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Catalyzing Red List Assessments of Underrepresented Taxa through Partner Networks and Student Engagement

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Abstract: Global biodiversity decline is continuing largely unabated. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species (hereafter, Red List) provides us with the gold standard for assessments, but taxonomic coverage, especially for invertebrates and fungi, remains very low. Many players contribute to the Red List knowledge base, especially IUCN Red List partners, IUCN-led assessment projects, and the Specialist Groups and Red List Authorities (RLA) of the IUCN Species Survival Commission. However, it is vital that we develop the next generation of contributors and bring in new, diverse voices to build capacity and to sustain the huge assessment effort required to fill data gaps. Here, we discuss a recently established partner network to build additional capacity for species assessments, by linking academia directly into the assessment processes run by Specialist Groups and RLAs. We aim to increase Red List "literacy" amongst potential future conservationists and help students to increase publication output, form professional networks, and develop writing and research skills. Professors can build Red List learning into their teaching and offer Red Listing opportunities to students as assignments or research projects that directly contribute to the Red List. We discuss the opportunities presented by the approach, especially for underrepresented species groups, and the challenges that remain.

Keywords: IUCN Red List; extinction risk; Species Survival Commission; capacity building; mentoring; academic learning; undergraduate research

1. Introduction

Biodiversity decline continues largely unabated [1], despite efforts to set policy targets to slow the rate of decline, bend the curve of biodiversity loss and "reverse the red" [2,3]. Recent estimates have projected a million species to be at risk of extinction [4], a figure derived from our current knowledge of extinction risk in different species groups, as measured via the IUCN Red List of Threatened Species (hereafter, Red List; [5]). With assessments for more than 147,000 species [6], the Red List is the world's most authoritative source on the extinction risk of species and forms the basis for species conservation planning and action. However, despite recent efforts, it still falls just short of its 2020 aim of 160,000 species assessments [7], and only covers a small percentage of all described species to date (7% of >2,130,000 species; [6]).

While to date, 80% of the world's described vertebrate species have been assessed, especially birds (100% of described species assessed), mammals (91%), reptiles (87%) and amphibians (86%) [6,8–10], plants, fungi, and invertebrates are still largely underrepresented or, if they have been assessed, are often classed as data-deficient [11]. Additionally, current biodiversity estimates of known animals, fungi, and plants are underestimated, and millions are likely yet to be discovered [12,13]. Of this enormous diversity, only 2% of described invertebrate species and only around 600 species of fungi and lichen have been assessed [6]. These are the "little things that run the world" due to their immense importance in maintaining healthy ecosystems, nutrient cycling, food and clean water provisioning, and sequestering of carbon, amongst others [14]. Insufficient conservation knowledge on these underrepresented taxa has left us lacking in establishing priorities and effective conservation action for these species [11]. Thus, despite their importance, we continue to neglect these species in targeted conservation initiatives, at our peril.

Although anyone with sufficient knowledge of a species can carry out its Red List assessment, in practice, most assessments for the Red List come from IUCN Species Survival Commission (SSC) Specialist Groups and Red List Authorities (RLAs). One such group, as an extreme example of the scale of the task at hand, is the Terrestrial and Freshwater Invertebrate Red List Authority (TIRLA; [15]). The remit of this group is to aid or carry out Red Listing for any terrestrial or freshwater invertebrate species not covered by a Specialist Group (Specialist Groups generally hold the Red List Authority for their respective taxonomic/regional focus). At present, there are 16 Specialist Groups with a terrestrial or freshwater invertebrate focus, of which only three so far focus specifically on beetles (Coleoptera—ladybirds, fireflies, and dung beetles—though some regionally focused invertebrate Specialist Groups such as the Mid-Atlantic Island SG and the South Asian Invertebrate SG may cover additional species). With around 400,000 species of beetle described [16], this group alone provides a stark reminder of the size of the assessment task ahead. At present, only 1810 species of beetle are listed on the Red List (<0.01% of described beetles; [6]).

There is an urgent need for new approaches that increase the capacity of the Red List to publish quality assessments, as a lack of them generally prevents or limits species representation in conservation planning, action, and policy. Here, we present a novel collaborative approach that integrates the efforts of academic institutions, biodiversity museums, non-governmental organizations, government agencies, and IUCN Specialist Groups (currently IUCN SSC Butterfly & Moth Specialist Group and IUCN SSC Bat Specialist Group) and Red List Authorities (currently TIRLA) around the world. We link academia directly into the assessment process, primarily through networking with professors to offer Red Listing opportunities to students as a part of biology or conservation science courses and through independent student/faculty research projects. We discuss how the approach was developed, the opportunities it presents for underrepresented species groups, and the challenges that remain.

2. Our Initial Approach

In 2020, as the world reeled from the impacts of the COVID-19 global pandemic, field projects were cancelled world-wide for safety reasons. Our (GPS, DLW) research expedition (funded in 2019), which included professors and students from Kutztown University (USA), to conduct field research on bats and beetles with our colleagues in Fiji, fell victim to the pandemic. To continue the project, we redirected the funding to an initiative that was more insulated from COVID issues. Our collaborative Red List initiative emerged from the chaos and uncertainty of the pandemic to provide a virtual opportunity for student engagement and career training on a globally important conservation research priority.

Initially, our approach focused on invertebrates of Melanesia as it connected with taxonomic expertise of our team (GPS), it was a region where the initial team (GPS, DLW) had personal research experience, colleagues, and interest, and there were large numbers of described invertebrates that had yet to be assessed. We connected with TIRLA (MB) as an entry point and facilitator of the Red List process for invertebrates. Our initial efforts resulted in seven species assessed with the involvement of ten students and four collaborators from the Philippines and Fiji. From there, our pipeline rapidly expanded to include at least 30 additional students and four collaborators involved in assessments of another 20+ species.

Our approach strongly encourages (and often requires) students and professors to complete the online Red List Assessment training course [17]. A growing network of species experts, including retired taxonomists, parataxonomists, field station staff, museum curators, and academic professors has been assembled to ensure that students have access to specimen and field data that may not be readily available through more traditional sources (e.g., published literature and web-based databases), and allow them to benefit from their expertise, and gain credibility through inclusion of experts as co-assessors. This network also provides students with opportunities to grow their own professional networks and work with others broadly connected to conservation research around the world, far beyond a typical classroom experience.

Through online video conferencing, students and professors began to share their work on the project with a broader audience, recruiting new colleagues to join the network. With this growing interest, we decided to scale the initiative to a global network of experts and students with a variety of taxonomic expertise and interests. We link each new network recruit to the online Red List training course and TIRLA (or other relevant IUCN SSC RLA) and provide guidance and oversight along the way. While our initiative is predominantly focused on the "Assess" component of the SSC's Species Conservation Cycle (Figure 1), it is not constrained to this one element and in fact is currently catalyzing further research on species that we hope will lead to the development of national conservation plans.

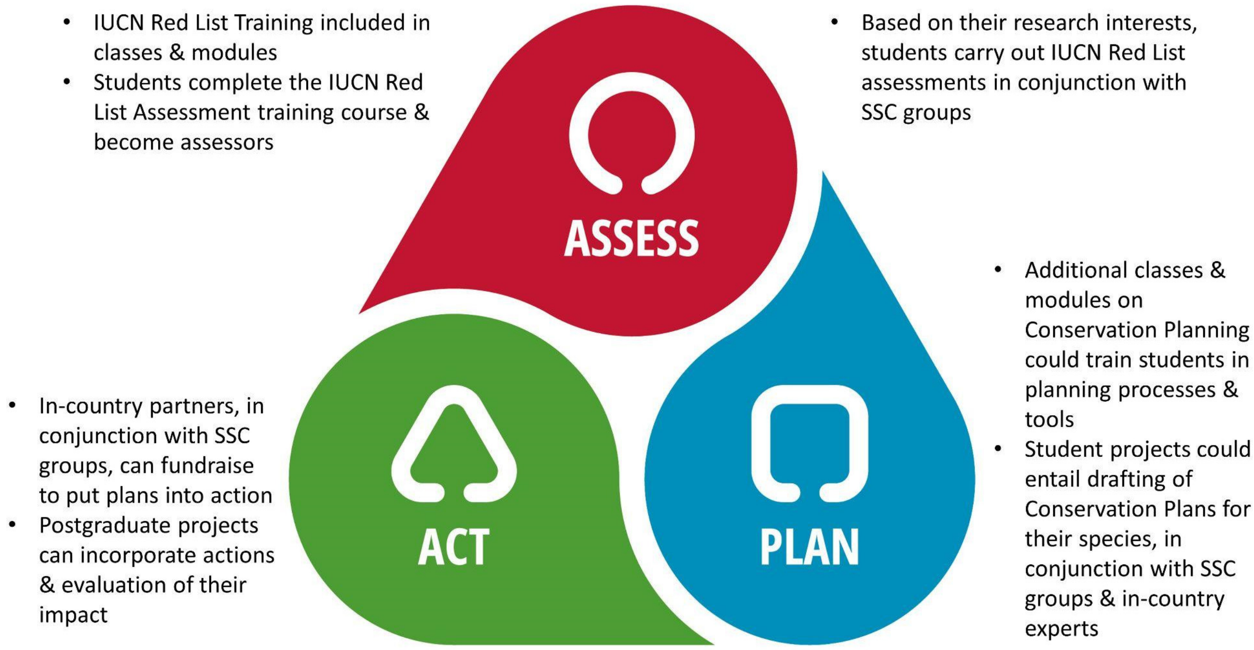

Figure 1. The IUCN Species Survival Commission's Species Conservation Cycle and how students and academic classes can feed into the process.

Our current network continues to be refined as new collaborators (termed "nodes", i.e., organizations and individuals committed to collaborative Red List assessments) emerge around the world. Very busy professionals benefit as they are included as co-assessors of priority species assessments, with students leading on the initial literature review, writing, and assessments. IUCN Specialist Groups and RLAs benefit as they tap into additional capacity for producing Red List assessments, which is of special value to those covering megadiverse and underrepresented taxon groups. Here, we provide insights into our active core collaborations in the United States, Fiji, and the Philippines.

United States: The initial team included Kutztown University of Pennsylvania, Christopher Newport University (CNU), Reading Area Community College, and TIRLA (currently coordinated from the Global Center for Species Survival at the Indianapolis Zoo). We engaged our existing network of collaborators, and recruited new ones, on assessing species that were underrepresented on the Red List. Students were initially recruited for independent assessment projects as part of academic labs. Subsequently, assessment projects were integrated into existing biology and environmental science courses where students could complete assessments through semester projects. New opportunities emerged and student-led assessments are now also completed as part of project-based independent study, writing-intensive seminars, and similar courses. Students were introduced to and worked directly with species experts in Fiji and subsequently the Philippines. Species for assessments are now selected as a team, reflecting the strengths and research priorities of in-country experts, research interests of students, and needs of TIRLA.

Fiji: Our first foray into this initiative, directly connected to our initial funding, took place in Fiji where colleagues at NatureFiji-MareqetiViti (Fiji's only national species conservation NGO) introduced our team to experts at the University of the South Pacific (USP; Suva campus) and the Ministry of Forestry who participated in the initial field research on Fiji's three endemic long-horn beetles (*Xixuthrus* spp.). These species were the first assessments produced through the network [18–20]. The collaboration has since broadened taxonomically to include other invertebrates and plants and is integrated into existing biodiversity and conservation classes at USP. New collaborations are underway with faculty and students at Fiji National University as well as with South Pacific Regional Herbarium which is housed at USP.

Philippines: The collaboration in the Philippines emerged from our interest in completing Coleoptera assessments and the recognition of the Coleoptera Research Center (CRC) at the University of Mindanao. This node of our initiative was launched by connecting leadership and students at CRC with student teams in seminar sections at CNU. The first two assessments have been submitted, seven assessments are nearing completion, and the next round of assessments is being discussed.

As with Fiji, the initiative in the Philippines is expanding, with a wider taxonomic scope and new colleagues at the University of the Philippines, Los Baños, and the associated Museum of Natural History. The Philippine Lepidoptera Butterflies and Moths, Inc. was established by citizen scientists in order to document the butterflies and moths in the country. This initiative resulted in various discoveries and documentation of the biology, ecology, and taxonomy of Philippines Lepidoptera as well as documentation of common and rare species [21]. Additionally, for the first time, several invertebrate species were included in the National Red List for Philippine fauna [22] through a special "Technical Working Group for Invertebrates", which includes members from the Institute of Biological Sciences (IBS) and the Museum of Natural History (MNH), University of the Philippines Los Baños. Although there is little overlap between the two red lists, in terms of the categories and criteria, this initial list could be given priority to be reviewed and assessed based on the IUCN Red List process, and with involvement of the IUCN SSC Butterfly and Moth Specialist Group.

While still in the early stages, at present, the network has grown to include ten active nodes in three countries, with more in the process of joining the network. At least 15 additional researchers and students have completed the online IUCN Red List Assessment Training course, and started to apply the skills learned to assessments of a variety of organisms, from the initial Fijian endemic long-horn beetles to rare plant species from Fiji, unique beetle species from the Philippines, aeglid crustaceans from South America (in collaboration with the IUCN SSC Freshwater Crustacean Specialist Group and the IUCN's Global Freshwater Assessment), and hopefully many more taxa in the future. Our initial efforts resulted in seven species assessed with the involvement of ten students and four collaborators from the Philippines and Fiji. Our pipeline is rapidly expanding, and we have at least 30 additional students and four collaborators involved in assessments of another 20+ species, and additional interest from collaborators in South America (Bolivia), Africa (Algeria, Rwanda and Kenya) and Asia (Malaysia) (Figure 2).

Figure 2. Country representation in current network to catalyze Red List Assessments of underrepresented taxa through academic networks and student engagement. The initial collaboration between partners in the United States and Fiji (green) now includes other partner organizations in Asia, Africa, and South America, which are already actively involved in Red Listing (orange) or are in the early stages of setting up Red Listing projects (grey).

3. Benefits of Red Listing to Post-Secondary Faculty

Post-secondary (higher education) faculty are commonly evaluated based on contributions in the areas of scholarship, teaching, and service as a part of a review, promotion, or tenure process [23,24]. Red Listing provides opportunities for faculty to increase their scholarship output, encourage innovation and student engagement in teaching, mentor junior researchers, contribute to academic citizenship [25], and improve overall faculty satisfaction within their own research programs [26]. Across the broad spectrum of academia, benchmarks that are used to mark career milestones for faculty and the types of evidence they are permitted to use in the tenure or promotion review process varies considerably [23,27]. In many cases, Red Listing can provide evidence for these reviews. For example, one author is a mid-career, tenured professor at a primarily teaching, undergraduate-serving university in the United States where faculty have annual performance reviews for four years until they apply for tenure. Tenured faculty have reviews every five years thereafter. In this case, Red List assessments count toward scholarship outputs (i.e., a peer-reviewed review publication or technical report) for the purposes of review and promotion. Assessments that include original research conducted by the faculty are treated no differently than any other peer-reviewed journal article. When undergraduate students are included as coauthors, the assessments also count toward faculty mentorship of students in research, which is categorized as a teaching expectation.

Research-focused universities often have expectations for original research and may not count Red List assessments towards review, promotion, or tenure in the same way as many liberal arts universities; however, a case can still be made that Red Listing has great value in academic settings regardless of the academic currency favored by specific institutions. Involving post-secondary students in publishable research has clear benefits for the students' success and integration into the larger research and conservation community [28,29]. Faculty–student collaboration on Red List projects can also provide evidence of a faculty member's commitment to the civic role of their university or service to their science at large [25]. Faculty also value having their publications viewed by a broad readership of peers more than the valuation metrics that are common in academia such as a citation index [24], and the Red List provides a worldwide readership with far reaching impacts.

Initiatives, such as the one described herein, provide faculty with the added benefit of joining and developing a global network of collaboration, catalyzing original research, and opening new opportunities to contribute their expertise to the network. Establishing these new network connections can naturally lead to new projects, identify shared resources and overlapping priorities, and funding opportunities. When students are introduced to this networked environment, we see increased interest and engagement as the real-world impacts of their semester projects are shared among the supporting nodes and their work is supported and improved by the valuable expertise comprising the network.

4. Benefits of Red Listing to Students

Species conservation, inclusion of rare, underrepresented taxa in conservation efforts, and generation of greater awareness concerning the current status of these species globally are common goals and dreams shared by many students and early-career professionals who have contributed to Red List assessments. While at times challenging, such shared goals have been a driving force for conducting and completing assessments. The applied nature of Red List assessments is an eye-opening experience that does not end with learning about species but creates opportunities to inform others and mobilize additional research projects, as it builds the basis for species conservation.

Students want their research experiences to be meaningful, impactful and to go beyond what is necessary to earn a certain grade on a class project. The Red List assessment initiative provides such an opportunity. Students must examine, evaluate, and correctly interpret all available data in the peer-reviewed literature and a variety of published and unpublished report formats and datasets to synthesize fundamentally important information for a species' assessment. Young researchers learn essential skills such as meticulously reviewing and appropriately interpreting literature to collect the requisite data for the assessment. Student's capacity to synthesize information from disparate sources and identify and update outdated information is essential for planning and protection of species, helping to solve real world problems in conservation.

Red List assessments provide opportunities to learn and exercise many new skills that are widely applicable for students in their careers. The Red List process introduces an effective framework for researching and writing species assessments. Application of the quantitative criteria and their relation to extinction risk [5] facilitates critical thinking and attention to detail about populations, distributions, and threats in a conservation context. The process helps to improve scientific writing and science communication proficiency as students learn the specifics of writing for the Red List format, which further strengthens their own writing process and discipline. They learn to express their findings clearly and concisely in a way that scientists, stakeholders, and the general public will understand. The common format of an assessment permits students to practice concise scientific writing within a prescribed format. Structure is already built into the assessment format so the student can focus on other aspects of the writing. Additionally, species distribution data is a required component of Red List assessments, and mapping species distributions provides an opportunity for students to learn and practice mapping techniques. GIS software, free online tools, and/or R can be used to produce species range maps, and calculate assessment metrics, namely Area of Occupancy (AOO) and Extent of Occurrence (EOO) [30]. Depending on the species in question, students may utilize open-access data repositories such as iNaturalist or GBIF to derive species' distribution estimates and will thus learn about the value as well as the potential shortcomings of these data sources for species mapping and Red Listing. Red Listing also adds to students' publication record as each Red List assessment has a digital object identifier and citation and is treated as an online journal article.

Not only do students learn valuable research skills through the Red List process but working on these assessments gives participating students an opportunity to learn from and work with peers, and alongside conservationists from around the world. Specialists help guide the students' work, and potentially act as mentors, getting students involved in future research, conservation, and Red Listing projects. These relationships can become lifelong professional (and personal) connections.

Student projects and activities can be expanded to cover other aspects of academic training. For example, students can present their findings and enhance their verbal communication skills. Where a field work component is included in the student project, grant money is crucial in making fieldwork plans happen. Thus, students can hone additional skills within the network, such as grant writing. Grant writing pushes applicants to market their project or research to the funders and encourages deeper thought about the big picture and impact of their research. Showing conservation impact via linkages to the Red List and the SSC network of Specialist Groups and RLAs can help facilitate successful funding applications. Field-work derived data on species localities can in turn also be submitted to open data repositories such as iNaturalist, thus building species knowledge in additional ways—not just via the Red List. Other components of the Species Conservation Cycle (Figure 1) could also be included into a student project to provide experience into how assessments drive planning and action for species conservation.

The assessments currently being drafted by students are just the first step of continuous learning and the development of skills necessary to participate in the broader assessment process. Students can also develop specific taxon expertise, learn to use the Red List's Species Information Service (SIS; the database underlying the IUCN Red List), and mastery of the Red List criteria. The student assessors are also continuing to build meaningful linkages and strengthen collaborations with fellow Red List assessors and experts from all over the world. The opportunity to participate in the assessments of underrepresented taxa and the chance to help win the race against time to have these species described, documented, assessed, and protected before it is too late, is not lost on our students.

5. Discussion

The approach presented in this paper provides a pathway to increase capacity for Red Listing of underrepresented species and regions and opportunities to start training the conservationists of the future. Given that nodes can refine the approach to their own requirements, there is flexibility also to focus attention on not just global but national Red Listing efforts, with those efforts subsequently feeding into National Biodiversity Strategies and Action Plans (NBSAPs). Ultimately, to sustain and expand Red List coverage of species, we need to think "outside the box" and increase capacity for Red List assessments outside of the current pool of SSC members and assessment projects led by IUCN or partner organizations.

5.1. Opportunity: Engagement of Underrepresented People

Red Listing can be carried out by anybody with sufficient knowledge about a species, and training in the Red Listing process is accessible to all through the online IUCN Red List Assessment course [17]. While the Red List recognizes the need to broaden the taxonomic coverage of extinction risk assessments, there has been a growing recognition within science, technology, engineering, and mathematics (STEM) that workers with diverse perspectives are needed to keep up with the 21st century workforce [31]. The combination of Red List training and direct engagement in species assessment processes can thus become a tool not only to help save species at risk of extinction. If implemented within the underrepresented student population, and coupled with guidance and mentorship, it can help to retain underrepresented students within higher educational systems before they go 'extinct' from the academic pool of students. This also provides a meaningful way to diversify Specialist Groups and RLAs, as is the goal of the SSC, and incorporate underrepresented voices into the network.

Diverse perspectives are far from being adequately represented in STEM in many parts of the world. For example, in the United States, 27% of underrepresented people (e.g., Hispanics, African Americans, American Indian/Alaska Natives) comprise the US adult population, but only 11% make up workers in STEM occupations; as of 2015, just over 20% of underrepresented minorities received science and engineering bachelor's degrees [32]. From a biodiversity perspective, diverse communities are more resilient to extinction in terms of environmental and anthropogenic threats [33]. Similarly, strengthening cultural diversity and resilience within academia will allow students to tap into a sociocultural context to overcome hardships and adversity that may aid in their retention within academic institutions [34] and ultimately lead to greater capacity in the broader Red List network and species conservation.

There are a variety of reasons why students leave college: student backgrounds, pre-college academic experiences, and structural characteristics of the academic institutions themselves (e.g., size, selectivity process, and interactions with faculty, staff, and peers) [35,36]. To retain students from diverse backgrounds, we need to develop and employ new student success strategies, and evaluate their efficacy in meeting learning outcomes, student self-efficacy, and promoting a supportive environment and valuable learning experience [31]. Mentoring is an essential strategy to assist underrepresented students in their navigation of higher education by addressing the aforementioned issues facing many colleges and universities today, such as retention and degree completion [37,38].

Mentoring programs aimed at STEM students provide academic and social support via peer-mentoring (with mentors themselves underrepresented students with demonstrated academic success) and faculty guidance to encourage scholarship, scientific identity, strength of community, and engagement in departmental and university life. Involvement in Red List assessments represents an ideal vehicle for an inclusive pedagogical component that, as a participatory research method, will allow students to become co-researchers and promote self-expression and reflection as suggested by Chelberg and Bosman [31]. Including underrepresented students as assessors allows them to share their diverse ideas and lived experiences in the hope that their involvement will provide equitable contributions, shared decision-making and ownership in the process, and that their ideas will help to promote both the conservation of biological and cultural diversity. This engagement provides direct pathways into conservation careers and is one piece of the puzzle to diversify the conservation sector.

This focus on engaging underrepresented students in Red List assessments will be trialed at Millersville University of Pennsylvania in the United States with the specific aim of promoting and celebrating the academic success and retention of underrepresented minority students in biology. The existing Biology Mentoring Program (BMP) will be expanded to include Red List assessment training as an inclusive pedagogical component and a participatory action research method. Different academic institutions can further mold this approach to fit not just their taxonomic and research interests, but also their institution's diversity goals.

5.2. Opportunity: Filling Taxonomic and Geographic Gaps

Around the world, there are significant regional and national gaps in the taxa represented on the Red List. As threats to biodiversity increase and biodiversity continues to decline, species are being lost even before they have been assessed, as evident from the more than 40,000 species reported to be threatened with extinction [6]. Recognition of the gaps and proactive initiatives to strengthen Red List assessment capacity to fill these gaps are required to ensure biodiversity conservation, from local to global scales.

Taxonomic Gaps: While assessments for several previously overlooked and ecologically important taxonomic groups are currently underway, these assessments are often driven by a limited pool of species experts. With the vast majority of invertebrate and fungi species not yet assessed for the Red List [6], there are ample opportunities for student assessors to help with filling assessment gaps. Species revisions that postulate the latest taxonomy of a group and provide additional data on species' habitat, distribution, and ecology have previously informed Red List assessments of underassessed groups and are relatively easily accessed by student assessors. In addition, ideal starting points may be systems or taxon groups where, because of a restricted range for many species and the same threat impacting all or most species, potential threat levels are high (i.e., urgent need) and threats are relatively easy to assess (i.e., ideal for student assessors). This is particularly well illustrated by cave invertebrates (e.g., [39]).

Cave-restricted species are generally very narrow endemics, and species occurring in the same cave system generally suffer the same threats (e.g., limestone quarrying in Southeast Asia, [40]; guano harvesting, [41]; introduction of invasive species, [42]), so it is comparatively easy for student assessors to compile Red List assessments for an entire cave system. In addition, assessment work on these species has high impact: given the likely high levels of threat, assessments are an important basis for conservation planning and action. Students could also learn about 'expedited' multi-species assessment processes for conservation planning, such as the IUCN's Assess to Plan (A2P) framework (e.g., [43]), and could include conservation planning approaches into their projects, in order to turn assessments into cave-scale conservation plans. Some recently completed Red List processes (e.g., [39]) can provide a roadmap for how to tackle the assessments. Spatial maps of karst and karst aquifers [44,45] can be used to aid distribution mapping and calculation of range-based metrics used by the Red List, such as EOO and AOO [46]. In addition, based on species characteristics such as depigmentation, loss or reduction of the eyes, and elongation of sensorial organs and limbs, it is relatively easy to determine which cave species are cave obligates (troglobites) and do not occur outside caves ([47,48], S. Henriques pers. comm.). This can help with estimating the impact of cave-related threats on the species.

Up until now, fungal Red List assessments have been produced mainly at expert workshops, and despite a nearly 1000% increase in the number of published assessments over the past four years (from 56 to 597), the process is still slow [49]. The number of trained assessors with capacity for producing fungal assessments is small and the review process is currently dependent on only a few mycologists. With c. 150,000 described species of fungi [50] (and potentially 2–4 million fungi species overall; [51]), it is imperative that alternative procedures are found to assess the extinction risk of fungal species. Building a larger network of assessors capable of applying the Red List method to fungi by engaging students and academia in the Red List process could significantly increase the number of fungal species assessed and potentially increase the number of experienced reviewers. However, given the current limitations of available data and the importance of ensuring they are appropriately interpreted for species assessment, it is paramount that student assessors are integrated closely into the network of expert mycologists and that assessments are connected with the biologists and conservation community in the country.

For any student assessment project, integration into an expert network is highly recommended. The data available for many understudied groups, such as fungi and invertebrates, are often limited to specimen data from natural history collections, supplemented by observational data posted to sites such as iNaturalist. As a result, understudied species are most often assessed using the Red List's range-based criteria (B and D2; [52]). There are no detailed data on the number of individuals nor comprehensive distribution information for most species. While students can easily contribute to the initial data gathering through literature and database searches, student assessors need to work closely with species experts to extrapolate distribution and abundance based on collection efforts, area of suitable habitat, and species detectability (e.g., see [53] for the process for fungi) and infer the necessary population and distribution variables to apply the Red Listing method. While cave species, as described above, could provide a great access point for student assessors, linkage with experts may also be required: for example, in those cases where troglobitic characters are also expressed in organisms living in other "subterranean" habitats (i.e., soil-dwelling fauna, nest inquilines) and where caution should be used in relying on visible morphological adaptations in caves (see [47]), especially under megadiverse tropical conditions. By linking students with species experts, such as entomologists and mycologists, an even greater impact could be achieved by increasing the knowledge and awareness of future conservation professionals on the importance of these groups of species and on how to protect them.

Geographic Gaps: The most significant geographic gaps in the representation of taxa on the Red List are most often found in the developing world (low- and middle-income countries) that are often rich in biodiversity (e.g., Africa, Asia, Oceania, Central and South America), especially for underrepresented taxa (e.g., several invertebrate groups, fungi, and non-tree plants). As we are establishing our first nodes in Africa (Figure 2), this presents a clear opportunity to address some key taxonomic gaps of the Red List within this biodiverse region.

Several factors are emerging as leading contributors to the relatively low numbers of species assessed within Africa and represented on the Red List, including taxonomic limitations, the lack of well-curated specimens, funding, equipment, technological tools, and people trained in the assessment process, and high costs of obtaining permits for studies. Further, much of the published peer-reviewed research is generated from South Africa, resulting in significant geographic gaps in scientific information available to inform Red Listing. Individually, each factor is extremely challenging to overcome and when combined they may seem to be insurmountable to some.

Nonetheless, in recent years, conservation advocacy groups have given a platform to use citizen science to enhance species recording from different localities, making data more easily available and accessible. For example, formation of smaller groups with interest in insects like Lepsoc (Lepidoptera Society of Africa; [54]) and Nature Uganda (Dudus; [55]) has been instrumental in getting the often-neglected insect fauna documented across Africa. In Rwanda, collaboration with the Royal Belgian Institute of Natural Sciences has been successful at building taxon expertise in ants, including discovery of new species and range extensions, and funding from the Volkswagen Foundation has recently supported training in specimen collections management as well as building taxon expertise in various animal and plant groups. Additionally, from the old poorly curated specimens, there are opportunities to salvage what has been collected as a starting point for bridging the gap in numbers of species on the Red List. Furthermore, educational institutions with a constant flow of students can contribute to data acquisition and the development of tools much more cheaply for fostering a continuous Red Listing process that results in the publication of quality assessments for Africa's underrepresented biodiversity. Development of trusted collaborations with other experts will strengthen capacity within Africa and help leverage funding and catalyze needed research. All these opportunities are currently being explored for collaborative nodes in Kenya (National Museums of Kenya), Rwanda (Center of Excellence in Biodiversity and Natural Resource Management at University of Rwanda), and Uganda (Makerere University) and will contribute to development of more complete checklists for neglected taxa, which then subsequently enable the global Red Listing of these species.

5.3. Opportunity: Integration with National Biodiversity Initiatives

Management of biodiversity at the national level is supported by both the recognition of valid species in a country and high-quality Red List assessments which provide important information for species conservation. Yet, quite often, Red List assessments are carried out at expert workshops and are disconnected to the biologists and conservation community in species' range countries. To address this disconnect, and steer their own conservation prioritization and planning processes, many countries are producing their own Red Lists (hereafter termed "national Red Lists") [56]. The IUCN greatly aided the global effort in harmonizing national Red Listing by publishing guidelines for the application of the IUCN Red List Categories and Criteria at sub-global levels [57]. The IUCN Red List Assessment training course also includes a module on applying Red Listing to national contexts. While national Red List processes have sprung up around the world, notable gaps in national Red List coverage remain, especially in Africa [56]. Several of our network nodes could also provide crucial capacity for not just global, but also national Red List initiatives.

An interesting angle to pursue, as part of student Red List projects, is to use national assessments to provide the basis for inclusion of species in National Biodiversity Strategies and Action Plans (NBSAP). Subsequently, this would allow students to work with taxonomic experts and governments to learn how to turn species assessments into conservation plans, action, and policy.

For example, conservation efforts in Bolivia are hindered by poor access to funding, technology, permitting, specimens, and trained taxonomists. However, The Red Book of Bolivian Invertebrates [58], a collaborative initiative with national and foreign specialists, represents a significant step forward. Its goal was to evaluate Bolivia's invertebrates and was supported by the government and the Ministry of Environment and Water. It was developed by 26 biologists, many of whom were young Bolivians that gained an interest in insect conservation when they were students. The work involved analyzing, ordering, and updating the taxa according to their risk and degree of population decline following the Red List methodology [57]. It used the different scientific collections in the country, mainly the Entomology Collection of the Noel Kempff Mercado History Museum, the Bolivia Fauna Collection, and the Alcide d'Orbigny Natural History Museum. This initiative demonstrates the value of engaging young biologists who contributed their time and effort to the conservation of insects with more senior experts to develop a national Red List.

Similarly to the Species Information Service (SIS) that was developed as IUCN's web application for conducting and managing Red List assessments, Malaysia has established its own one-stop repository database system, which provides and facilitates access to information on biodiversity studies and management in its country. It is known as Malaysia Biodiversity Information System (MyBIS). MyBIS provides the information exchange platform of the Convention on Biological Diversity. Created in accordance with Article 18(3), it has evolved into a global network of websites, with the CBD website [59] as its central node, and MyBIS as a national node of the network. Biodiversity information deposited in this website is taken from published books, journals, expert checklists, and specimen databases. MyBis will ease public access for information and updated statistical analysis on biodiversity data. Above all, MyBis will aggregate all the updated information of biodiversity in Malaysia as a reference basis for IUCN's SIS to assess underrepresented taxa for publication on the global Red List.

5.4. Recognizing and Overcoming Challenges

Building global capacity for Red Listing via student and academic engagement also presents several challenges. Perhaps one of the greatest challenges is that of access to the Red List process itself. Many species experts outside the IUCN network are unaware that they can contribute assessments to the Red List. In practice, most major assessment processes for the Red List are either led by IUCN or IUCN Red List partners, or by IUCN SSC Specialist Groups and RLAs [60]. Experts outside the IUCN network interested in contributing should coordinate directly with the appropriate taxonomic authority (Specialist Group or RLA; [15]) to confirm species, understand expectations and processes, and ultimately submit their assessment to the Red List Unit where the relevant RLA will establish an appropriate review for each assessment. This is a process akin to the peer-review process of a scientific journal but may be made potentially more complicated because of a number of factors.

SSC group chairs and RLA coordinators are volunteering their time to IUCN work, and are often busy, so that sometimes, receiving timely responses to submitted assessments is understandably difficult. Several Centers for Species Survival (CSS; [61]) have been established worldwide which can act as initial points of contact to engage with the SSC network. This includes the Global Center for Species Survival, based at Indianapolis Zoo, which works directly with and supports the efforts of taxon-focused SSC Specialist Groups and RLAs [62].

Given that SSC chairs and RLA coordinators provide their work on a voluntary basis, engaging with an "outside" assessment process may seem an additional burden on an already thinly spread capacity. Mediation via a CSS coordinator can help with overcoming capacity issues and help Specialist Groups and RLAs appreciate that ultimately our approach aims to generate more Red List assessments without taking much of their time. Assessment help can be seen as especially beneficial to Specialist Groups and RLAs if species chosen for assessment align with the group's targets and goals, while not interfering with ongoing, already well-progressing efforts. Therefore, engaging early with Specialist Groups and RLAs allows sticking points to be ironed out before they become challenges. It also allows discussion of the approach taken for assessment, i.e., how Red List parameters are derived from available data, to ensure consistency among assessments carried out by different people (e.g., see fungi section).

While many challenges are generally associated with the Red List assessment process itself, they may be exacerbated for student assessors, especially those in developing countries. Good, reliable internet connectivity is vital to allow students' access to the online IUCN Red List Training course, the SIS database, online data sources for distribution data such as GBIF, iNaturalist or taxon-specific databases, and for literature searches and to conduct online meetings with species experts. These provisions should be made to students by their academic organization or a partner organization within the network, so it does not add financial or logistical burdens to students and undermine their ability to complete a high-quality assessment.

Another challenge is to ensure that all relevant training is provided to students to succeed in their endeavor of species Red Listing. Many resources exist that allow students to gain training easily and freely. The online Red List training course should be incorporated into any Red List academic module that directly supports and produces IUCN Red List assessments. Not only is it vital that students complete this online training, but academic staff involved in the module should do the same. Since Red List assessments require species' range maps as supporting documentation [30], student assessors should receive training and access to online mapping tools or GIS software. If this is not possible, mapping support must be provided to the student assessor to complete the Red Listing process. This could be achieved by linking them with students proficient in producing species maps, thus further helping students to not just achieve Red List outputs but build collaborative relationships with their peers and a wider academic community.

Furthermore, it is important that longevity and viability of the approach is considered right from the start. Officially, Red List assessments are considered out-of-date after 10 years [63], and up-to-date Red List information provides the best possible information to conservationists; more current assessments are likely warranted for threatened species and species with new information that would impact their status on the Red List. It is therefore vital to not only focus on new species assessments but ensure long-term viability of Red List assessments. For example, future cohorts of students should become engaged in regular reassessments of species—both of species previously assessed through student assessments, but potentially also of long-outdated assessments. The IUCN Red List currently still contains nearly 2000 mollusk and arthropod species which were last assessed in 1996 [6]. These are clear priorities for groups such as TIRLA to update with latest assessments carried out to current IUCN Red List standards (or to discard where taxonomy is now invalid). In effect, the assessment process for these species would very much mirror that for previously unassessed species, due to changes in the required documentation standards over time.

6. Conclusions

Completion of assessments through our nascent approach is gathering momentum (7 assessments published or formally submitted and 20+ assessments nearing completion) and it has been rewarding to see students participating in the initiative proactively, requesting additional species to assess, recruiting other students to the initiative, and integrating some aspects of Red Listing into their existing graduate projects or even developing their research proposals with Red List assessments as a core objective.

Given differences in assessment approaches for specific taxonomic groups, academic and institutional organization, and regional variation in the challenges that may need to be overcome, we are aware that our approach will not work for all. Instead, we are proposing a flexible model that can be molded to fit different situations. There is no hard and fast approach—the main emphasis is on integrating student assessors into Red List processes to benefit students, the SSC network, and ultimately the IUCN Red List.

We envisage that the process, over time, provides benefits to everyone involved. The IUCN SSC network will increase its capacity for more assessments of under-assessed groups, welcome new members from underrepresented regions and backgrounds, and increase youth engagement and membership. This is particularly important as diversification of the network has become a major focus of the IUCN overall [64]. It may link SSC groups with academic partner organizations that are long-term committed not just to the Red List assessment process itself, but to develop research grants that can assist the generation of new species knowledge or implementation of conservation actions. Ultimately, limited capacity is the main hurdle that SSC groups need to overcome to establish a more comprehensive picture of the conservation status of megadiverse species groups and the status of species in megadiverse countries. Our approach has the potential to provide huge benefits in these megadiverse countries, given that they harbor large student populations (such as China and India; [65]).

For academics, Red Listing provides opportunities to further personal research and scholarship and contribute to the mentorship of student researchers with clear benefits for the academic review, promotion, and tenure process. Students benefit directly by establishing collaborative networks, which provide direct conservation outputs, becoming proficient in Red List assessments, and adding Red List publications and experience to their resume. Insight into IUCN processes can guide their future research interests by highlighting areas requiring research and putting them in touch with the relevant experts on the ground. Additionally, our approach can be molded to integrate involvement in other IUCN assessment or conservation planning processes. Assessments of the IUCN Green Status of Species [66], Assess to Plan processes, and systematic species conservation planning can all be incorporated into the model (although some processes, such as Green Status evaluations, may be limited by data availability for understudied taxa).

Ultimately, the Red List can only benefit from further integrating local expertise into the process, by improving assessments through integration of local knowledge and unpublished data (or data published in other languages). In addition, increasing conservation and Red List literacy amongst students of the natural world is required if we want to engage a workforce well-equipped in the pressing conservation questions that need urgent action now and in the future.

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