Chapter 6:

Summary and Conclusion
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This thesis has broadly three parts. The first part (Objective 1) deals with spatial distribution of freshwater in taxa in India. The second part (Objective 2 and 3) deals with developing a new protocol to identify priority sites for freshwater habitats in India. The third part (Objective 4) deals with framing of freshwater biodiversity conservation and the gaps in the existing legal frameworks of India.

Summary of Objective 1

The first objective of this thesis deals with distribution of freshwater taxa in India and the determinants of this distribution pattern. For the study, four freshwater taxa were considered: freshwater molluscs, freshwater fishes, amphibians, and aquatic birds. A total of 2,254 sub-basin layer of India was used as the study unit.

The data on species distribution was collected from both primary and secondary sources. As expected, the number of studies and thus number of species recorded in the Western Ghats region is comparatively higher than other parts of India. It is interesting to note that certain urban regions have high richness for birds than other regions. This is mainly because of the presence of large number of birdwatchers in the urban areas. The species distribution maps for all the taxa clearly show that there is a huge gap in data especially in central and western India.

A list of variables was selected which are known to influence freshwater biodiversity and the data for each variable were extracted at sub-basin level. The variables used for the study are area under dams, length of railway network, length of road network, population density, rainfall, altitude, temperature, temperature seasonality, river length and land use land cover (LULC) map. Non-parametric Spearman rank correlation analysis was used to remove auto-correlated variables, and finally six determinant variables were identified. The variables selected for further analyses were mean rainfall, elevation (coefficient of variation), temperature seasonality (standard deviation), river length, dams and land use land cover heterogeneity. Generalised Linear Model (GLM) was used to identify the combination of independent variables
that are the best determinant of the freshwater taxa distribution. The result shows that mean rainfall, CV of elevation, and land use heterogeneity are the most important variables that positively correlates with distribution. The temperature seasonality, as expected, shows negative correlation with species richness. The influence of river length and area under dams on species distribution is weak.

One of the biggest caveats of this study is that, large number of sub-basins in India does not have data for the freshwater taxa studied. Extensive survey is required to address this data deficiency. With more data, clear patterns in distribution will emerge and also better understanding of concordance between different freshwater taxa.

**Summary of Objective 2**

The second objective of this thesis was to develop a protocol to identify priority sub-basins for freshwater biodiversity conservation, by considering both biodiversity information as well as anthropogenic activities. The variables identified in objective 1 were used to develop this protocol.

This protocol highlights Himalayan region, the Western Ghats and north-east India as high priority regions which are the biodiversity hotspots in India. Since anthropogenic factors and resource use practices were also considered, regions with high threats were also highlighted. One major issue faced was lack of species distribution data from a large number of sub-basins.

The disadvantage of this method is that it is time consuming and requires high computational resources and also depends on the availability of physical, resource use and threat data for the region to be prioritized. The performance of the protocol is highly dependent on the availability of good datasets. However, there are many advantages in using the method developed here. One of the main advantages is, it is a holistic approach for prioritizing sites for biodiversity conservation. Approach developed here is the first ever attempt in India where apart from biodiversity, other variables are also considered for identifying priority sites. Due to inclusion of a number of factors, it provides better results that other existing protocol. This approach
is not to identify areas for creating protected areas, but to provide priority ranking to each study unit by considering the biodiversity as well as livelihood practices prevalent in these sites. This model will be helpful in bridging the gap between conservation of habitats and biodiversity and resource use practices, while identifying regions that need conservation efforts.

This protocol is not only applicable to freshwater systems, but can be used for different types of ecosystem, by only changing the study units. For the present study, the modelling has been done at sub-basin level, because freshwater systems being continuous are affected by upstream activities and requires management at catchment level. However, for terrestrial systems, the study units can be changed to grids of desired size and then the same protocol can be applied.

**Summary of Objective 3**

The third objective of this study was to compare the protocol developed in objective 2 with 2 existing and popularly used protocol for prioritizing freshwater habitats for conservation of biodiversity.

The comparison between these three protocols shows that the number of high priority sites is highest under HCV protocol. Zonation is used for identifying new protected/reserve area and thus the aim is to identify stretches of pristine freshwater habitats for conservation. The output from Zonation completely removes those areas with human activities and highlights only those areas that are pristine. The KBA protocol identifies the sites of high biodiversity. The output of KBA protocol highlights the regions with high species richness and higher number of threatened and endemic species. Sub-basins with higher species richness as well as high number of endemic and threatened species gets higher priority. HCV protocol not only considers the biodiversity, but also other environmental factors and human activities that affect the overall habitat condition and the biodiversity. Thus, the output highlights maximum number of high priority value sites. HCV gives priority ranks to all sub-basins and thus every sub-basin gets certain value based on the condition of the habitat and the
status of biodiversity present. Sub-basins with more threats and higher number of species and priority species get maximum priority.

Conservation and livelihood has always been dealt separately and thus the existing protocols also follow the same. The aim of the study is to step away from “protected areas” approach and look at a bigger landscape. The use of HCV protocol will help in linking conservation of biodiversity and resource use. It not only highlights areas with high biodiversity, but also helps in understanding the overall condition of the habitat, which will not only affect biodiversity but will also impact livelihood.

Summary of Objective 4

The fourth objective of the study was to understand how conservation of freshwater biodiversity is framed within the legal frameworks of India. A list of legal frameworks in India, at both state and national level, was prepared. Several themes were identified through reading of these frameworks to understand the how biodiversity conservation appears within these frameworks. Result shows that there is hardly any framework that includes freshwater biodiversity for conservation. The major focus has been on resource driven utilization of water resources. The frameworks on biodiversity conservation focus only on charismatic species. For example, there are a few freshwater taxa included under Wildlife Protection Act (1972) of India. The other smaller vertebrates and invertebrates are ignored. For example, to maintain a healthy fish population it is also important to understand its position in food web and how other organisms present affect their population. The importance of maintaining biodiversity for their role in maintaining ecosystem services is not acknowledged. Lack of awareness of the importance of biodiversity and their roles in maintaining the ecosystem is often the reason for formulation of policies and legislation without an inclusive approach. The context of freshwater habitat conservation is mostly focused on preventing pollution and conversion. Most of these frameworks have a list of restricted or prohibited activities like encroachment, diversion of water bodies, polluting, excessive fishing, etc., which indirectly assist in freshwater habitat and biodiversity conservation.
I took an example of wetland conservation as a case study to compare policies at state and national level. There are several contradictory provisions within these policies. The policies at state level are driven by state’s agenda. Even though the wetland related policies at state and national level gives importance to habitat conservation. However, the motive appears to be of deriving economic benefits, and not for the conservation of ecosystem. Freshwater ecosystems in India are often placed within complex socio-economic structure. These systems are one of the most productive ecosystems with very high monetary value for the ecosystem services they provide. Due to the involvement of multiple stakeholders, the focus is often on the use of water. Presence of multiple legislations with conflicting provisions at national and state level also affects strict implementation of laws.

**Conclusion**

Freshwater systems are important source for meeting daily human needs and to maintain livelihood. Thus, they have been associated with human activities since time immemorial. They are part of complex socio-ecological systems and are used by multiple stakeholders. This association has led to over exploitation of these systems. Due to the decreasing quality of freshwater resources, concerns for pollution, livelihood dependencies and availability of safe water has increased. However, the association of freshwater with human has often leads to exclusion of the biodiversity when it comes to formulation of management practices. Several studies have already shown the importance of biodiversity to maintain healthy ecosystem and ecosystem services (an important source of livelihood, especially in developing countries). Given the rate at which freshwater taxa population is decreasing, it is important to take immediate action for their conservation. Chapter 2 shows that, there is a huge gap in distribution data for freshwater taxa (aquatic birds, freshwater molluscs, amphibians and freshwater fishes) in India. Lack of data on freshwater taxa distribution is true everywhere in the world but more so in developing countries. The lack of understanding of the importance of biodiversity in maintaining the ecosystem health and services leads to the formulation of ecologically blind policies. In this chapter, I have tried to obtain a broad spatial distribution of freshwater taxa in sub-basins of India, and the variables (resource use practices and threats, and physical layers) that affect the distribution. This may, however, vary at different spatial scale. These
variables were then combined with species distribution data to develop a protocol to identify sub-basins of high priority (Chapter 3 and 4). This approach helps in moving away from “protected area” approach and looks at a larger landscape through inclusion of maximum number of variables that play role in maintaining these habitats and its biodiversity. This protocol is flexible to include more information wherever available. It can be calibrated and used at different spatial scales.

Identification of sites, however, is not enough for conservation. Legal frameworks are required to implement and monitor such plans and actions for a successful effort. Thus, in chapter 5, I looked at the framing of freshwater biodiversity conservation within the legal frameworks of India at both national and state level. Result shows that there are no criteria defined for identifying conservation sites for freshwater biodiversity. The rules defined by Ramsar Convention are for identifying wetlands of international importance based on the biodiversity criteria only. Factors like physical variables and resource use practices are not included. Moreover, it doesn’t include other freshwater habitats. Thus the protocol I have developed can help in identifying priority regions for India, which can feed into policy and management of freshwater ecosystems in India. The approach is to move away from creation of protected area and involve the local people to conserve and manage these sub-basins. Therefore, there is also a need to deal with this lack of coordination between stakeholders, policy makers and scientists. We need to have an open flow of knowledge that will make the transfer of knowledge easier and probably help in better interaction between different sectors.