INQUIRY & INVESTIGATION

Computer-Based Activity to Engage Students in Exploring Biodiversity Decline & Extinction

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Abstract

Understanding the main causes of biodiversity decline is an essential part of the syllabus of any university-level course in conservation biology. A novel computer-based activity is described for introducing students to using the International Union for Conservation of Nature (IUCN) Red List database. The specific objectives of this activity are (1) to understand the main causes that threaten species worldwide and, if these causes differ, to try to elucidate the underlying processes that might be responsible for these differences in a given country and (2) to train students how to use digital biological data platforms, such as the IUCN Red List, and how to analyze and interpret biological data. To achieve these goals, students must obtain information from the IUCN Red List to assess why species are threatened globally and in a given country. Based on the total number of threatened species, students calculate the percentage of species affected by each threat within each Red List category and for all categories combined both globally and at the national level. The activity ends with a discussion in the classroom where the students are expected to share their interpretations about the main causes that threaten biodiversity at different scales of analysis and the applications of their findings in a conservation context. The activity is expected to increase the awareness of students regarding environmental issues and to develop different key competencies and basic skills as learning outcomes, including expertise in biological diagnosis, information management, and using the internet as an information source.

Key Words: *conservation biology; International Union for Conservation of Nature; threatened species; university student.*

○ Introduction

Understanding what drives species extinction is a central goal of conservation biology (Purvis et al., 2000). The *extinction* of *species* is closely tied to the *process* of natural selection, and thus it is a major component of progressive *evolution (Raup, 1994)*. However, over the past few centuries, human activities such as habitat destruction, overharvesting, introductions of invasive species, the release of toxic pollutants, and climate change have accelerated this process (Ehrlich and Ehrlich, 1981; Hughes et al., 1997; Vitousek et al., 1997). As a result, the extinction rate caused by human activities is now thousands of times higher than the expected background rate (Ceballos et al., 2010). However, many location-dependent factors that simultaneously threaten species can vary among locations on the planet and at different scales. Uncovering the underlying threats and processes that determine current species declines could improve our predictions of future declines and facilitate subsequent conservation efforts (Purvis et al., 2000).

Studying the main threats to biodiversity is an essential part of the syllabus of any university course in conservation biology, and it could also be included in general biology courses at university or high school levels. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species provides reasonably standardized estimates of the global extinction risk under past and recent conditions (Mace et al., 2008), which can be used to analyze the major threats to biodiversity. The IUCN operates in the fields of nature conservation and the sustainable use of natural resources. The IUCN is involved in data collection and analysis, research, field projects, advocacy, and education. The aims of the IUCN are to influence, encourage, and assist societies around the world in order to conserve nature and to ensure the equitable and ecologically sustainable utilization of natural resources. The IUCN has observer and consultative status at the United Nations and it plays key roles in the implementation of international conventions on nature conservation and biodiversity, although it is best known to the general public for compiling and publishing the IUCN Red List of Threatened Species, which provides assessments of the conservation status of species throughout the world.

In this article, I describe a computer-based activity for introducing university level students to the main threats to biodiversity at global and regional scales by using the IUCN Red List. This activity aims to develop different key competencies and basic skills as learning outcomes, including expertise in biological diagnosis, information management, and using the internet as an information source. The specific objectives of this activity are (1) to understand the main threats to species worldwide and to elucidate the specific underlying processes that might be responsible for any differences in a given country and (2) to provide students with training

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in the use of digital biological data platforms, such as the IUCN Red List (Table 1 provides a more comprehensive list of biological databases), and the analysis and interpretation of biological data. This activity was developed to increase the awareness of students regarding environmental issues and to encourage them to explore the causes of biodiversity decline, which aligns tightly with United Nations Sustainable Development Goal SDG15 (to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

○ Description of the Activity

The proposed activity is intended for senior high school and college biology classes. High school students with some basic biology background might also benefit from this activity because studies of invasive species, human interaction, and environmental changes are specifically included in the Advanced Placement Biology assessment. The activity can last from two to three hours, and it should ideally be complemented with a prior theoretical session (one to two hours) explaining in more depth the main threats to biodiversity (e.g., deforestation rates in different biomes and their impacts on species loss). The activity must be conducted in a computer room with no more than 20 to 30 students to allow closer interaction between the instructor and students to facilitate discussion and debate. If necessary, the activity can also be performed independently by students as homework or taught virtually as distance education provided that they are given a step-by-step tutorial about how to proceed (see Supplemental Material Appendix 1, available with the online version of this article).

The IUCN Red List of Threatened Species is continually expanded and updated, and the number of threatened species grows each year. In the IUCN Red List, species are classified according to nine categories (IUCN Standards and Petitions Committee, 2019) based on criteria such as the rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation. These categories include not evaluated (NE), data deficient (DD), least concern (LC), near threatened (NT), vulnerable (VU), endangered (EN), critically endangered (CR), extinct in the wild (EW), and extinct (EX). The threatened categories include VU, EN, and CR, whereas species at lower risk of extinction include LC and NT. In addition, for each species, the Red List provides information such as the type of system where it is usually found (terrestrial, marine, or freshwater), preferred habitat (forest, savanna, scrub, grasslands, wetlands, etc.), plants' growth forms

Table 1. Examples of worldwide biological databases used for research and teaching in biodiversity and conservation. Authoritative and comprehensive lists of species names and taxonomic or barcode databases are not included.

Database	Scope	Data Type	Data Access
AlgaeBase	Global database of information about algae, including terrestrial, marine, freshwater organisms (Guiry & Guiry, 2021)	Algae taxonomy, nomenclature, distribution information	https://www.algaebase.org
eBird	Online community of bird watchers who collect, manage & store observations in a globally accessible, unified database (Sullivan et al., 2009)	Bird distributions, abundances, habitat use, trends	https://ebird.org/explore
FishBase	Global biodiversity information system about finfish (Froese & Pauly, 2020)	Finfish taxonomy, biology, trophic ecology, life history, uses, historical data back 250 years	https://www.fishbase.in/home.htm
Encyclopedia of Life	Aggregated data about biological organisms (Parr et al., 2014); includes educational tools	Biological organism descriptions, media (images, videos, sounds, maps)	http://eol.org (API & 'taxize' R package) (Chamberlain et al., 2020)
Global Biodiversity Information Facility	Global network & data infrastructure funded by governments to provide open access to data about all types of life on Earth (Yesson et al., 2007)	For all types of species, georeferenced occurrences	https://www.gbif.org (API & 'rgbif' R package) (Chamberlain et al., 2021)
IUCN Red List of Threatened Species	Global list of species' conservation status, which can be used to inform & catalyze action for biodiversity conservation & policy change	For all types of species, conservation status, range, population size, habitat, ecology, use and/or trade, threats, conservation actions	https://www.iucnredlist.org (or the 'taxize' R package can be used to check species conservation status) (Chamberlain et al., 2020)
Ocean Biogeography Information System	Open-access data & information clearinghouse about marine biodiversity for science, conservation, and sustainable development (Grassle, 2000)	Marine organism diversity, distribution, abundance	https://mapper.obis.org

(annuals, epiphytes, parasites, lianas, trees, etc.), and threats (residential development, agriculture, pollution, climate change, etc.).

During this activity, students must obtain information from the IUCN Red List to assess why species are threatened globally and in a given country. I use Spain as a case study to illustrate the activity but the exercise can be conducted with data from other countries. Alternatively, different groups of students can investigate the main causes that threaten species in different countries, regions, or continents. The students then answer some questions based on the data collected. The activity ends with a discussion in the classroom where the students are expected to share their interpretations of the results and applications of their findings in a conservation context. A step-by-step summary of the activity is provided in Supplemental Material Appendix 1.

○ Procedure

Part 1. Assessing the Factors That Threaten Species Globally

To facilitate the compilation of data from the IUCN Red List, the instructor provides the student with an Excel spreadsheet (Supplemental Material Appendix 2) before the activity begins. To access the Red List search engine, students go to the IUCN Red List page (http://www.iucnredlist.org) and click on the Advanced icon. From the Red List Category tab on the left bar, the student selects only the VU category (Figure 1).

In the lower part of the bar, the student verifies that only the Species option is checked in INCLUDE, which ensures that assessments made at the level of subspecies, varieties, or populations will not be considered in the search. After making this selection, click on the Threats tab and a submenu is displayed with the different threats, and the number of species threatened by each factor is shown in parentheses (Figure 2).

The student then inserts these values in the Excel sheet in the Total values section in column B (VU). The IUCN threat category "Other options" is not included in the analyses because it provides little information about the causes that drive species extinction. It should be noted that the same species can be affected by several threats simultaneously, so the total number of species listed in a Red List category will not necessarily match with the total number of species obtained by considering all possible threats. Therefore, the total number of species classified under each Red List category (row 15 in the spreadsheet) is obtained from the Red List search engine when applying the first selection criteria (Figure 1).

The same procedure is performed for the other two Red List categories, i.e., endangered (EN) and critically endangered (CR), and the information obtained is inserted in the corresponding columns of the Excel spreadsheet (Total values). After collecting all the results, the totals for the three categories combined are calculated for each threat by summing each row for the total species included in the three Red List categories.

Part 2. Assessing Factors That Threaten Species at the National Level: Spain as a Case Study

This procedure is similar to the assessment of factors that threaten species globally (Part 1), but in the search criteria tab, students also select the country or countries under evaluation (Spain in this example) from the Land Regions drop-down list (Figure 3). The results obtained are inserted into the corresponding columns of the Excel spreadsheet, and the totals for the three categories combined are calculated (Appendix 3).

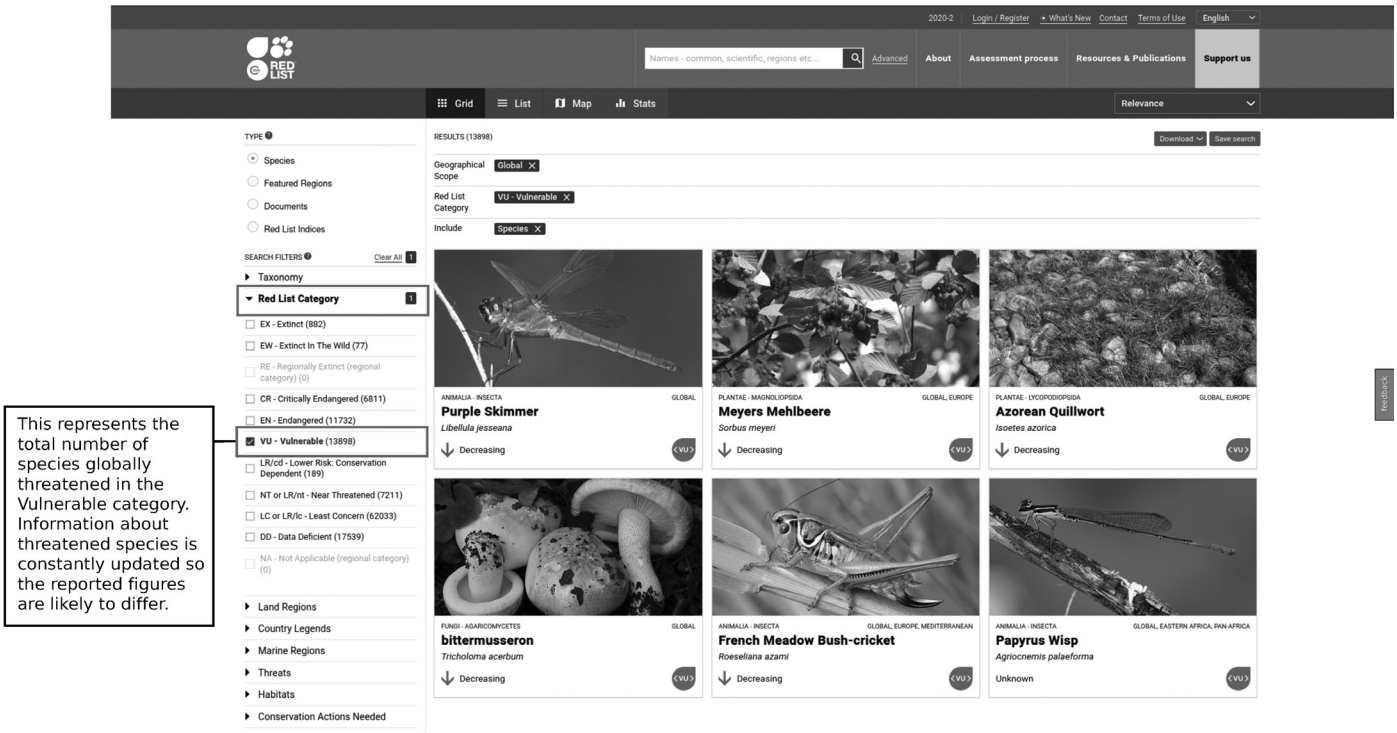

Figure 1. Display options provided by the IUCN Red List advanced search engine (left bar) for selecting species listed in one or more Red List categories.

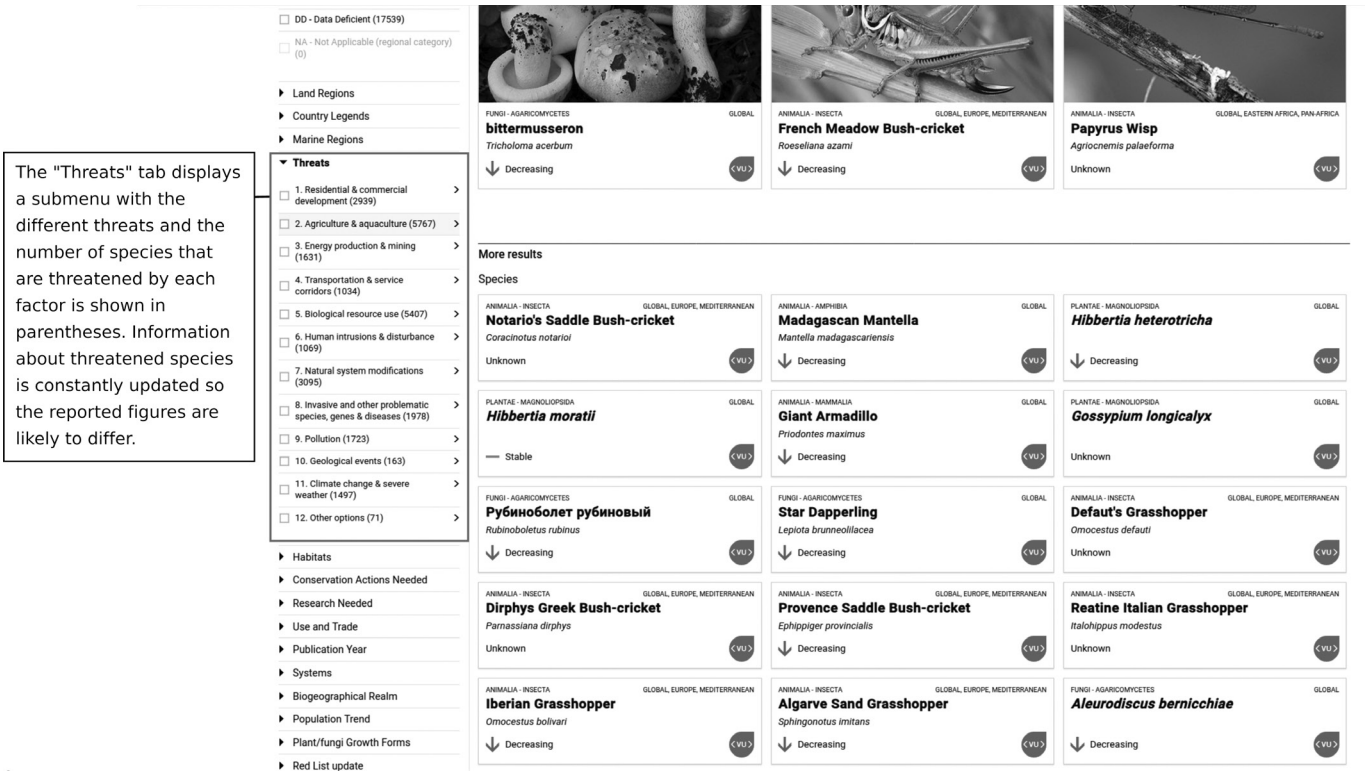

Figure 2. Display results obtained from the IUCN Red List showing the number of species under each threat listed in the vulnerable category (VU). Note, the number of species listed in each Red List category changes each time that the IUCN Red List is updated.

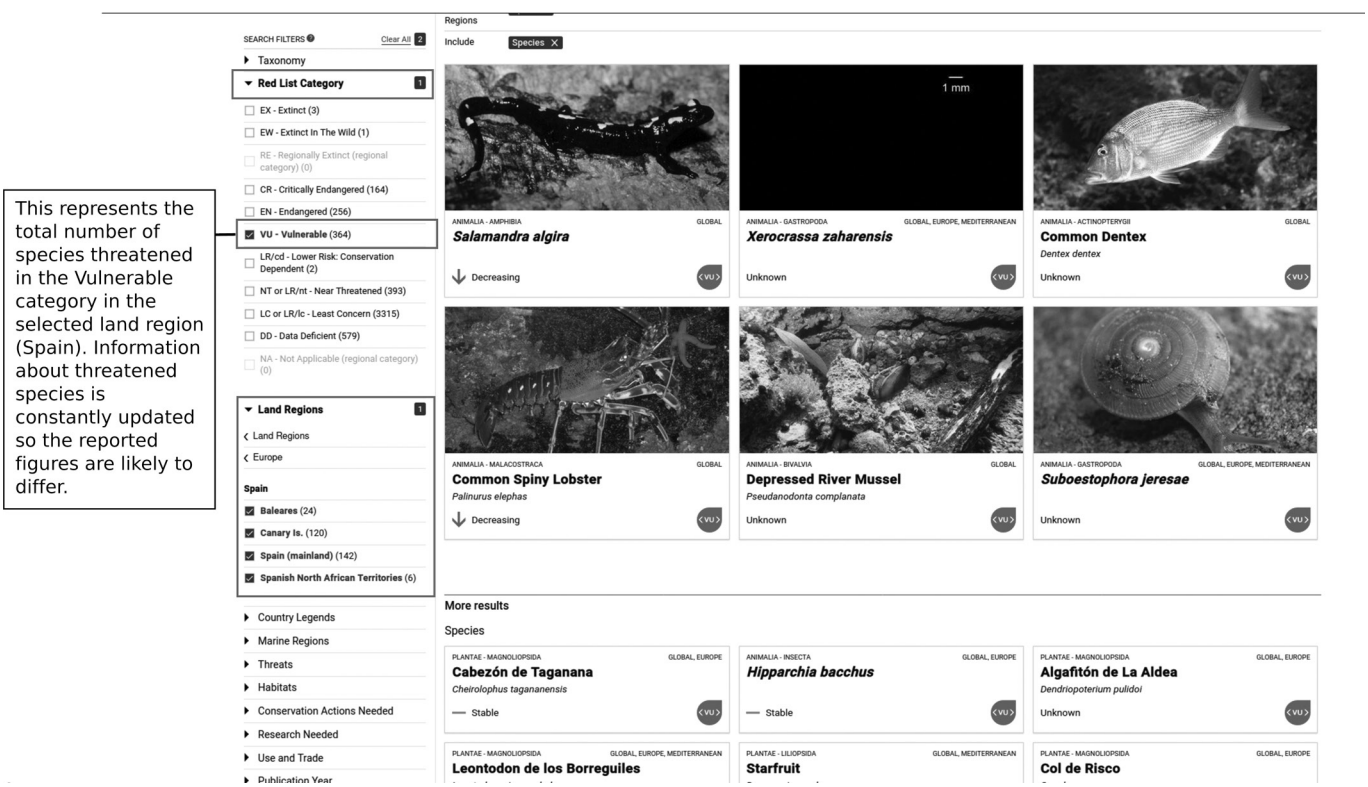

Figure 3. Display results obtained from the IUCN Red List showing the number of species under each threat listed in the vulnerable category (VU) for a particular land region, Spain in this case. Note, the number of species listed in each Red List category changes each time that the IUCN Red List is updated.

Part 3. Interpretation of Results

Based on the totals, students can calculate the percentage of species affected by each threat in each Red List category as well as for all categories combined at both the global and national levels. The procedure is repeated for the remaining Red List categories, including all categories combined.

The students then prepare a bar plot (the R code required to generate this figure is provided in Supplemental Material Appendix 4) to compare the percentage of species affected by each threat for each Red List category (including all categories combined). Only global data are used to prepare this plot (Figure 4). Similarly, students need to prepare another bar plot (the R code is provided in Appendix 4) that allows them to visually analyze whether the threats that affect species at the national level are similar to those that affect species globally (Figure 5). Only the values for all categories combined (Columns E and I) are used to produce this plot.

Part 4. Discussion Session

At the end of this activity, students are expected to address the following questions using the results obtained during the laboratory session.

1. What are the most important threats globally? Does the importance of these factors vary according to the Red List category?
2. What are the most important threats at the national level? Are there differences between the results obtained at the global and national levels? What are the main differences? What might cause these differences?

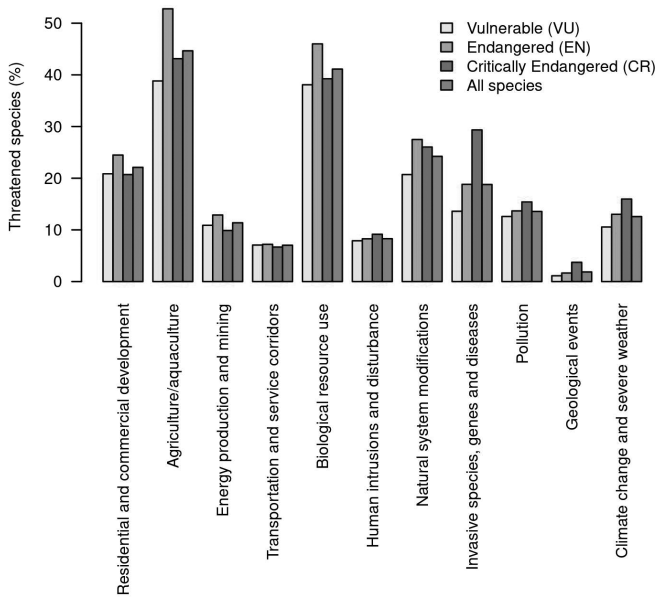

Figure 4. Example of a bar plot summarizing the threats to biodiversity for different Red List categories (vulnerable [VU], endangered [EN], critically endangered [CR], and all categories). According to this plot, the main threats to biodiversity include agriculture/aquaculture and biological resource use (e.g., overfishing and overhunting). Threats such as invasive species, genes and diseases, climate change, and severe weather or pollution are more frequent as the threat category increases (i.e., CR vs. VU and EN).

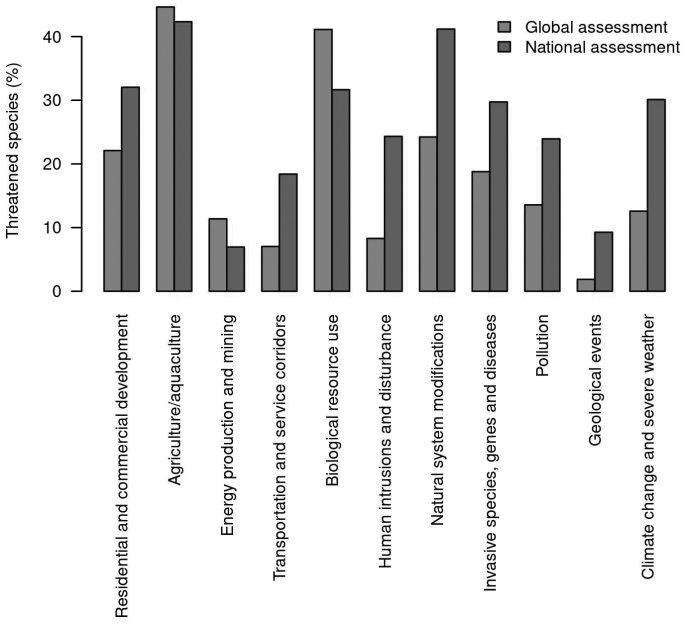

Figure 5. Example of a bar plot comparing major biodiversity threats at the global (blue) and national (red) scales. Percentages are based on all species. For the case study, the results indicate that some threats are more frequent in Spain than worldwide, such as residential and commercial development, transportation and service corridors, human intrusion and disturbance, natural system modifications (e.g., construction of reservoirs), invasive and other problematic species, genes and diseases, pollution, and climate change. Note, the sum of the percentages of threatened species across threats both globally and nationally exceeds 100% because the same species can be affected by several threats simultaneously.

3. Where should conservation actions at the national level be directed?
4. Finally, what is the pattern obtained after summing the percentages of threatened species in the columns for all three categories combined at the global and national levels? What are the implications of the results in terms of biodiversity conservation?

In the first phase, these questions should be addressed individually by students. At the end of the activity, an open discussion is conducted in the classroom to allow students to compare their findings and interpretations of the results. Students discuss the differences in the observed patterns of threats to biodiversity in different geographical regions and infer the underlying processes or mechanisms that might trigger species extinctions in different study regions.

Further options for analysis and discussion might include comparison of threats to biodiversity between plants and animals and/or by habitat types (forests, savannas, scrublands, grasslands, wetlands, etc.).

○ Assessment of the Activity

To analyze the performance of the activity at generating learning outcomes, third-year university biology students conducted the activity

as part of a conservation biology course, and they were requested to complete an anonymous survey after finishing the course. In total, 56 students from the 2019/2020 academic course at Rey Juan Carlos University, Spain, were asked to evaluate the acquisition of different key competencies and basic skills as learning outcomes, including awareness of environmental issues, expertise in biological diagnosis, information management, and use of the internet as an information source. Thirty-six respondents completed the survey, and they represented 64% of the cohort. The responses provided by the students were highly variable, but the average scores in all cases ranged between eight and nine, and awareness of environmental issues and using the internet as an information source were the key competencies that received the best ratings from students (Figure 6).

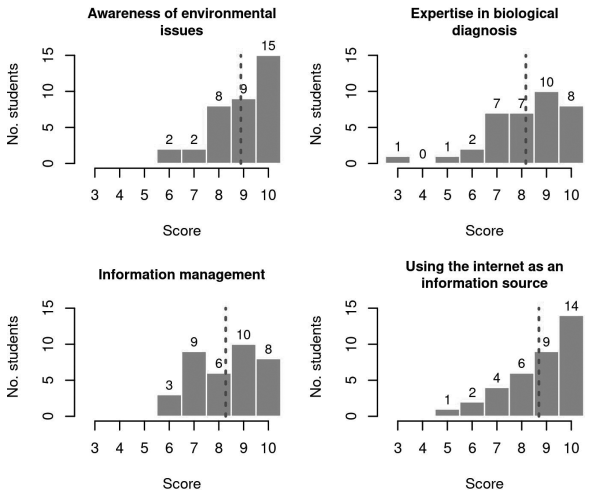

Figure 6. Responses of students to a survey conducted for assessing learning outcomes. The students were asked to score (from 1 to 10) the acquisition of key competencies and basic skills, including awareness of environmental issues and expertise in biological diagnosis, information management, and use of the internet as an information source. Out of 56 students, 36 responded to the survey (64% of the cohort). Dashed lines represent average values.

○ Conclusions

This computer-based activity aims to engage students in exploring the main threats to biodiversity at global and regional scales by using the IUCN Red List. The activity also helps to increase concerns about declines in biodiversity, and thus it is suitable not only for university-level students in courses related to conservation biology but also for senior high school biology students. Conducting the activity can contribute to the development of several key competencies and basic skills, including expertise in biological diagnosis, information management, and using the internet as an information source. These competencies are evaluated during the implementation phase of the activity and in the discussion session where the students compare their results and conclusions.

Supplemental Material

Appendices 1–4 are available with the online version of this article.

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