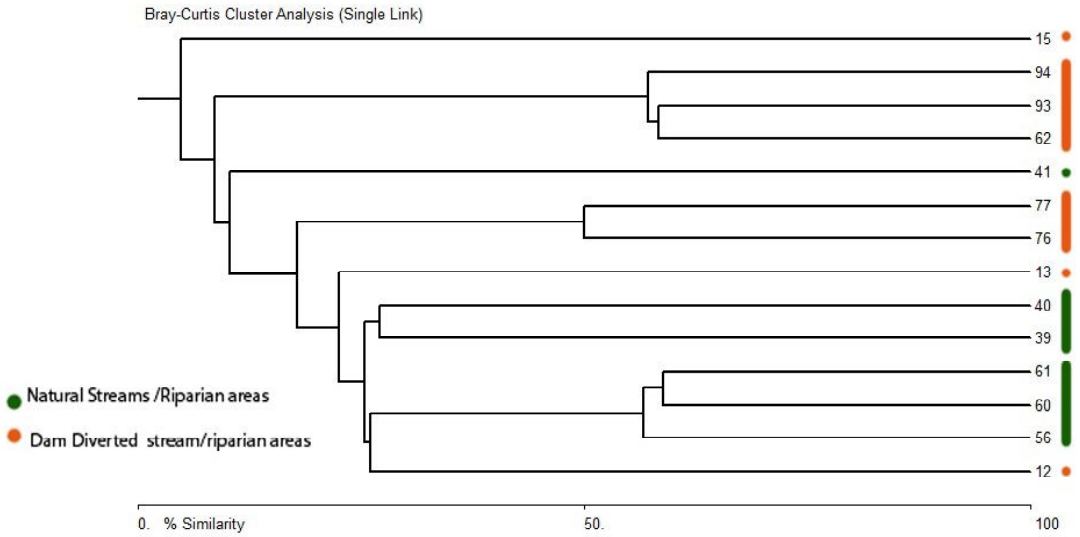


Fig. 3. Comparison of Riparian Vegetation plots using species similarity Index

3. Results and Discussion

The mapping showed that 60 km of riparian vegetation submerged due to the six dams and 28.8 km of riparian vegetation dried up due to complete diversion of waters downstream to dams in the Chalakkudy River (Fig. 2). This has destroyed an extent of 2.66 Sq. km of Riparian Forests equivalent to 80% of the now remaining riparian vegetation in the Chalakkudy river.

There are 80 dams in the rivers of Kerala of which 43 are large dams. The present estimate in the Chalakkudy river throws light into the fact that the development of dams and reservoirs could be an important reason for the degradation of riparian vegetation the rivers of Kerala. The important rivers like Periyar, Bhrathapuzha, Chaliyar, Chalakkudiyar and Pamba could be the major victims.

The plots data were subjected to Bray Curtis species similarity clustering based on the percentage of species similarity between each plot. The cluster analysis (Fig.3) revealed the segregation of plots in the five different locations differentially with less than 50% similarity in species. Hence plots in each location selected were clustered together A – Natural Riparian Vegetation, B – Natural Streamside Vegetation, C – Parambikulam downstream to Dam, D – Anakkayam Stream, E – Poringalkuthu Dam etc. This is in line with the hypothesis that the flow diversion and flow control by dams has an impact on the species composition. The similarity matrix shows that the riparian vegetation in the Dam diverted, dam-controlled, and natural flow areas differ.

Species composition of the Riparian vegetation and impact of Dams

The species composition elucidated from the IVI graph (Fig. 3) revealed the following structure and species composition in the four locations. The maximum species diversity (36 species) was observed in the location iii. Riparian areas of Sholayar River with a natural flow (after the confluence of the perennial streams); cluster A. The predominant and characteristic species include *Persea macrantha, Knema attenuate, Elaeocarpus tuberculatus, Calophyllum calaba, Aglaia barberi, Dyospyros assimils, Olea dioica* etc. out of the 36 tree species eight species (*Calophyllum calaba, Elaeocarpus tuberculatus, Hopea parviflora* etc.) are true riparian species, six (*Aglaia barberi, Terminalia bellirica, Leea indica*, etc.) are climax species, 18 are climax associated species (*Persea macrantha, Argyreia hirsuta, Hydnocarpus pentandra, Schleichera oleosa*, etc.) and only two (*Spondias pinnata* and *Ochlandra travencorica*) represent ruderal species.

Second highest species diversity was observed (22 species) for cluster B (Fig. 3) –Natural Streamside vegetation (location iv) along the natural stream of Anakkayam stream. The characteristic vegetation composition includes *Syzygium occidentalis, Salix tetrasperma, Aglaia barberi, Diospyros paniculate* etc. and several other species. Among these four species (*Syzygium occidentalis, Salix tetrasperma, Madhuca neriifolia, Callophyllum calaba)* are true riparian species, five tree species (*Vteria indica, Diospyros paniculate, Mangifera indica, etc.*) are climax species, other 12 species like (*Aglaia barberi, Schleichera oleosa, Gracinia gummi- gutta*..etc) are climax associated species. *Ochlandra travencorica* is the only ruderal species

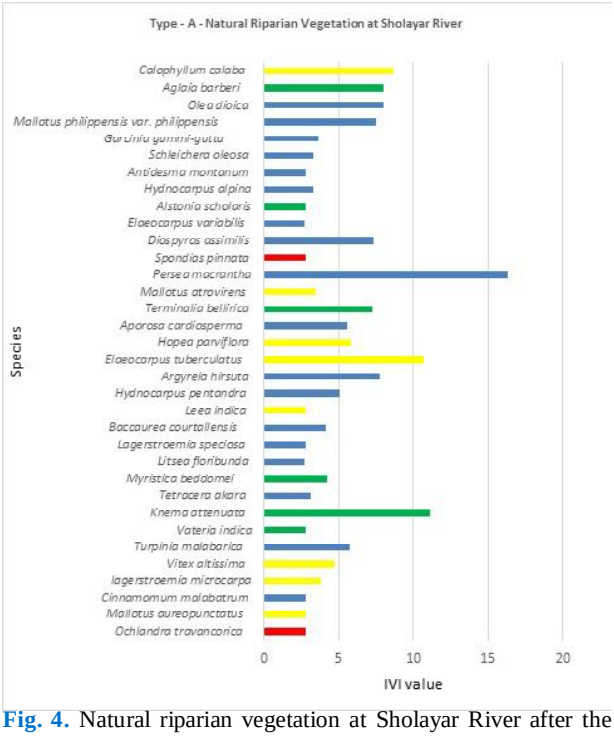


Fig. 4. Natural riparian vegetation at Sholayar River after the confluence of perennial streams

but predominate indicating a disturbance of the adjacent vegetation. (Fig. 5).

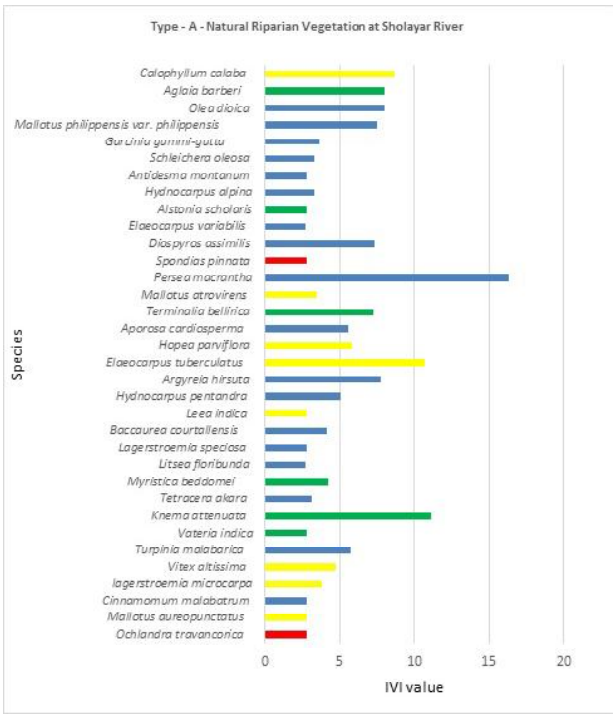
Cluster 3 represents the species diversity for C-Parambikulam downstream to dam vegetation, location i(b). The characteristic vegetation composition includes ten species mainly *Trewia nudiflora, Macranga peltate, Lannea coromandelica, Briedelia retusa*, etc. Among these *Lannea coromandelica, Macranga peltate* are ruderal species, four true riparian species (*Pongamia pinnata, Trewia nudiflora, Vitex leucoxylon, Gmelina arborea),* several other species like *Terminalia elliptica, Terminalia paniculata,* etc. The most peculiar feature is the absence of climax species in this area (Fig. 6).

The cluster (D) represent the species diversity for – Anakkayam Stream - flow controlled by Sholayar Power House tail release vegetation location ii. Here, the characteristic vegetation composition includes *Vernonia arborea, Artocarpus hirsutus, Antidesma montanum, Elaeocarpus tuberculatus*. etc. 3 climax species (*Elaeocarpus tuberculatus, Artocarpus heterophyllus, Alstonia scholaris*) and other climax related species (*Vernonia arborea, Antidesma montanum* are predominantly seen over these areas (Fig. 7).

Anakkayam Stream -downstream to Sholayar Power House tail release

The cluster E represent the species diversity for Poringalkuthu, location i(a). The characteristic vegetation composition includes *Xylia xylocarpa* as the most predominant species, four ruderal species (*Ochlandra travancoria, Lannea coromandelica* etc.) 2 true riparian species (*Ficus racemosa, Barringtonia acutangula)* and other climax related species (Fig. 8).

Shannon diversity index, total Basal area of climax species also indicate the less diversity for trees in the dam diverted riparian vegetation (Fig. 9 & Fig. 10) and dam controlled areas when comparing to riparian vegetation with the natural flow.



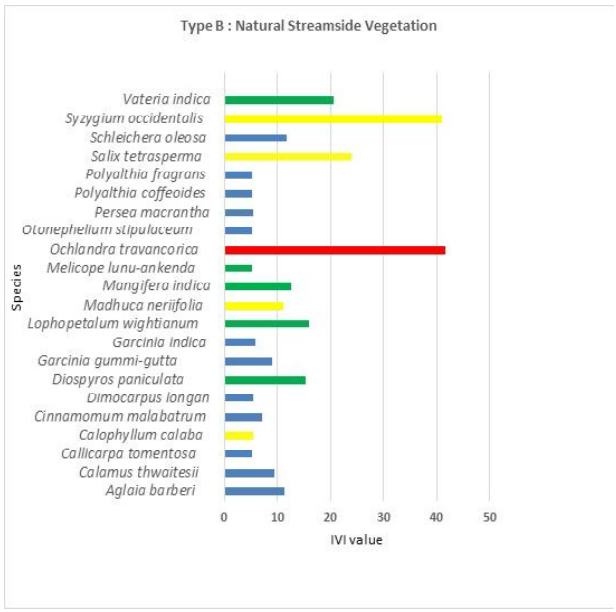


Fig. 5. Composition of natural streamside vegetation – Anakkayam Stream upstream

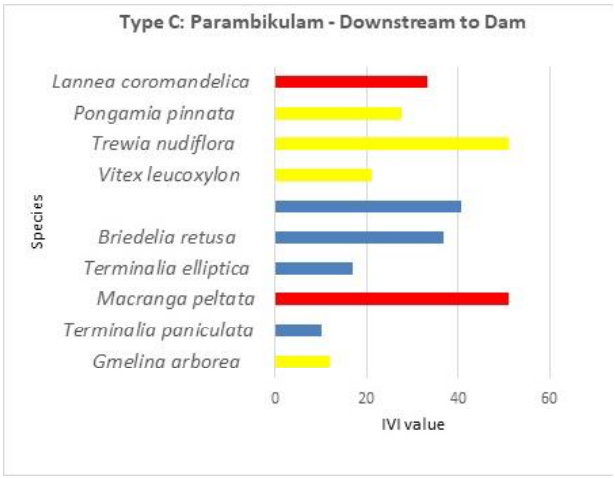


Fig. 6. Composition of riparian vegetation in Parambikulam downstream to the dam

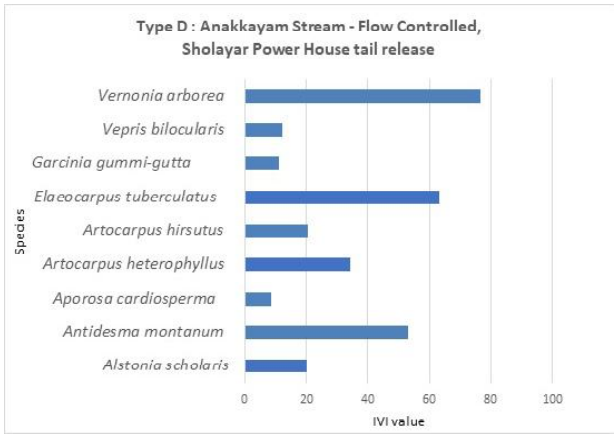


Fig. 7. Riparian vegetation composition of the flow controlled stream

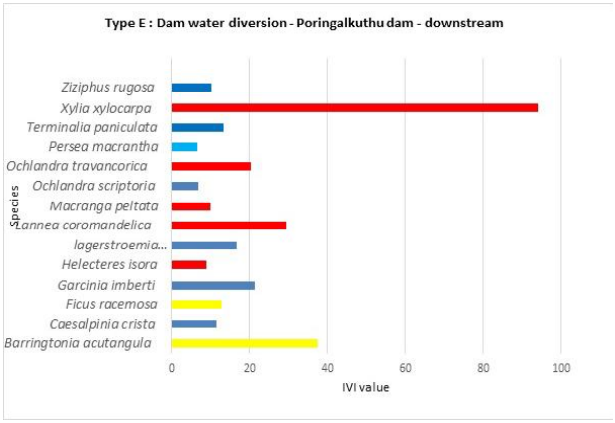


Fig. 8. Riparian vegetation composition downstream to Poringalkuthu Dam

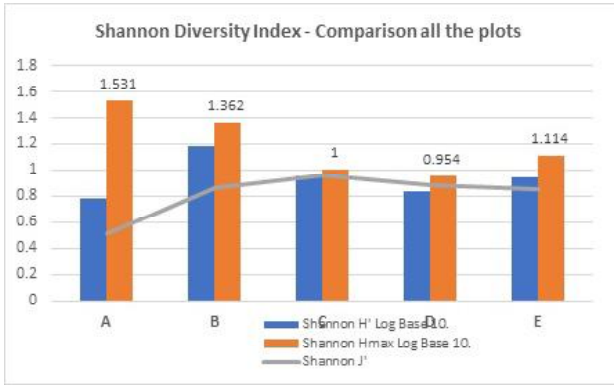


Fig. 9. Shannon diversity index – Dams impact on Riparian Vegetation

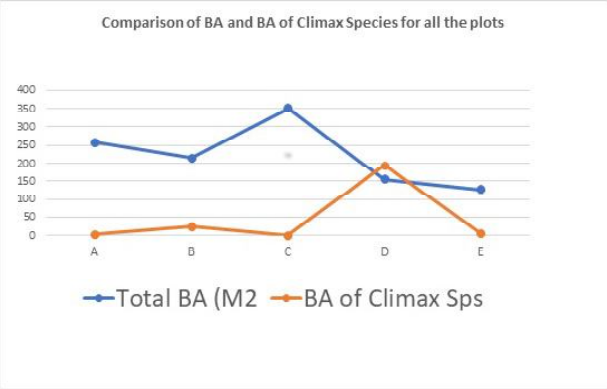


Fig. 10. Comparison of basal area and basal area of climax species

Impact of dams on riparian vegetation of the Chalakkudy river is mapped to understand the total riparian area submerged and dried up due to dams and found to be 60 km and 22.8 km respectively destroying nearly 80% equivalence tot eh now existing riparian vegetation in the River (Bachan, 2010). In the Tucuruí project in the Amazon, 20 million m3 of high-quality timber were inundated (Barrow, 1988). Although upstream and downstream reaches are both impacted by some alterations such as fragmentation of the river corridor (Jansson *et al*., 2000).

Both physical and biological understanding of the consequences of Dams on riparian and streamside vegetation is important (Williams and Wolman 1984; Nilsson and Berggren 2000. The comparative statistical analysis of riparian vegetation in four different situations at five locations reveals there have been drastic impacts of dams on riparian vegetation in its composition, structure, diversity and vegetation characteristics. The species composition in different selected locations varies in relations with the impact of dams, i.e. 1. complete diversion 1(a) and 1(b), 2. Water flow is dam controlled (location ii). These compositions are of less species diversity, absence or less climax or climax associated species, more number of ruderal species and presence of secondary riparian vegetation types when compared to the potential vegetation. Other studies also indicate Riparian wetlands, deltas, and estuaries are usually highly productive and have high species numbers but may degrade following river regulation (Foote *et al*., 1996).

The vegetation in the other two locations where dams have no impact, perennial river and stream showed natural vegetation location iii. and iv. have high species diversity, more number of climax, climax associated and riparian species and less number of ruderal indicating the healthy evergreen riparian vegetation in the same area where there is no impact of dams and reservoirs. The presence of ruderal species are the indicators of high intensity of light, openings in the riverfront could be treated as a part of the regular dynamism of the riparian systems when up to a tiny percentage. The relative percentage of ruderal species increases with disturbance and more in entirely dam diverted regions when compared to dam-controlled areas and natural riparian areas.

Comparative account of phytosociological parameters, IVI and vegetation composition of location 1 dam diverted (Fig. 6 and Fig. 8) and location 2 (Fig. 7) where the flow is dam controlled indicate that the complete diversion of river water by dams cause heavy damage to the riparian vegetation in its composition, diversity and phytosociological characteristics. The flow control by dams also degrade riparian vegetation but little better than a complete diversion. This is evidence that the riparian restoration requires ecological flow or flow regulation has to be brought in accordance with the natural flow of the river. Water regulation from dams has to be regulated looking at the regular flow pattern of the river in each stretch since this has a significant influence on the structure and composition of riparian vegetation. Studies indicate that the removal of dams and bringing regular ecological flow downstream to dams based on the natural flow pattern is essential for river restoration process (Shafroth *et al*., 2016). The present investigation suggests decommissioning of dams in possible locations and bringing the natural regular flow while synchronised operationalization of dam waters as an essential process for restoration of riparian vegetation. This is also important for the restoration of other functional aspects of the river and riverine ecosystem, including the migration of fishes (Thomas *et al*., 2020).

4. Conclusion

The present study reveals that the dam diversion and alteration decreased the climax species, increased the presence of ruderal species, decreased diversity and degraded the riparian vegetation into secondary degradation types. Comparative account of phytosociological parameters, IVI and vegetation composition of dam diverted has heavy damage to the riparian vegetation in its composition, diversity and phytosociological characteristics where as that of the dam controlled has degraded the diversity and composition. The study suggests synchronized operationalisation of dams to maintain the regular flow as essential process for the conservation of remaining riparian vegetation as well as for other essential ecological functioning of the river.

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5. References

Amitha Bachan, K. H. 2019. Ecological Monitoring of important forest resources Hornbills, Smaller Mammals and MFPs Involving and empowering communities in supporting working plan preparation towards developing an online platform for the Hornbill Monitoring since 2005. Final Research Report. Submitted to FDA Vazhachal, Kerala Forest Department. 245pp.

Amitha Bachan, K. H., Shajan, M.P., Anitha, K. T., Pooja Suresh. and Sreehari, S. Nair. 2019. Assessment of Impact of flood/ landslide on Biodiversity and developing methodology for long-term monitoring and evaluation of changes in the ecosystem and biodiversity: A case study in the Athirapilly Panchayath. Flood Impact Study. Final Research Report. Submitted to Kerala State Biodiversity Board. 224pp.

Amitha Bachan, K.H. and Pradeep, A.K. 2010. The community composition and classification of the riparian vegetation of the Chalakkudy River, Western Ghats and its significance in the management of forested landscape and biodiversity, proceedings of the First Indian Biodiversity Congress, December 2010, Thiruvananthapuram.

Amitha Bachan, K.H. and Anitha, K.T. 2020. A classification system for streams and watersheds in Rivers of Kerala for effective watershed and river basin management: A case study in Chalakkudy River. Proceedings of the International Conference on River for Future International Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram. 25 p.

Amitha Bachan, K.H. and Pooja, S. 2020. Riparian forest types in Kerala: An addition to Champion and Seth forest classification. Proceedings of the International Conference on River for Future, Journal of Aquatic Biology and Fisheries,, University of Kerala, Thiruvananthapuram. 21 p. Proceedings.

Amitha Bachan, K.H. 2003. Riparian Vegetation along the Middle and Lower Zones of the Chalakudy River, Kerala, India. Final Research Report 26/2000. Submitted to, KRPLLD, CDS, Thiruvananthapuram.314pp.

Amitha Bachan, K.H. 2005. Riparian Vegetation Along Chalakudy River. In: Nair K.N. & S. Chattopadhyay. (eds.), Water Resources of Kerala – Issues and Case Studies. KRPLLD, Centre for Developmental Studies, Thiruvananthapuram. 83-86.

Amitha Bachan, K.H. 2010. Riparian flora of the Chalakkudy river basin and its ecological significance. PhD Thesis, Calicut University, Kerala, INDIA. 945 pp.

Barrow, C. 1988. The impact of hydroelectric development on the Amazonian environment: With particular reference to the Tucuruí Project. *Journal of Biogeography*. 1567-78. DOI: 10.2307/2845047

Braatne, J.H., Rood, S.B., Goater, L.A., Charls and L. Blair. 2008. Analyzing the Impacts of Dams on Riparian Ecosystems: A Review of Research Strategies and Their Relevance to the Snake River Through Hells Canyon. Environmental Management., 41, 267-281. DOI: 10.1007/s00267-007-9048-4

Capon, S. J. and Dowe, J. L. 2007. Diversity and dynamics of riparian vegetation, in: Principles for riparian lands management, edited by: Lovett, S. and Price, P., Land & Water Australia, Canberra, AUS, 3–33, 2007.

Champion, H.G. and Seth, S.K. 1968. Revised survey of the forest types of India. New Delhi: Manager of Publications. 404 pp.

Foote, A.L., Pandey, S. and Krogman, N.T. 1996. Processes of wetland loss in India. Environmental Conservation 23. 45-54. https://www.jstor.org/stable/44519180

Gamble, J.S.1925. Flora of the Presidency of Madras. Vol. 2. Adlard and Son. Ltd., London, pp. 126-132.

Jobi, P. and George, K.V.2010. Studies on riverine flora of Pamba river basin, Kerala. Proceedings of XVIII Annual conference of IAAT and international seminar on multidisciplinary approaches in angiosperm systematics. pp. 121–122.. 10.1038/ npre.2010.5135.1

Levine, R. and Meyer, G.A. 2019. Beaver-generated disturbance extends beyond active dam sites to enhance stream morphodynamics and riparian plant recruitment. Sci Rep 9, 8124.

Lind, L., Hassel Quist, E.M. and Laudon, H. 2019. Towards ecologically functional riparian zones: a meta-analysis to develop guidelines for protecting ecosystem functions and biodiversity in agricultural landscapes. J Environ Manag., 249 (1):109391.

Mats, D. and Christer, N. 1994. Fragmentation and Flow Regulation of River System in the North Third the World, Science, New Series., American Association for the Advancement of Science. 266, 753-762.

Naiman, R.J., Decamps, H. and Pollock, M. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applicatio*ns, (3): 209-212.

Nilsson, C. and Berggren, K. 2000. Alteration of riparian ecosystems caused by river regulation. *BioScience* 50:783–792

Ravi, S.P., C.G. Madhusoodhanan., A. Latha., S. Unnikrishnan and Amitha Bachan, K.H. 2004. Tragedy of Commons – The Kerala Experience in River Linking. River Research Centre & South Asia Network on Dams Rivers & People. RRC, Thrissur, Kerala, India.

Robert, J. Naiman., Kevin, L. Fetherston., Steven, J. McKay, and Jiquan, Chen; 1998, Riparian Forests, In; R.J. Naiman, R.E. Bilby. (eds.), Ecology and management of Streams and Rivers in the Pacific Northwest Coastal Ecoregion, chapter- 12, Springer-Verlag, pp. 289-323.

Sasidharan, N. 2004. Flowering plants: Biodiversity documentation Kerala. Kerala forest Research Institute.

Shafroth, P. B., L. G. Perry, C. A. Rose, and Braatne, J. H. 2016. Effects of dams and geomorphic context on riparian forests of the Elwha River, Washington, Ecosphere, 7(12).

Sunil, C., Kalegowda, R., Badenhally, S and Nagaraja, B.C. 2016. Diversity and composition of riparian vegetation across forest and agro- ecosystem landscapes of river Cauvery, southern India. Tropical Ecology 57(2):343-354.

Thomas, T., Alexandre, C., Anthony, A., Fabien, C., Virgile M, Valentin D and Éric, F.2020. When “safe” dams kill: Analyzing combination of impacts of overflow dams on the migration of silver eels. Ecological Engineering. 145. 105741.

Williams, G.P. and Wolman, M.G. 1984. Downstream effects of dams on alluvial rivers. U.S. Geological Survey Professional Paper, 1286, 83 p. DOI: https://doi.org/10.3133/pp1286

Yu-jun Y., Zhou Y., Song J., Shanghong Z., Cai Y., Yang W.and Zhifeng, Y. 2018. The effects of cascade dam construction and operation on riparian vegetation. Advances in Water Resources. 131: 103206. DOI: https://doi.org/10.1016/ j.advwatres.2018.09.015.