**Rarity and viability value of different type of ecosystem and plants species in tropical forest ecosystem of Bungoh Catchment, Sarawak, Malaysia**

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**Abstract:** Bungoh catchment is located in the southern part of Sarawak, Malaysia and south east of Kuching town and densely covered by tropical forests. A study was conducted to determine the rarity and viability values of plant species and also the rarity and viability values of the four different types of forest ecosystem of Bungoh Catchment. The four major forest ecosystems include the primary forest, old secondary forest, young secondary forest and agroforestry. The numbers of trees were recorded from the entire three different forest ecosystem using single plant method of size 400 square meters (20m X 20m). A total of 373 individual trees representing 148 species were recorded from the four different types of forest ecosystem. Out of 148 species, 22 species were recorded from the primary forest, 72 species were recorded from old secondary forest whereas 37 species were recorded from young secondary and the remaining 17 species were recorded from agroforestry. The rarity and viability value of plants species or ecosystem types is of immediate importance for the biodiversity conservation. The approach is designed for assessment of the rarity and viability values of plants species in the four major forest ecosystems in Bungoh Catchment. The rarity values are measured based on the frequency of certain plants species or ecosystems types are encountered whereas the viability value is assessed by considering three indicators which includes the core area, isolation and disturbances. The results indicate that the rarity value of all the four types of ecosystem namely the primary forest, old secondary forest, young secondary forest and agroforestry were relatively high indicating that the species in the ecosystem are distributed equitably and reflect the commonness of the species. Conversely, the viability value of the entire four ecosystems relatively low indicating that the species are prone to extinction.

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**1. Introduction**

In its broadest definition ecosystem rarity refers to how frequently an ecosystem type is found within a given area which includes limited geographic distribution and limited population size (Wood, 2002; Geneletti, 2003; and Nageswara Roa, 2012). The phenomenon of rarity in tropical tree communities has been known qualitatively in Western scientific circles at least since the writings of Alfred Russel Wallace (1878). However, not until recently have bio geographers and ecologists systematically quantified diversity, rarity and viability in tropical tree communities (Hubbell, 2013). According to Fiedler (2001) and Nageswara Roa (2012) there are two distinct types of rarity namely natural rarity and anthropogenic rarity. The natural rarity occurs because the species lives in a very limited habitat and those species have always been rare during their evolutionary history whereas the anthropogenic rarity occurs because its habitat has been converted by humans to other uses agriculture, dams and other form of land development. The conservation of biodiversity focus on the rare species has been further justified by the potential role that rare species may play in maintaining overall ecosystem functionality (Curtis et al. 2007). Being the basic goal of biodiversity conservation to maintain the full richness of life on earth, it appears logical that the actual cover and distribution of an ecosystem type influence its relevance and protection worthiness. As a result, the use of rarity as criteria in biodiversity conservation is due to the fact that the rarer is the feature the higher is its probability of disappearance (Geneletti, 2003 and Flather et al. 2007).

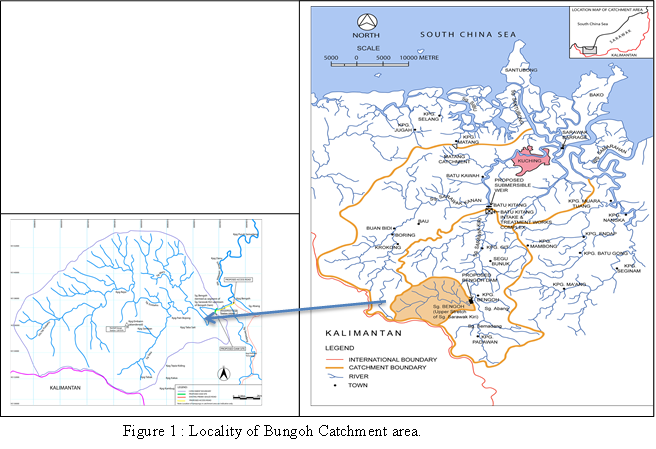
The viability value of the species is affected by the relative increase of the edge length of the habitat fragment (Ryszkowski, 1992; Restrepo et al. 1999; Honnay et. al, 2005). Viability assessment is viewed as an integral part of the on-going forest service and land management as well as decision process, and, in turn, monitoring is an integral component of the overall process used by the forest service to manage species viability, including selected species whose likelihood of extinction is minimal, to ensure they remain so ( Sandy et. al, 2001). Thus, the population viability is of immediate importance for plant conservation. Nevertheless, the current documentation of viability assessments of plants species particularly in the tropical forest ecosystem is inadequate (Sandy et. al, 2001).

In this study, rarity value is a measure based on how frequently certain species or ecosystem types are encountered (Edwards-Jones et al.2000, Geneletti 2003; Flather et al. 2007; Thonoir 2010). The rarity value is in the form of numerical and the value ranging between zero and one. One corresponds to the highest relevance, i.e., to ecosystems whose remnant cover has dramatically decreased, posing a serious threat to their chances of conservation within the Bungoh Catchment whereas zero corresponds to the lowest relevance, i.e., to ecosystems whose original cover is virtually entirely preserved with the area. The ecosystem viability is to be assessed by considering three indicators which include the core area, isolation and disturbance (Geneletti 2003; Monavari 2010). The value function of the three indicators are first generated, and then summed up. Weights can be used to express the relative relevance of each indicator. The function assigns a dimensionless score between zero and one. Such a score is a numerical representation of the degree to which the indicator value contributes to the ecosystem viability. A score of zero indicates the worst possible condition, whereas a score of one indicates the ideal ones.

**2. Material and Methods**

**2.1 Study area**

The study was carried out at the Bungoh catchment which is a segment of Sarawak Kiri River catchment areas and upstream of Bungoh Dam. It is located in latitude between 1.184° to 1.296° N and in longitude between 110.106° to 110.242° E and 60 km from Kuching, the capital of Sarawak (Figure 1).



The catchment covers an area of approximately 127 square kilometres. The altitude ranges from 20m to 1300 m a.s.l. The forest ecosystem constitutes primary forest, secondary forest and agro-forest. The climate is equatorial type with warm and humid weather throughout the year; and annual rainforest of the area is approximately 3.990 mm/year with a high proportion falling during the North West monsoon season from November to February. The driest period occurs from June to August. The mean temperature is approximately 26.6°C and the mean relative humidity is around 85.3%. The wind pattern in this area generally shows relatively calm condition with 33.9% of the time with wind blowing and light breezes were recorded for 42% of the time. The catchment is an area of complex geology involving a whole range of sedimentary rocks, igneous intrusive and extrusive rocks with associated metamorphism.

**2.2 Field Sampling**

A survey was carried out by the single plot method based on 29 random sampling plots. Each plot (20 m x 20 m) was divided into four subplots (10 m x 10 m). In each quadrate, the parameters recorded during the vegetation survey include circumference (diameter at breast height, dhb ≥5 cm), trees height, type of forests ecosystem and plant species. All terrestrial plant species encountered during field survey were identified and when it was impossible to do so, the voucher specimens were collected and identified in the herbarium and a list of plant species that occurred within the study boundary were compiled.

**2.3 Rarity Value**

Rarity value is a measure of how frequently certain species or ecosystem types are encountered (Tallis et al. 2011) and can be calculated as:



*REi* = Rarity value of species *i*

= Total value of species in ecosystem *j*



= Total number of species in ecosystem *j*



**2.4 Viability values**

Three patch indicators have been selected to measure ecosystem viability. The indicators are the core area, isolation and disturbance.

(a) Core

This indicator can be calculated as follows:



*Sci* = Core area of species *i*

*Sj* = Actual area of species *j*

*Fj* = Fragment area of species *j*

( 0 ≤ *Vci* ≤ 1)



*Vci* = Core value of species *i*

*Scj* = Core area of species *j*

*Hvj* = The highest value core area of ecosystem *j*

(b) Isolation

This indicator can be generated based on edge-to-edge distance between a patch and its surrounding patches and calculated as follows:



*Ii* = Isolation of species *i*

*Fj* = Fragment area of species *j*

= Total area remaining of species *j*



= Total isolation of species in ecosystem *j* ( 0 ≤ ≤ 1 )



= Isolation value of species *i*



*Ij* = Isolation of species *j*

*HIVj* = highest isolation value of species in ecosystem *j*

(c) Disturbance

This indicator can be generated by measuring the average distance between the edges of an ecosystem patch and the surrounding sources of disturbance, i.e., anthropogenic activities such as shifting cultivation and resettlement (villages).



*Di* = Disturbance of species *i*

*Fj* = Fragment area of species *j*

= Remaining perimeter of species *j*



= Total disturbance of species in ecosystem *j*



*DVi* = Disturbance value of species *i*

*Dj* = Disturbance of species *j*

= Highest disturbance value of species in ecosystem *j*



(d) Viability value

Ecosystem viability can be calculated using the following expression ( Geneletti 2003):



**3. Results and Discussion**

A total of 373 individual trees representing 148 species were recorded from the four different types of forest ecosystem namely the primary forest, the old secondary forest, the young secondary forest and agroforestry of Bungoh catchment. Out of 148 species, 22 species were recorded from the primary forest (Table 1), 72 species were recorded from old secondary forest (Table 2) whereas 37 species were recorded from young secondary ( Table 3) and the remaining 17 species were recorded from agroforestry (Table4).

Table 1. Rarity and viability values of Primary forest

|  |  |  |
| --- | --- | --- |
| Species | Rarity  Value | Viability  value |
| *Koompassia excelsa* | 0.939 | 0.451 |
| *Tristaniopsis whiteana* | 0.939 | 0.481 |
| *Shorea scabrida* | 0.954 | 0.451 |
| *Shorea macrobalanos* | 0.957 | 0.601 |
| *Syzygium sp.* | 0.962 | 0.475 |
| *Artocarpus kemando* | 0.964 | 0.486 |
| *Ilex cissoidea* | 0.965 | 0.576 |
| *Dryobalanops beccarii* | 0.969 | 0.653 |
| *Alphitonia excelsa* | 0.970 | 0.677 |
| *Ficus sp.* | 0.972 | 0.777 |
| *Sterculia sp.* | 0.979 | 0.454 |
| *Mangifera foetida* | 0.982 | 0.475 |
| *Shorea angustifolia* | 0.982 | 0.608 |
| *Cratoxylum glaucum* | 0.983 | 0.464 |
| *Litsea sp.* | 0.983 | 0.549 |
| *Knema sp.* | 0.984 | 0.466 |
| *Artocarpus sarawakensis* | 0.985 | 0.469 |
| *Myristica lowiana* | 0.985 | 0.625 |
| *Pometia pinnata* | 0.985 | 0.780 |
| *Ixonanthes reticulata* | 0.986 | 0.569 |
| *Alangium kurzii* | 0.987 | 0.462 |
| *Xylopia ferruginea* | 0.987 | 0.505 |

Table 2 : Rarity and viability values of old secondary forest

|  |  |  |
| --- | --- | --- |
| Species | Rarity Value | Viability Value |
| *Alstonia angustifolia* | 0.936 | 0.612 |
| *Artocarpus kemando* | 0.972 | 0.469 |
| *Artocarpus elasticus* | 0.976 | 0.456 |
| *Litsea sp.* | 0.980 | 0.440 |
| *Nephelium maingayi* | 0.985 | 0.380 |
| *Campnosperma auriculatum* | 0.986 | 0.414 |
| *Garcinia nitida* | 0.986 | 0.416 |
| *Aporosa sp.* | 0.988 | 0.409 |
| *Adinandra dumosa* | 0.988 | 0.369 |
| *Castanopsis pedunculata* | 0.989 | 0.403 |
| *Artocarpus integer* | 0.990 | 0.399 |
| *Syzygium sp.* | 0.990 | 0.391 |
| *Sterculia rubignosa* | 0.990 | 0.368 |
| *Pternandra cognianxii* | 0.991 | 0.396 |
| *Xylopia sp.* | 0.992 | 0.392 |
| *Ochanostachys amentacea* | 0.992 | 0.383 |
| *Pellacalyx lobbii* | 0.992 | 0.374 |
| *Canarium sp.* | 0.994 | 0.383 |
| *Cratoxylum arborescens* | 0.994 | 0.385 |
| *Cratoxylum cochinchinense* | 0.994 | 0.384 |
| *Albizia dolichadena* | 0.994 | 0.385 |
| *Koompassia malaccensis* | 0.994 | 0.384 |
| *Norrisia malaccensis* | 0.994 | 0.382 |
| *Carallia coriifolia* | 0.994 | 0.393 |
| *Sarcotheca glauca* | 0.994 | 0.369 |
| *Baccaurea maingayi* | 0.995 | 0.380 |
| *Parkia speciosa* | 0.995 | 0.378 |
| *Castanopsis hypophoenicea* | 0.995 | 0.381 |
| *Ardisia sp.* | 0.995 | 0.381 |
| *Nephelium subfalcatum* | 0.995 | 0.399 |
| *Elaeocarpus sp.* | 0.996 | 0.375 |
| *Dialium indum var. indum* | 0.996 | 0.375 |
| *Cantleya corniculata* | 0.996 | 0.375 |
| *Lasianthus sp.* | 0.996 | 0.368 |
| *Saurauia acuminata* | 0.997 | 0.371 |
| *Melanochyla speciosa* | 0.997 | 0.370 |
| *Cratoxylum formosum* | 0.997 | 0.370 |
| *Cratoxylum glaucum* | 0.997 | 0.372 |
| *Dillenia sp.* | 0.997 | 0.371 |
| *Archidendron jiringa* | 0.997 | 0.370 |
| *Gnetum gnemon* | 0.997 | 0.372 |
| *Ixonanthes petilolaris* | 0.997 | 0.373 |
| *Fagraea borneensis* | 0.997 | 0.370 |
| *Prainea frutescens* | 0.997 | 0.371 |
| *Knema galeata* | 0.997 | 0.371 |
| *Knema latifolia* | 0.997 | 0.372 |
| *Morinda elliptica* | 0.997 | 0.368 |
| *Eugenia elliptilimba* | 0.997 | 0.385 |
| *Saurauia myrmecoidea* | 0.998 | 0.368 |
| *Alangium javanicum* | 0.998 | 0.369 |
| *Vernonia arborea* | 0.998 | 0.370 |
| *Garcinia bancana* | 0.998 | 0.369 |
| *Ardisia sp.* | 0.998 | 0.368 |
| *Archidendron borneense* | 0.998 | 0.368 |
| *Xanthophyllum griffithii* | 0.998 | 0.368 |
| *Lithocarpus havilandii* | 0.998 | 0.370 |
| *Ficus grossularioides* | 0.998 | 0.368 |
| *Artocarpus odoratissimus* | 0.998 | 0.369 |
| *Horsfieldia crassifolia* | 0.998 | 0.368 |
| *Ardisia* *macrophylla* | 0.998 | 0.368 |
| *Syzygium bankense* | 0.998 | 0.398 |
| *Porterandia sessiliflora* | 0.998 | 0.375 |
| *Porterandia sp.* | 0.998 | 0.369 |
| *Tarenna winkleri* | 0.998 | 0.368 |
| *Canthium glabrum* | 0.998 | 0.368 |
| *Meliosma rufo- pilosa* | 0.998 | 0.420 |
| *Eurya nitida* | 0.998 | 0.406 |
| *Gironniera parvifolia* | 0.998 | 0.368 |
| *Vitex pubescens* | 0.998 | 0.369 |
| *Vitex vestita* | 0.998 | 0.369 |
| *Timonius flavescens* | 0.998 | 0.382 |
| *Pithecellobium jiringa* | 0.998 | 0.373 |

Table 3: Rarity and viability values of young secondary forest

|  |  |  |
| --- | --- | --- |
| Species | Rarity  Value | Viability  value |
| *Endospermum diadenum* | 0.940 | 0.640 |
| *Gaetnera vaginans* | 0.952 | 0.625 |
| *Alstonia spatulata* | 0.958 | 0.590 |
| *Macaranga becceriana* | 0.971 | 0.521 |
| *Macaranga hosei* | 0.977 | 0.487 |
| *Helicia attenuate* | 0.979 | 0.477 |
| *Adinandra dumosa* | 0.981 | 0.462 |
| *Litsea varians* | 0.987 | 0.430 |
| *Cratoxylum arborescens* | 0.988 | 0.428 |
| *Glochidion borneense* | 0.989 | 0.420 |
| *Fagraea fagrans* | 0.990 | 0.413 |
| *Horsfieldia grandis* | 0.990 | 0.416 |
| *Sarcotheca glauca* | 0.992 | 0.402 |
| *Macaranga gigantean* | 0.992 | 0.405 |
| *Helicia petiolaris* | 0.992 | 0.406 |
| *Vernonia arborea* | 0.993 | 0.398 |
| *Xylopia furruginea* | 0.993 | 0.400 |
| *Kostermanthus heteropetala* | 0.994 | 0.393 |
| *Cratoxylum formosum* | 0.994 | 0.395 |
| *Pithecellobium jiringa* | 0.995 | 0.385 |
| *Ploiarium alternifolium* | 0.995 | 0.388 |
| *Elaeocarpus nitidus* | 0.995 | 0.388 |
| *Timonius borneensis* | 0.995 | 0.389 |
| *Euodia latifolia* | 0.995 | 0.389 |
| *Anthocephalus cadamba* | 0.996 | 0.382 |
| *Hevea brasiliensis* | 0.997 | 0.375 |
| *Artocarpus elasticus* | 0.997 | 0.376 |
| *Barringtonia sarcostachys* | 0.997 | 0.377 |
| *Macaranga pruinosa* | 0.997 | 0.378 |
| *Millettia chaperii* | 0.997 | 0.379 |
| *Dillenia suffroticosa* | 0.998 | 0.372 |
| *Anisophyllus disticha* | 0.998 | 0.372 |
| *Garcinia havilandii* | 0.998 | 0.372 |
| *Lepisanthes alata* | 0.998 | 0.372 |
| *Vitex pubescens* | 0.998 | 0.373 |
| *Adinandra acuminate* | 0.998 | 0.373 |
| *Parkia javanica* | 0.998 | 0.373 |

Table 4 : Rarity and viability values of agroforestry

|  |  |  |
| --- | --- | --- |
| Spcies | Rarity Value | Viability  Value |
| *Hevea brasiliensis* | 0.806 | 0.640 |
| *Durio zibethinus* | 0.883 | 0.529 |
| *Nephelium lappaceum* | 0.920 | 0.476 |
| *Elateriospermum tapos* | 0.936 | 0.453 |
| *Shhorea macrophylla* | 0.975 | 0.396 |
| *Artocarpus integer* | 0.979 | 0.390 |
| *Garcinia mangostana* | 0.981 | 0.387 |
| *Shorea palembanica* | 0.983 | 0.385 |
| *Mangifera foetida* | 0.987 | 0.379 |
| *Baccaurea angulata* | 0.987 | 0.379 |
| *Artocarpus heterophyllus* | 0.987 | 0.379 |
| *Shorea splendida* | 0.989 | 0.376 |
| *Parkia speciosa* | 0.991 | 0.373 |
| *Theobroma cacao* | 0.991 | 0.373 |
| *Nephelium maingayi* | 0.993 | 0.369 |
| *Annona foetida* | 0.994 | 0.369 |
| *Artocarpus elasticus* | 0.994 | 0.369 |

**3.1 Rarity value**

In the primary forest ecosystem, the lowest value of rarity is shown by Tristaniopsis whiteana and Kompossia excelza with the rarity value of 0.939 and the highest rarity value is shown by Alangium kurzii and Xylopia ferruginea with the value of 0.987 (Table 1). In the old secondary forest, Alstonia angustifolia gives the lowest rarity value ( 0.936) followed by Artocarpus kemando (0.972) and Artocarpus elasticus (0.976) and 20 species exhibit the highest rarity value which is 0.998 (Table 2), whereas in young secondary forest, Endospermum diadenum gives the lowest rarity value(0.940) followed by Gaetnera vaginans (0.952) and the third lowest is shown by Alstonia spatulata with the rarity value 0.958 and seven species exhibit the highest rarity value which is 0.998 (Table 3). In the Agroforestry ecosystem, the lowest rarity value is shown by Hevea brasilienis which is 0.806 followed by Durio zibethinus with the rarity value 0.883 and Nephelium lappaceum with the rarity value of 0.920 whereas the highest rarity value is given by Annona foetid and Artocarpus elasticus which is 0.94 (Figure 4). Among the four types of forest ecosystem, secondary forest shows the highest (Table 5) rarity value (0.994) followed by the young secondary forest (0.989). Agroforestry gives the lowest rarity value which is 0.963 whereas primary forest exhibits the second lowest with the rarity value of 0.973. Hubbell(2013) state that species in tropical forests demonstrate high value of rarity particularly in the lowland tropical forest. A similar result shows in this study where the old secondary forest and young secondary forest which dominate the entirely lowland area of the Bungoh Catchment exhibit the highest rarity value which is 0.994 and 0.989 respectively. This provides a significant challenge for conservation of tropical forest tree diversity.

Generally, all the four forest ecosystem exhibit high rarity values. This corresponds to the highest relevance, i.e. to ecosystem where remnant cover has dramatically decreased posing a serious threat to their chances of conservation within the area. The driving force behind plant rarity in Bungoh Catchment is the destruction, degradation, and fragmentation of habitat by anthropogenic activities which include a huge dam projects. Similar to our results, Noss and Peters(1995) and Nageswara Roa (2012) found out that the common cause of rarity for plant species include conversion of their natural habitat into other unsuitable habitats by agriculture, forestry, dams, harvesting of plants, and recreation.

Table 5 : Rarity and viability values of four different types of forest ecosystem of Bungoh catchment

|  |  |  |
| --- | --- | --- |
| Ecosystem types | Rarity value | Viability value |
| Primary forest | 0.973 | 0.548 |
| Old secondary forest | 0.994 | 0.398 |
| Young secondary forest | 0.989 | 0.420 |
| Agroforestry | 0.963 | 0.413 |

**3.2 Viability values**

In primary forest, Koompassia excelsa and Shorea scabrida give the lowest viability value which is 0.451 followed by Sterculia sp (0.454) whereas the highest viability value is shown by Pometia pinnata (0.780). In the old secondary forest, thirteen species exhibit the lowest viability which is 0.368. Those species encompass of Sterculia rubignosa, Lasianthus sp. Morinda elliptica, Saurauia myrmecoidea, Ardisia sp, Ardisia macrophylla, Archidendron borneense, Xanthophyllum griffithii, Ficus grossularioides, Horsfieldia crassifolia, Tarenna winkleri, Canthium glabrum and Gironniera parvifolia whereas the highest viability value is shown by alstonia angustifolia (0.612). In the young secondary forest ecosystem, four species show the lowest viability value which is 0.372. Those species are Dillenia suffroticosa, Anisophyllus disticha, Garcinia havilandii and Lepisanthes alata. The highest viability value is shown by Endospermum diadenum (0.625). In agroforestry ecosystem, three species exhibit the lowest viability value which is 0.369. Those species are Nephelium maingayi, Annona foetida and Artocarpus elasticus. Hevea brasiliensis shows the highest viability value which is 0.640 whereas Durio zibethinus gives the second highest viability value (0.529). Out of the four types of forest ecosystem, primary forest shows the highest viability value which is 0.548 whereas the young secondary forest gives the second highest with the viability value of 0.420. Old secondary forest shows the lowest viability value (0.398) followed by agroforestry with the viability value of 0.413.

The low viability value of the old secondary forest, agroforestry and young secondary forest is mainly due to the high fragmented area caused by anthropogenic activities such as selective logging, agriculture, i.e. shifting cultivation and dam projects. The effects of ecosystem fragmentation at the landscape and habitat scale are important for assessing the species viability values which is vital for the population viability (Belinda J.N. et al 2013). Fragmentation of an ecosystem particularly due to anthropogenic activities produced different size of an ecosystem patches which is thought to play an important role in its long-term viability (Gilfedder and Kirkpatrick 1998; Lonsdale 1999; Parkes et al. 2011), with longer patches having a better prognosis for long-term survival(Drayton and Primack 1996; Ranjito 1999; Parkes et al. 2011).

**4. Conclusion**

This work is an attempt to describe the importance of rarity value and viability value of an ecosystem with respect to biodiversity conservation of Bungoh catchment. The area is badly affected by the dam projects. As a result, forest edges and fragments are becoming dominant features affecting the area and consequently threatening the native populations and communities and the function of the ecosystem. The rarity value of all the four types of ecosystem namely the primary forest, old secondary forest, young secondary forest and agroforestry is relatively high indicating that the species in the ecosystem is distributed equitably which reflects the commonness of the species. Conversely, the viability value of the entire four ecosystems relatively is low indicating that the species are prone to extinction. This is due to the fact that the entirely ecosystem is being affected by anthropogenic activities which the dam projects contribute the most adverse impact to the ecosystem resulting in the loss and fragmentation of ecosystem. The rarity value and viability value of species of an ecosystem is vital not merely for academic exercise, but has profound implication for conservation and it is detrimental for the maintenance of biodiversity as the species in the entirely ecosystem needs functional ecosystem to survive.

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