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Research Article

Role of Academic Institution to Inform Local and Regional Scale Biodiversity in the Eastern Philippines

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ABSTRACT

The Philippines is among the most threatened biodiversity hotspots. Developing effective conservation requires science-based evidence from field data and observations. Yet, many important biodiversity information remain unpublished, particularly from academic institutions and NGOs. Here, we synthesized 34-year data from biodiversity studies from Bicol University in Luzon Island, Philippines. We found a large number of studies that increased in the post-2000 period with the majority of the studies focused on community surveys and animal and wildlife studies. While there is a massive number of studies, we found clear disproportionate distribution in terms of geographic and thematic areas. Our results may be based on a regional level, but if taken carefully, it has important implications and applications to other higher education institutions in the Philippines in promoting biodiversity studies and conservation in the country.

Keywords: Anthropocene, Education, Policymaking, Priorities, Universities

Introduction

The exchange of relevant information and data from the field observations is needed to develop effective conservation prioritization. This is also to bolster biodiversity protection and to minimize the negative impacts of the rapidly changing human environment on ecosystem service provisions and sustainability [1]. The rate of imperilment has been higher than the previously projected extinction risks and many species have poor ability to recover quickly from these losses [2]. Our demand for resources increases as we advance to a more technologically developed human civilization. More threats from multiple anthropogenic activities such as habitat modification and rapid urbanization are encroaching forests and other natural habitats [3, 4], affecting water systems [5, 6], and fragile biodiversity [7, 8]. Anthropogenic activities are coupled with changing climate and their effects are exacerbated in many territories particularly in developing countries where demand for natural resources is higher [9, 10, 11].

While the challenge and most analyses are global, equitable solutions should be developed and implemented on a local or national scale due to ecosystem uniqueness, cultural and socioeconomic background, and scientific capacity of respective territories. Therefore, understanding biodiversity on a local or regional scale is valuable to match with challenges and framing of effective protection policies [12, 13]. For example, the majority of the Philippine key habitats are threatened by increasing land-use changes chiefly caused by growing economic and industrial developments [14, 15]. Yet, progress addressing these growing developments remains slow despite the extensive efforts on resource management in the last three

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decades [14]. The deforestation rate in the country is increasing with a roughly 5.9% reduction in tree cover (10,900 km^2) from 2000 to the present [16], which is largely due to illegal logging and slash and burn "*kaingin*" practices for agricultural and urban expansions [17]. Thus, effective and holistic conservation efforts that are fitted to address national environmental threats are crucial to lessen drastic loss and local extinction risks in the country. Challenges from threats often stem from the lack of strong implementation of biodiversity policies and the scarcity of biodiversity data and exchange to reinforce conservation efforts. This reflects from the limited number of conservation professionals within and outside government offices, the limited number of academic programs to train the next generation of conservationists, and the limited up-to-date natural science and socioeconomic information to guide biodiversity management plans [18]. The role of the academe particularly local higher education institutions (hereafter "HEIs") is thought to be fundamental in supporting biodiversity conservation efforts predominantly by capacitating scientific manpower and establishing collaborative explorations [19]. For instance, the proximity of HEIs to protected areas or important ecosystems allows access to logistics and communications with ease optimizing biodiversity cataloguing and explorations. University research and data are primarily sourced from the output of undergraduate or graduate studies (i.e., in the form of thesis and dissertation). Important biodiversity data including species occurrence, population trends, threats, and local ecosystem services are yielded by these researches and therefore could guide at least the local conservation policies when academics and policymakers genuinely collaborate. Yet a small proportion of these works are rarely published online, presented in scientific conferences, or are turned over to authorities responsible for policymaking [20]. This often leads to many vital biodiversity information remaining least useful in developing biodiversity conservation efforts in local communities or habitat that requires urgent attention. This is a predominantly occurring challenge yet under-discussed in many Philippine HEIs that hampers effective conservation prioritization [21, 19]. To address this, we examined archived data from Bicol University, from Luzon Island, Philippines, and analyzed the patterns and trends in biodiversity-related research in HEIs. Using these data, we identified gaps, challenges, and opportunities in improving biodiversity studies in their effective use in the region. We hope that our findings would aid in developing appropriate priorities within different HEIs to bolster the impacts of biodiversity studies to policymaking that is not only applicable to the region but also to other HEIs in the Philippines and Southeast Asian regions.

Material and Methods

Data source and sampling

Bicol University (hereafter "BU") is a state-funded higher education institution in the Bicol region, the fifth geopolitical cluster of six provinces in Eastern Philippines. The Bicol Region or the Bicol peninsula is at the southernmost of mainland Luzon. BU has campuses in two of the provinces, Albay and Sorsogon. Our analyses have only focused on biodiversity studies generated from the Department of Biology of the University's main campus in Albay. The Department is now running for 42 years offering the Bachelor of Science in Biology degree program. A range of 80 to 120 biology students comprises per year level who are required to do a thesis as partial fulfilment of the degree program.

We performed a combination of a bibliometric and systematic review of all existing thesis accessible through an electronic database accessible to faculty members and students of the department. We performed a rigorous evaluation of the existing studies to assess the completeness of the database using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) procedure [22]. We sorted and classified all research titles that mention or include the following keywords: "biodiversity", "taxonomy", "conservation", "ecosystem", "ecology" and studies that mention species name, group, or ecosystem types. Classified titles were then re-assessed to sort out only those biodiversity-related studies. To ensure the relevance of the study, the thesis abstract and content were checked. The final database was checked for spelling, scientific names, and cross-referenced. The complete list of the papers can be requested from the corresponding author.

Statistical analyses

We classified studies according to period, year, geographic location, taxa, and thematic areas (e.g., [21]). We also classified studies based on the period when it was conducted e.g., pre-2000

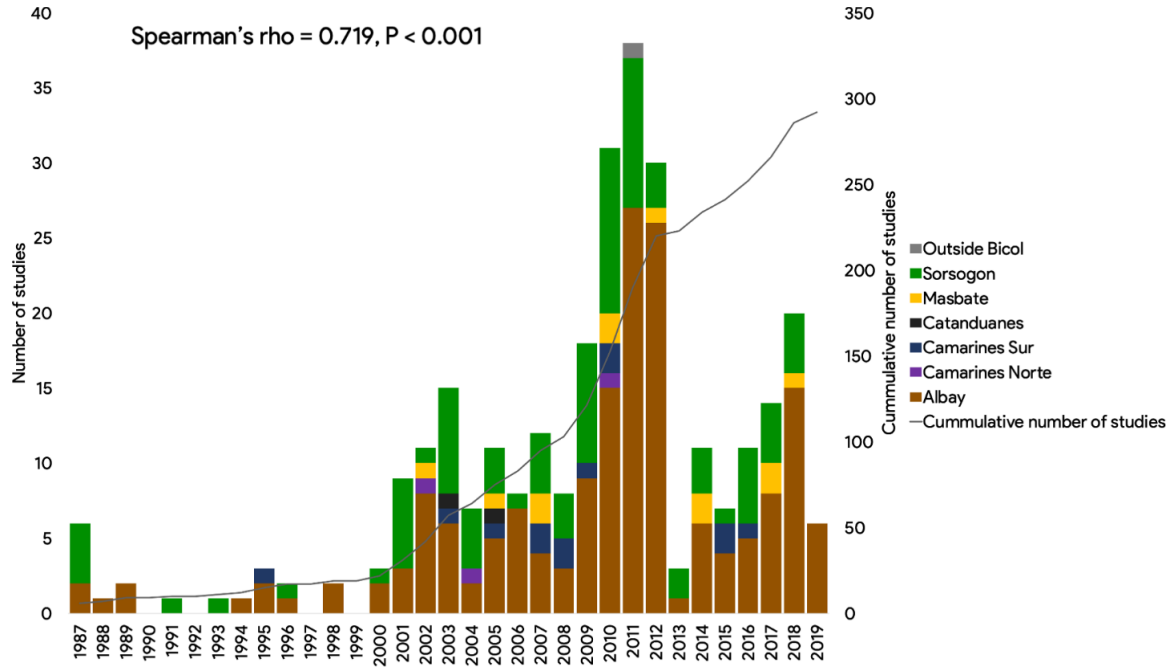

Figure 1. Temporal patterns of Bicol University (BU) biodiversity-related studies from 1987 to 2019 showing the number of studies per year, cumulative number of studies, and the association of number of studies across time period

and post-2000. We performed a non-parametric Mann-Whitney *U* test or Kruskal-Wallis test where it is applicable to determine the significant difference in the number of studies between period, province, habitat type, and domain or taxa. A Spearman rank correlation test was performed to determine temporal association in the number of biodiversity studies across different provinces. Lastly, we performed a Chi-squared (χ^2) goodness of fit test to determine a significant association in the proportion of studies across thematic areas. All statistical tests and visualization were performed using JAMOVI open-source software (version 1.2.6.0) [23] and GraphPad Prism (version 8) [24], respectively. All statistical significance was set to $p < 0.05$.

Results and Discussions

Spatiotemporal patterns of biodiversity studies

We assessed a total of 865 studies, of which 33% (n = 282) were biodiversity related. A strong positive correlation was observed between years and the overall number of studies (Spearman's rho = 0.719, $p < 0.001$) with only Albay showing a strong positive correlation with years (Spearman's rho = 0.736, $p < 0.001$) (Figure 1) in provincial scale. We found a significant difference in the number of studies between periods with a lower number of studies in pre-2000 (mean = 0.21 ± 0.62) compared to the post-2000 period (mean = 1.95 ± 4.11) (Mann-Whitney U test = 4272, $p < 0.001$) (Figure 2a). The distribution of studies significantly differs across the provincial level (Kruskal-Wallis test, $\chi2 = 106.01$, df = 6, $p < 0.001$) where at least 61% of the studies are from Albay (n = 173, mean = 5.24 ± 6.71) followed by Sorsogon (31%, n = 88, mean = 2.67 ± 3) (Figure 2b and Figure 2e). Thirteen studies (n = 13) constituting 4.61% of all biodiversity studies were conducted from more than one province. All of which are conducted within adjacent provinces such as Albay and Sorsogon (n = 9), Masbate and Sorsogon (n = 3), and Camarines Sur and Albay (n = 1). The island provinces of Masbate (4.11%) in the south and Catanduanes (0.68%) in the east were surveyed sparingly, along with the province of Camarines Norte (1.03%). Single research was conducted in the province of Marinduque, a province outside of the Bicol region.

Biodiversity studies across ecosystems

The number of studies according to ecosystem types significantly differed (Kruskal-Wallis test, $\chi2 = 18.66$, df = 3, $p < 0.001$). Half of the total number of studies were from terrestrial ecosystem (n = 141, mean = 4.27 ± 5.85) and the 32% (n = 88, mean = 4.27 ± 5.85) were from marine ecosystem, 6% in coastal (n = 19, mean = 0.58 ± 0.79),

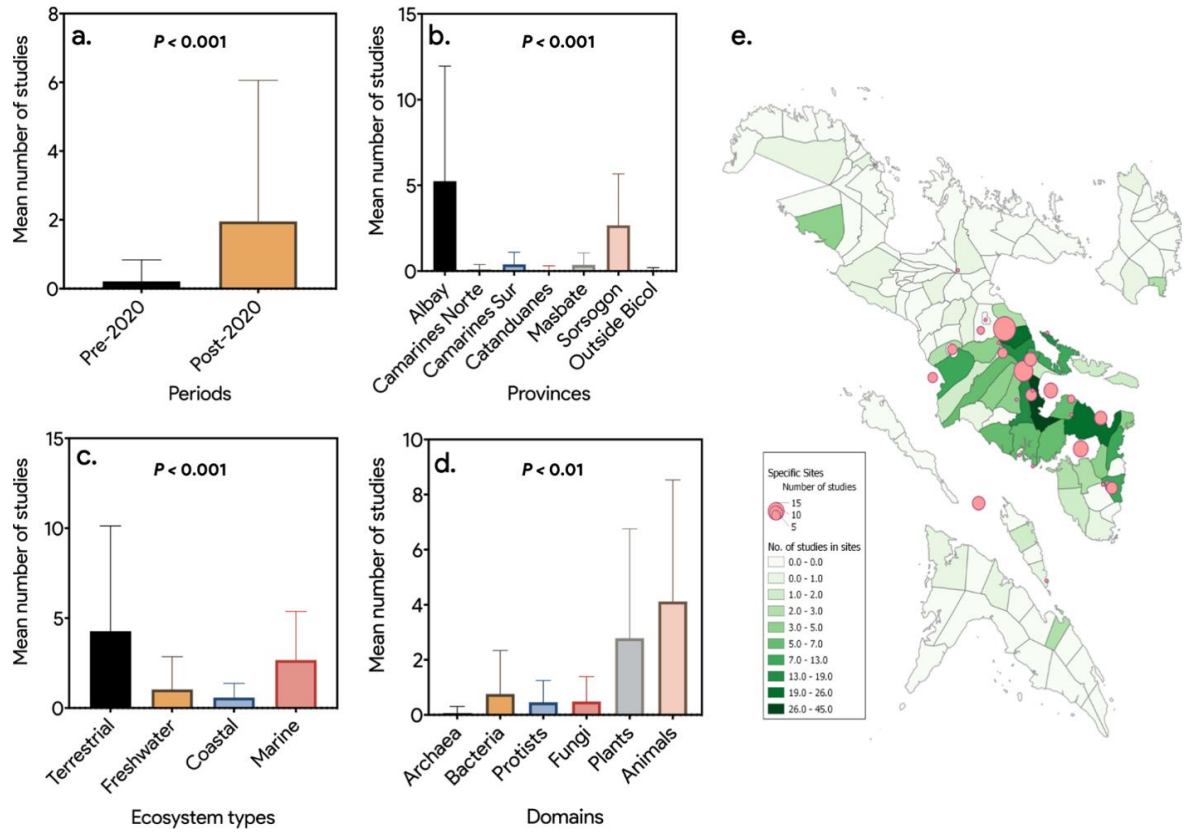

Figure 2. Patterns of Bicol University (BU) biodiversity-related studies based on period (a), provinces (b), ecosystem types (c), domain (d), and spatial pattern number of sites studies in municipal-level (e). Values are expressed in Means (dots) and Standard Deviation (SD) are shown in error bars. Statistical significance is also shown. Maps were created using Quantum GIS version 3.12 (The Quantum GIS team, 2020)

and 12% (n = 34, mean = 1.03 ± 1.83) in freshwater ecosystems (Figure 2c). In the terrestrial ecosystem, the highest proportion of biodiversity studies were conducted in Mt. Malinao (n = 21, 7%) and Mt. Mayon Natural Park (n=14, 5%), both sites are in the province of Albay. In Sorsogon, six (n = 6, 2%) studies were performed in Bulusan Volcano Natural Park. On the other hand, most studies on aquatic ecosystems (marine and freshwater) were from Sorsogon bay and Albay gulf. There were only 1.27% of studies on mangrove ecosystems across the region. Apart from natural ecosystems, there were also studies on urban ecosystems with at least 17 (6%) focusing on different taxa in the vicinity of Bicol University.

Studied taxa and thematic areas

We found a significant difference in the proportions of studies across thematic areas ($\chi2$ = 138.15, df = 2, p < 0.001) with "diversity", which comprise the 65% (n = 183) of the overall studies, followed by "Ecology" (26%, n = 73) and "Taxonomy and Systematics" (9%, n = 26). Albeit, no significant relationship between thema-tic areas and period ($\chi2$ = 4.10, df = 2, p = 0.129). The number of studies across domains showed a significant relationship with the period (Kruskal-Wallis test, $\chi2$ = 53.88, df = 5, p < 0.01) (Figure 2d). The majority of the biodiversity studies were focused on animals and wildlife (n = 136, 47%, mean = 4.12 ± 4.41/year), with 116 (85% of all animal studies) on invertebrates and only 15% on vertebrates (Figure 3). On the other hand, floristic studies were identified high (n = 92, 33%), wherein most of the studies are focused on medicinal plants and few on taxonomic and ecological topics. Furthermore, there are only 16 (5.6%) mycological studies on lichens, macrofungi, and soil-borne microfungi. Lastly, organisms surveyed in microbiological diversity were focused on water (57.69%), soil (23.08%) or residing within other organisms as endophytes (19.23%) with a single study on thermophilic bacteria.

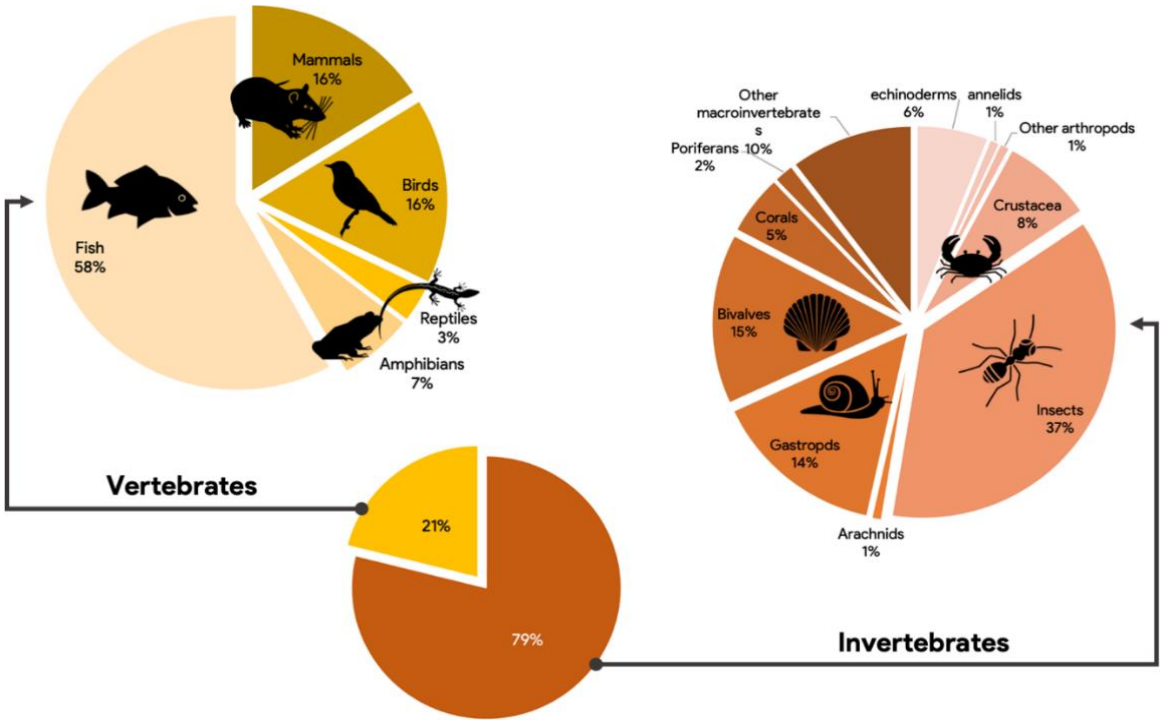

Figure 3. Distribution and comparison of Bicol University biodiversity studies related to animals or wildlife. Values are expressed in percentages.

Importance of biodiversity data from HEIs

Our analysis has shown the potential contribution of academic institutions in providing important biodiversity information at the regional and local scale. The trend in biodiversity research increased over time suggesting increasing interests in the field of biodiversity and conservation science within Bicol University. We observed a massive yet disproportionate amount of data from 34 years of biodiversity research at the University. Evidence of this is the homogenous research themes across a period and skewed distribution of studies across taxonomic groups. These trends and patterns will mirror the understanding and improving the state of biodiversity in the region in the future period. Although the advent of big data biodiversity science has entirely changed how we understand and make priorities for global biodiversity [25], small scale data (i.e., from rapid assessments or single observation), perhaps not equally important as those big datasets, are essential in understanding local biodiversity patterns relevant to framing local policies [21] and even unpublished records and studies are equally vital sources for identifying biodiversity hotspots in the national level [26]. It is shown in our study how important datasets can be generated or pooled from studies located from academic institutions such as HEIs, particularly information on species occurrence and distribution records, natural history records, and local use and economic potential (e.g., ethno-economic studies or medicinal plant studies). However, this key information is often unpublished and or inaccessible from institutional archives. This may be attributed to many factors but mainly the lack of data information regulation policies in HEIs, capacity to write and publish the data in reputable journals, or the lack of localized journals that allow the publication of small datasets from local biodiversity projects.

Information from undergraduate studies on protected areas are required to be provided to the environment ministries (e.g., Department of Environment and Natural Resources). This information is rarely utilized and ends obsolete with time. For instance, in our datasets, only 28 studies from BU were in records at the regional environmental office as of 2018 that is equivalent to less than 10% of the overall biodiversity studies from the HEIs. Biodiversity conservation and management programs should be more effective when local policymakers and academics work collaboratively and assure that policies are science-based when implemented [27]. Therefore, research from HEIs is expected to be communicated to localities and respective policymaking bodies from where the data

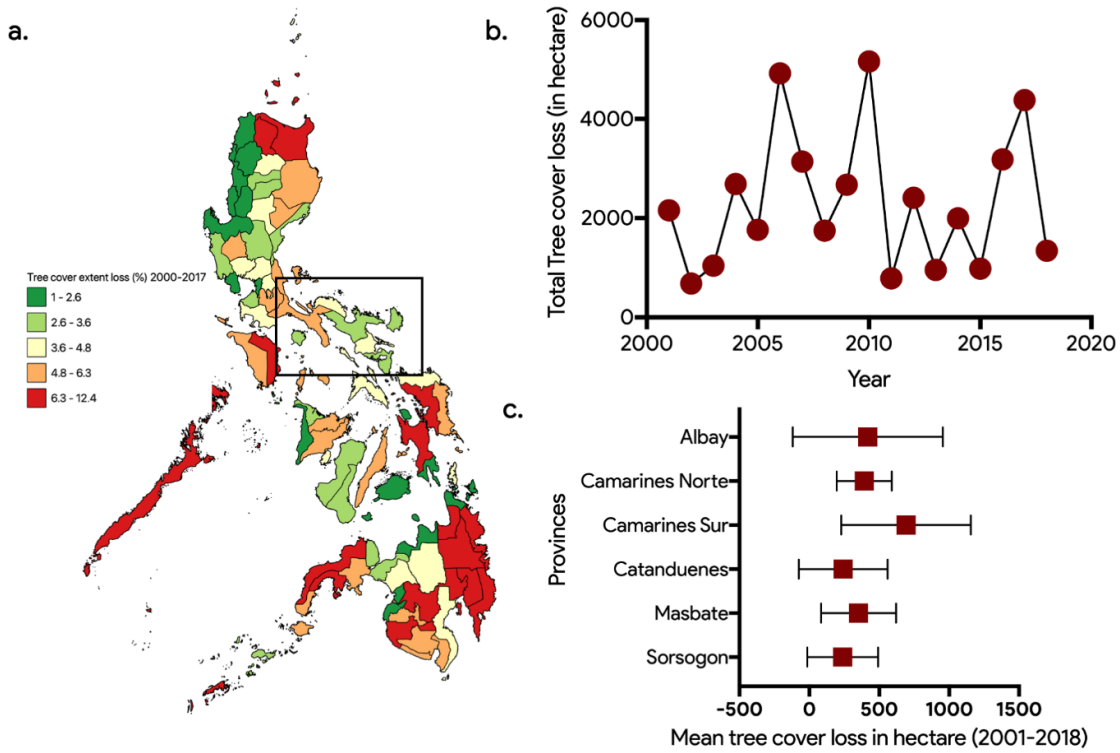

Figure 4. Comparative tree cover loss in the Philippines (%) (a) and temporal pattern of tree cover loss across the Bicol region (in hectare) (b), and mean tree cover loss in different provinces from 2001-2018 (in hectare) (c). Data were generated from Global Forest Watch database (GFW, 2017). Maps were created using Quantum GIS version 3.12 (The Quantum GIS team, 2020).

was gathered. This highlights the need for translating biodiversity data into intuitive and comprehensible information to optimize its effectiveness in guiding local conservation action plans. Apart from these challenges, the observed distribution of studies is biased in terms of thematic areas, taxa studied, and geographical location. Tantipisanuh and Gale (2018) attribute these biases to proximity, accessibility, and capacity of the researchers to the target study site. The province of Albay, where Bicol University's main campus is located, and Sorsogon, Albay's adjacent province, were surveyed more than the rest of the provinces due to their proximity. Ample funds to support research expeditions and the availability of experts and collaborators are other constraints in implementing successful biodiversity studies in many local areas.

Academic institutions have an intrinsic role in biodiversity conservation. Global strategies to conserve diminishing flora and fauna are reliant on local leadership and investment in local capacities [28]. Improving the understanding of rural people on local knowledge builds social capital which eventually turns to biodiversity gains [29]. Although this is ideal there are other factors including the lack of scientific capacity of an academic institution. For example, in many countries including the Philippines, there is a widening gap between taxonomy and biodiversity science [30, 21]. Students and professionals practicing Taxonomy (and systematics) are thought to be decreasing and this threatens the establishment of appropriate and correct species conservation measures [31, 30]. Poor taxonomy such as misidentification of species hinders conservation focus such as the Red List of threatened species [32]. We observed the patterns of biodiversity studies from the region mostly rely on external morphology-based identification. While this is an important foundation in species identification, integrative taxonomy that combines both morphology and genetics are vital and encouraged to bolster species identification [33, 34].

We observe the lack of ecological studies from the dataset we analyzed with most studies skewed towards community diversity assessments and inventories. Ecological studies in the Philippines is generally scarce and demonstrated in many taxa (e.g., discussed in Tanalgo and Hughes, 2018) [21]. Although community inventories are important to provide baseline information, under-

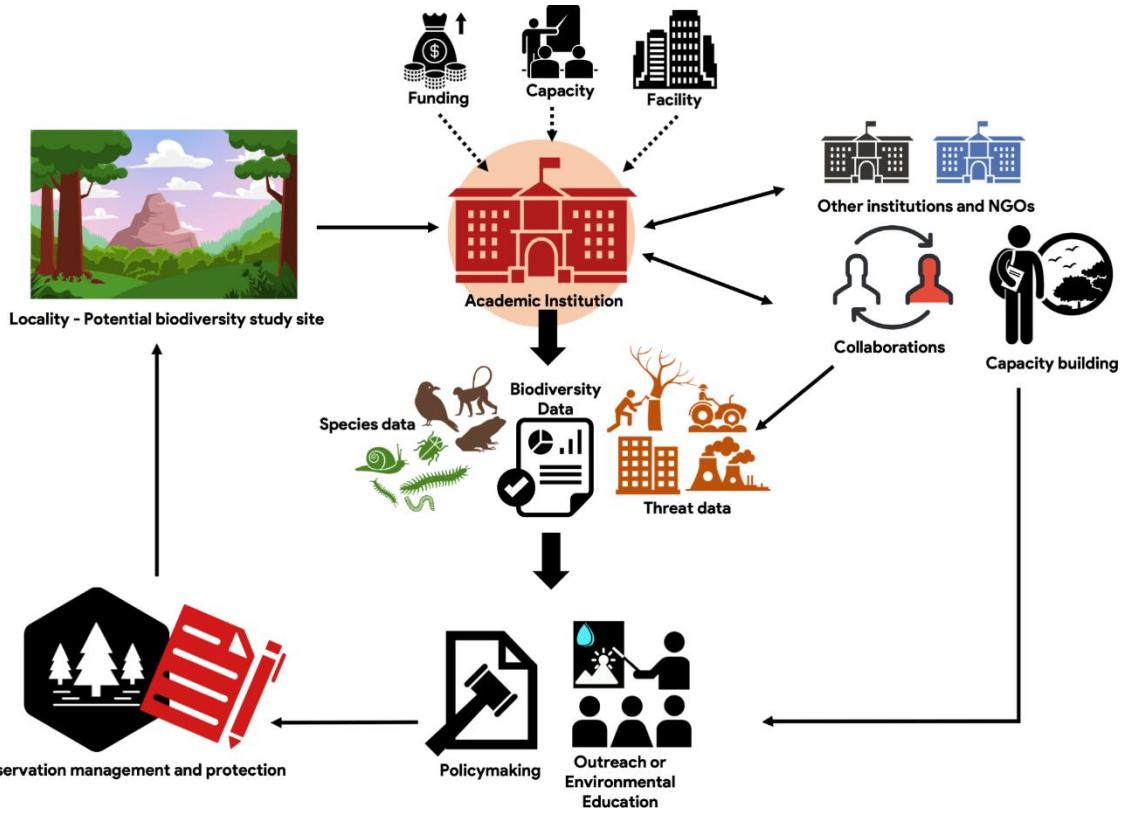

Figure 5. A simplified schematic diagram showing the proposed strategies to improve biodiversity research in academic institutions in the Philippines to bolster its impacts in biodiversity conservation and environmental management. Here we show the core role of an academic institution and collaborative work in generating biodiversity data and environmental threats, which are all vital in policymaking and environmental management.

standing the ecological and ecosystem roles of a species and taxa better inform their conservation biologists together with policymakers to comprehend the dynamics of the species to improve their protection [35, 36, 21], as well as management and monitoring of species population (e.g., threatened species or invasive species) [37, 38], ecosystem services in varying landscapes [39], and valuation of cultural values [40]. Furthermore, ecological studies should be complementary in species community surveys as they provide insights on species ability to persist in a changing environment and the impacts of diverse threatening processes on both population and ecosystems. The Bicol peninsula is located at the southern tip of mainland Luzon uniquely characterized by active volcanoes [42] and rich biodiversity. Yet, ecological, and anthropogenic threats imperil a large proportion of species and ecosystems in the region. For instance, using the data from Global Forest [16] the tree cover loss in the region from 2001-2018 has reached 42 thousand hectares (from six provinces) with a mean annual of 2,335-hectare loss (Figure 4a, b). This is mainly driven by logging, shifting agriculture, and urbanization. At the provincial level, the highest tree cover loss is from Camarines Sur (12, 450 hectares, mean=641) (Figure 4c) yet the number of biodiversity studies in this province remains low. This suggests that aside from focusing on biodiversity-rich regions or landscapes, future studies should also look at these regions with high threatening process potential.

Our synthesis from this study showed the potential of the academic institution we investigated to provide valuable biodiversity data for regional to local scale institutions (Figure 5). Our findings may vary per institution and this does not equally represent the overall HEIs in the country but the trends we observed may be true to most academic systems. To address these challenges in the present and future, we suggest different strategies that apply in the Bicol region and to other similar academic institutions in the Philippines. First, future studies should prioritize areas that lack baseline data or imminent threat to the local biodiversity is present. While for areas with established baseline

biodiversity data, advancing these studies to more ecological or long-term monitoring is an ideal next move forward. To optimize data gathering in these areas, institutional collaboration should be sought to maximize logistics and forge equitable capacity building to establish a long-term scientific network and expert manpower. Diversifying areas of focus or thematic areas of biodiversity studies are essential but should be relevant and appropriate based on the ecological context or landscape features of the target region or localities (e.g., Protected areas, urbanized landscapes). Identifying focal species such as keystone species or ecological indicators is a primary strategy to maximize monitoring at the same time effectively protecting other coexisting species and their habitats. For example, monitoring bats in the cave inform ecosystem health in karsts and subterranean habitats [21, 42] and bird diversity in urban areas [43]. Also, this approach creates balance in the appropriation of socio-economic and cultural activities (e.g., tourism) and vulnerable areas with high biotic potential [21] eventually resulting in true sustainability.

Understanding threats and drivers of biodiversity loss is the second challenge and opportunity in the region for the future. There are numerous important studies as a result of efforts from the University research, yet a small proportion has explored different threatening processes and their extent, including their impacts on both species population and ecosystems. Our knowledge of the patterns and effects of different threats to Philippine biodiversity is limited and lacks pragmatic investigations to date, hence, localized efforts to investigate known threats will contribute to the national-level efforts. Understanding threats and drivers of biodiversity are essential to design pragmatic and sensible biodiversity conservation measures and protection and should be explored on multiple scales.

Conclusion

Our study explores the potential contribution of Philippine academic institutions in informing local biodiversity. Addressing these challenges and opportunities in the long-term, it is vital to develop and support a strong scientific foundation and capacity within the academic institutions. There should also be the promotion of equitable partnerships and collaborations among other academic institutions and NGOs working in the field of biodiversity conservation to build a strong scientific powerhouse in regional. While we found that there are clear disproportionate efforts and priorities in biodiversity studies from HEIs, albeit we cannot deny its potential to bolster biodiversity conservation on a regional or national scale. We strongly emphasize the necessity to publish and exchange biodiversity data from academic institutions to bolster its contribution to environmental management and conservation in the country.

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