FEATURE ARTICLE

Biodiversity Education & the Anthropocene: An Indicator of Extinction or Recovery

JOEL I. COHEN

Abstract

The importance of extant biodiversity, concerns regarding the rising Anthropocene extinction rates, and commitments made by signatories to biodiversity conventions each increase demands for timely data. However, as species and conservation indicators become more complex, the less accessible they are to educators. New pedagogies are needed so that students can generate their own data for studies of biodiversity and extinction. I present a simple indicator of species diversity that examines declines in species' populations and whether or not these species subsequently recovered or faced extinction. Using such data, 14 threatened species are used as examples of the time taken for each species to reach a point of either recovery or extinction. The learning and pedagogical context for this information is reviewed, student use of the data demonstrated, and the lesson evaluated according to its learning objectives.

Key Words: *Biodiversity; education; NGSS; Anthropocene; species diversity; extinction; recovery; lesson plan and pedagogy; ASEI biodiversity indicator; Endangered Species Day.*

○ Introduction

Since the 1980s, evidence and explanations have mounted regarding increased extinction levels in what has been named the Anthropocene epoch (Crutzen, 2002) – or the next major extinction event of the Phanerozoic eon. Either way, this increase, also referred to as the "sixth extinction," differs from the previous five macro-extinction events, in that sixth-extinction losses are caused by the presence and exponential population growth of *Homo sapiens*. This current extinction event has catalyzed new research and publications; however, proven pedagogy (i.e., the process of imparting and questioning knowledge in a classroom) lags far behind.

Since the 1980s, evidence and explanations have mounted regarding increased extinction levels in what has been named the Anthropocene epoch.

This is why educators, who have resources for teaching and querying the first five extinctions, must reach beyond this material to convey how human-related extinctions affect biodiversity. However, in searching for such information, little published literature on biodiversity education and assessment is to be found (Navarro-Perez & Tidball, 2012). To improve this situation, lessons are needed that allow for student-centered research, data collection, and evidence-gathering regarding species loss during the Anthropocene. Such a shift toward student-centered understanding and consensus-building versus acquiring facts alone has proved successful through the use of models in cellular biology (Cohen, 2014).

During lesson planning, further complications arise from the complexity of biodiversity concepts, definitions, and content to select among. Teachers can become confused when juggling international or political terminology with scientific approaches (Dreyfus et al., 1999). For many teachers, a lack of familiarity with evolution (a springboard for discussing biodiversity) and/or a lack of confidence in their own professional understanding of the subject also creates hesitancy or reluctance in teaching it (Mervis, 2015). Adding complex measurements of biodiversity that teachers cannot fully develop, manipulate, or have time to explain and utilize would place additional burdens on these teachers.

In addition, lessons covering the sixth extinction must often be fit into a biology curriculum with established objectives, standards, and alternative lessons vying for inclusion. I have taught this biodiversity lesson within a unit on evolution in seventh-grade biology and as a graduate-level course for the Graduate School USA and the Audubon Naturalist Society of Woodend, Maryland.

Having enough data, theory, or measurements of diversity available to create new content is not the problem. Instead, it is precisely this pool of information that presents a conundrum to educators. Biodiversity indicators are increasing in quantity,

The American Biology Teacher, Vol. 78, No 4, pages. 293–299, ISSN 0002-7685, electronic ISSN 1938-4211. DOI: 10.1525/abt.2016.78.4.293.

focus, and measurements (Duelli & Obrist, 2003; http://jncc.defra.gov.uk/page-4233; http://www.bipindicators.net/nationalindicatordevelopment/indicatordevelopmentframework; http://old.unep-wcmc.org/datasets-tools–reports_15.html) as a result of demands by international organizations for more timely and precise information (Waldron et al., 2013; Pimm et al., 2014).

Because of the increasing complexity and level of detail, I have found these resources impractical for educational purposes. Here, I suggest new pedagogies to help students use accessible data and generate their own studies of biodiversity and extinction, which will increase their awareness of declines in species diversity. To help educators scaffold a manageable approach, I set out to formulate a biodiversity lesson that incorporates a deliberately simplified indicator of Anthropocene events and whether or not a species became extinct or, after a call to action, was able to recover, either in the wild or in captivity. This indicator of species diversity, the Anthropocene Species Event Indicator (ASEI; suggested pronunciation: *ahh-see*), along with the data needed for its calculation, presents an immediate resource that students can use in secondary, university, and adult learner communities, as well as providing opportunities for student or graduate-level research.

To test the utility of the ASEI, data were collected for 14 species under threat of extinction due to human-caused events. Some of these data, plus data produced by students, were then used in lesson pedagogy. Animal species and taxonomic classes selected for this article are illustrative; others could be substituted, based on the region or species of interest. The species data allow students to compare their results with trends of species decline documented by other authors, other indicators, and from research describing biodiversity distribution (Dirzo & Raven, 2003).

In addition, the Red List of Threatened Species, produced by the International Union for the Conservation of Nature (IUCN), was used to categorize these species, based on information regarding the global conservation status of animals, fungi, and plants. Animal rather than plant species were selected because students have more background knowledge and personal contact with animals.

○ Learning Outcomes

In conjunction with the *Next Generation Science Standards* (NGSS; see next section), the proposed activity includes the following learning goals for students:

1. Compose a letter to family explaining what biodiversity is and how humans affect endangered species.
2. Complete a 15-species organizer for Black Rock Reptiles presentation, noting conservation concerns such as habitat loss and urbanization.
3. Analyze and compare ASEI data for six endangered or extinct animals and develop a report or poster comparing one species to the other five species.
4. Complete a before/after survey on biodiversity, ethical perspectives, and the impact of the current lesson (Cohen, 2015).
5. Answer assessment questions on biodiversity and the Anthropocene extinction as part of a test on evolution.

○ Lesson Correlation with the *Next Generation Science Standards*

In the case of secondary education, the NGSS embraced a focus on biodiversity through its Core Idea LS2 (Ecosystems: Interactions, Energy, and Dynamics; NGSS Lead States, 2013). As an example, the NGSS performance expectation MS-LS2-5 calls for students to be able to evaluate competing design solutions for maintaining biodiversity and ecosystem services. Learning objectives described previously, their relation to NGSS standards, and use of ASEI data are connected in lesson format in Table 1. Together, these lesson connections offer a new way to combat the lack of educational exposure to biodiversity that is of concern to many, while advancing its study in biology curriculums (Wilson, 2006, p. 130).

In this paper, the most important learning standard is LS4.D: Biodiversity and Humans. Its focus question is "What is biodiversity, how do humans affect it, and how does it affect humans?" This serves as the central question for this lesson as well.

○ Lesson Context

Addressing learning outcomes using ASEI data was tested in a course on biodiversity for adults and graduates at the Audubon Naturalist Society, Woodend, Maryland, held under the auspices of the Graduate School USA, Washington, D.C. It was also used during a course in biology for seventh graders at a Maryland middle school. For the second venue, the lesson on biodiversity coincided with National Endangered Species Day (http://action.endangered.org/p/salsa/event/common/public/?event_KEY=70317).

Students populated the database with species information using dates from as early as the 1600s, often concluding in 2015. The dates they entered established when an endangered or extinct species was first described or encountered, and extended to its eventual extinction or recovery. Species selected for study were finalized by ensuring that all requisite data could be found and verified for accuracy and consistency, and that they were focused on "sixth extinction" events. In this way, the indicators provide, even in one lesson, an ability to communicate the impact of human choice on biodiversity (the relations among the various data points used for ASEI calculations are diagrammed in Figure 1).

In addition, to augment the biodiversity lesson with hands-on learning, a partnership was developed with Black Rock Reptiles, a conservation/educational breeding center for animals (http://www.blackrockreptiles.com/index.html). Two of the species used in the students' studies, the Woma python and African spurred tortoise, were among the animals brought to my classroom for students to examine, hold, photograph, and touch.

While showing the animals, the breeders inform the students of each species' conservation status, and how urbanization and habitat destruction put certain species at risk. The students take notes on a species organizer, capturing information to be used later in the lesson (Cohen, 2015). This information highlights the various levels of endangerment and helps students understand the importance of conservation and protection.

Table 1. Aligning NGSS standards or performance expectations with proposed lesson objectives, data required or prepared by students, and approximate classroom required for each objective.

NGSS: Relevant Performance Expectations or Disciplinary Core Idea	Lesson Number & Learning Objective	Data or Activity Conducted by Students	Approximate Classroom Time Required
2-LS4-1. Make observations of plants and animals to compare the diversity of life in different habitats.	2. Complete 15-species organizer based on Black Rock Reptile presentation	Observations made by students, as shown in Figure 3	One class period plus half period for follow-up discussion and comparison of notes
LS4.D: Biodiversity and Humans There are many different kinds of living things in any area, and they exist in different places on land and in water. (Disciplinary Core Idea)	3. Analyze and compare ASEI data for six endangered or extinct species	Use of books (Table 2) and other information links for species by environment relation	Two class periods, in room with suggested reference books (Table 2) and computers set on relevant web pages
LS4.D: Biodiversity and Humans Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change.	1. Compose short letter to family explaining what biodiversity is and how humans affect endangered species 4. Complete a before/after survey on biodiversity, ethical perspectives and impact of current lesson on student perspectives	Based on lessons learned from Black Reptile Presentation and notes as shown in Figure 2	One period
HS-LS2-2. Performance expectation: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]	3. Analyze and compare ASEI data for six endangered or extinct species	ASEI data compiled for specific species as selected by students, with agreement by teacher	One period
HS-LS4-6. Biological Evolution: Unity and Diversity. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.	3. Analyze and compare ASEI data for six endangered or extinct species, and prepare simulations for endangered species protection	Use of ASEI data to prepare simulations or projections on potential recovery of selected endangered species	Extra time needed for this extension of the lesson

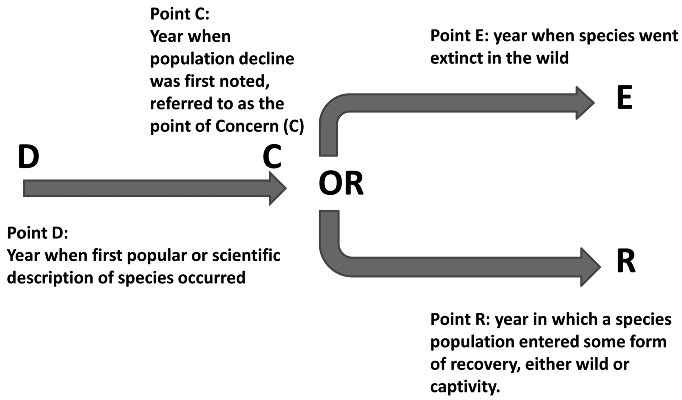

Figure 1. Relations of four values (in years) describing the fate of an endangered species, as used with the ASEI.

○ Implementing the Lesson Using the ASEI

Collecting Information

The ASEI relies on diverse references to obtain data points in order to cross-check points of human intervention. In addition to journal publications, I provided reference books and texts for student use and to judge student engagement in the selection of their species of choice (Table 2). Indicator values for a given species are computed by comparing the following intervals:

- **C – D:** D is the year the species was first described (either formally or informally) – that is, the year in which the species was recognized, taxonomically described by colonists or nonindigenous peoples, or recorded in other printed records of human encounters with the species. This period extends to a point of concern (C), indicating the year in which a population decline was first documented. By marking this point of decline, the value for C leads to a third date, at which the species has been eliminated or saved by explorers and settlers. Thus, the value for C – D represents the time between recognition and when the population decline became noteworthy.
- **R – C or E – C:** This span of years represents the time between the first concern noted over a decline in population numbers and an eventual outcome from this decline, using C to mark the point of concern as described above, and E or R to mark the year when the species was either doomed to extinction or had recovered. If the recovery is limited, then the most recent figures available are given as to its present population status.

I made a student version of the ASEI data sheet available in Excel. With some guidance and data verification by me, the students were able to enter information for six species of their choice.

Analysis of ASEI Data Input by Instructor

To provide an example for students of how the ASEI is populated, data for 14 species were entered and labeled according to four IUCN Red List categories (http://www.iucnredlist.org/): extinct (ex), critically endangered (cr), endangered (en), or of least concern (lc). These data demarcate, in specific years, what happens when a species' path intersects that of *Homo sapiens*. Species data are focused on two intervals: the time taken until a decline in a species population has occurred, and the subsequent time needed for a species to reach recovery or extinction. When the ASEI indicator value is low, the time taken to reach both intervals is essentially the same, avoiding the extensive time seen in other species to recognize a declining population in the wild (Figure 2).

When the indices are high, it means that the difference between intervals is large. For example, the values for the African spurred tortoise show a lengthy C – D value and a very short period from concern to approaching recovery. Second, the species data can be sorted by years required from C to D, which reveals a range of 25 to 365 years from description to concerns of a population decline. The thousands of unique genes harbored by such species mean that the more species saved (such as those in Figure 2 for which restoration has begun), the more unique genes are conserved. Given the importance of genetic diversity (as I discuss in the previous unit in class on heredity and inheritance), can we afford not to bring such calculations of Anthropocene extinctions and recoveries into the classroom?

Analysis of Student-Provided Data Using the ASEI

Two examples of student work using the ASEI are presented in Figure 3. The examples are taken from two students in the Biodiversity course offered through the Audubon Naturalist Society of Maryland and the Graduate School USA. Both students used the ASEI successfully in locating species of interest, inputting data, and deriving their own conclusions. Their successful input and use of the data indicate that students as well as instructors can find this analysis doable and valuable. It also puts the educator and student in control of data assembly and entry, allowing individuals to build the database to address their own interests rather than relying on global biodiversity indicators, which cannot be manipulated easily for classroom research. These two examples were also used for subsequent presentations to the class on their species of interest.

Following successful completion of the ASEI, students can be offered a series of follow-up questions to extend their knowledge. Instead of requiring all students to do one or another, giving students a choice in this matter will stimulate, rather than contract, subsequent class discussion. Extension questions to prompt further discussion, research, or open-ended responses using ASEI calculations include the following:

(1) Why has recovery taken a longer or shorter time for one species than for other species?

(2) What might "ideal" values and indices look like for species conservation?

(3) What Anthropocene events may have caused the values cited to compute the final indicator?

(4) Are there ways to speed up awareness when a species nears the point of concern, and would that have an effect on the number of years to recovery?

(5) Why has extinction occurred for some species, but not for others with comparable indices?

(6) What criteria could be used to prioritize conservation?

(7) What would ASEI look like when grouping species belonging to megadiversity hotspots?

(8) What similarities or differences in values do you obtain when comparing your species of choice to that of another student?

Table 2. Books used to engage students in their own selection of endangered or extinct species, and to provide data and information to analyze with the ASEI.

Title	Author	Publisher and Year
Endangered Species *Volume 1: Mammals* *Volume 2: Arachnids, Birds, Crustaceans, Insects, and Mollusks* *Volume 3: Amphibians, Fish, Plants, and Reptiles*	Rob Nagel	UXL, 1998–1999
Endangered Animals: Species Facing Extinction and the Threats to Their Habitats	Willi Dolder and Ursula Dolder-Pippke	Parragon, 2009
Endangered: Wildlife on the Brink of Extinction	George C. McGavin	Firefly Books, 2006
The Atlas of Endangered Species	Richard Mackay	University of California Press, 2009
Extinct Animals: An Encyclopedia of Species That Have Disappeared during Human History	Ross Piper	Greenwood Press, 2009
A Gap in Nature: Discovering the World's Extinct Animals	Tim Flannery and Peter Schouten	Atlantic Monthly Press, 2001
Dinosaurs to Dodos: An Encyclopedia of Extinct Animals	Don Lessem	Scholastic Reference, 1999
How to Clone a Mammal: The Science of De-Extinction	Beth Shapiro	Princeton University Press, 2015
Ivory Crisis	Ian Parker and Mohamed Amin	Chatto and Windus, 1983

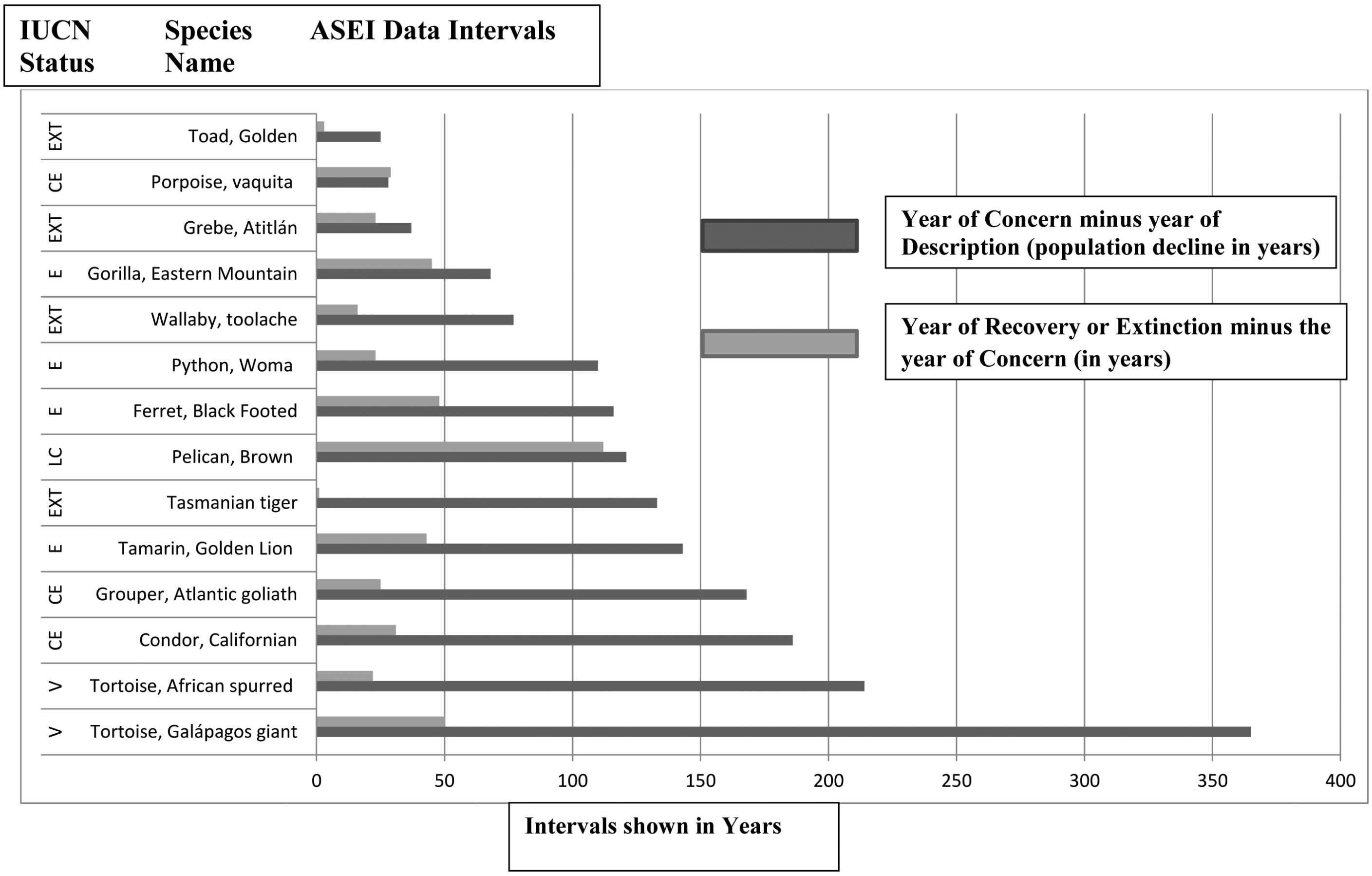

Figure 2. Fourteen species, listed by IUCN category and by ASEI values for years taken to reach either extinction or recovery.

Common Name	Scientific Name	D: Description Date	C: Date of Concern	C-D	R: Date of Recovery	E: Date of Extinction	R or E - C	(C-D)/(R Or E-C)
Tasmanian Tiger	*Thylacinus cynocephalus*	1808	1928 (in Tasmania)	120		1936	8	15
Toolache wallaby	*Macropus greyi*	1845	1923	78		1937	14	6
Bridled nail-tail wallaby	*Onychogalea fraenata*	1841	1973	96	2015- possibly 1100 individuals		42	2
Northern hairy-nosed wombat	*Lasiorhinus krefftii*	1873	1982	109	2010 – estimated 163 individuals		28	4
Numbat	*Myrmecobius fasciatus*	1836	1980	144	2015- possibly 1000 individuals		35	4
Banded hare-wallaby	*Lagostrophus fasciatus*	1807	1970 (est)	163	1988 – 7700 individuals		18	9

Common Name	Source	Status and HIPPO	Species Scientific Name	Period: D: Description Date	Date: C: Date of Concern	Listed as Endan-gered (USA)	C-D	Recovery (Assumed recovered but not definitely for ever)	E: Date of Extinction	R or E - C	(C-R)/(RorE-C) needs correction 5/12/15 (C-D)/(RorE-C)
Black-footed ferret	SCBI and USFW	Highly endangered; Goal is to save endangered species and reintroduce species in native habitat when land becomes available. Recovery Plan USFW in 2013.	*Mustela nigripes*	1851	1967	1967	116	2015		48	0.41
Przewalski's horse	SCBI	Endangered; Wild equid; ancestor of all domestic horses; Endangered; Plan is to save endangered species and reintroduce species in native habitat when land becomes available; Przewalski's Horse Foal - First Wild Horse Born from Artificial Insemination at Smithsonian Conservation Biology Institute (SCBI) on July 27, 2013 at Front Royal. Trinomial name and description, L. S. Poliakov, 1881.	*Equus ferus przewalskii*	1881	1903		22	2015		112	5.09
Scimitar-horned oryx	SCBI	Endangered; Goal is to save endangered species and reintroduce species in native habitat when land becomes available; overhunting for horns and climate change; Extinct in the wild; has diseases and parasites; central north Africa (Niger and Chad)	*Oryx dammah*	1816	2004		188	2015		11	0.06
Southern white rhinoceros	IRF	Near Threatened was Endangered; Plan is to save endangered species and reintroduce species in native habitat when land becomes available; overhunting; lives in South Africa. By 2013, white rhino numbers had increased 1,000-fold – up to about 20,000 animals. Wide mouth. White rhinoceroses are found in grassland and savannah habitat. The white rhino is under threat from habitat loss and poaching.	*Ceratotherium simum simum*	1817	1961		144	2013		52	0.36

Figure 3. Examples of student-generated data using the ASEI in an Audubon Biodiversity class.

○ Discussion

Equally important as (or perhaps more important than) the data are opportunities for student engagement and the indices' role in an inquiry-based pedagogy. While the species-specific data required are not always easy to come by – and, in fact, can be quite challenging to find and verify – with a careful selection of "doable" species, the activity can be readily taken on by students of all ages. Such questions, along with access to data for the ASEI, can be incorporated into a lesson developed with species-specific or location-specific case studies (Potter et al., 1993) by launching investigations in which students adopt a species, compute its indicator, compare it to other species, and answer one or more of the above questions.

Extension of lessons on the species diversity concept can be merged with habitat, ecosystem, or environmental information to develop a more complete story of the species' current state of endangerment. Such books as *The Atlas of Endangered Species* (Table 2) can help students address these interests.

Conclusions

This article presents a deliberately simplified indicator for species diversity as one means to engage students in understanding the consequences of Anthropocene events. The status of each species, as to whether it enters recovery or ends in extinction, is something each student creates. Once the indicator is populated, it can be annotated by students by adding other interests, such as actions leading toward or away from recovery. One variable would be time (in years), while secondary variables could include funding obligations, major actors (local, regional, and international), roles of multilateral conventions, ecological significance of the species, or what happens if the species disappears.

Many endangered species have been "adopted" by conservation organizations seeking an organism's protection. This information, available on most organizational websites, would allow students to analyze conservation options for the species listed in their ASEI data, leading some to more direct involvement with a species' protection. It has not escaped attention that ASEI indicator values could even be used by such conservation organizations for mobilizing resources. Using the indicator would allow conservationists to explain and react to the timelines presented and, as such, build relations with students who will be the face of future conservation efforts and support, thus increasing chances for timely conservation. ASEI also presents options to promote specific educational links and actions among conservation organizations in the classroom. Special projects could be envisioned with names such as "Adopt a Species," "Beat the Clock," "I Dare You to Survive," "Not This One," or "There Is Still Time."

But what else is needed? The pedagogy and database described could help build a cadre of educated youths, graduate students, and others to form a new constituency for conservation. From my classroom experience, there is a more-than-ample base of interest for such lessons. While new students may not be able to help save the Vaquita porpoise (Figure 2), given its imminent extinction, they will certainly be making decisions regarding species with longer time-frames for recovery. Nor should educators ignore their responsibility to teach future generations of the Anthropocene epoch and species extinctions, as teachers can use such lessons to help students consider whether our growing population and use of resources will continue unabated or be brought under control.

○ Acknowledgments

I am grateful to Dr. Sy Sohmer, retired director of the Botanical Research Institute of Texas, for his support and suggestions during the article's preparation, to the students of the Audubon Naturalist Society course "Biodiversity," and to Dr. Peter Raven for review and encouragement. There was no funding designated for the required research or results. There is no conflict of interest to note, and no hindrances due to MTAs, patents, or patent applications that apply to data used in this paper. Cited student work is available anonymously through institutional instructional waivers.

References

Cohen, J.I. (2014). "A cellular encounter": constructing the cell as a whole system using illustrative models. *American Biology Teacher, 76,* 544–549.

Cohen, J.I. (2015). Ethical values and biological diversity: a preliminary assessment approach. *Journal of Microbiology & Biology Education, 15,* 224–226.

Crutzen, P.J. (2002). Geology of mankind. *Nature, 415,* 23.

Dirzo, R. & Raven, P.H. (2003). Global state of biodiversity and loss. *Annual Review of Environmental Resources, 28,* 137–167.

Dreyfus, A., Wals, A.E.J. & van Weelie, D. (1999). Biodiversity as a postmodern theme for environmental education. *Canadian Journal of Environmental Education, 4,* 155–176.

Duelli, P. & Obrist, M.K. (2003). Biodiversity indicators: the choice of values and measures. *Agriculture, Ecosystems & Environment, 98,* 87–98.

Mervis, J. (2015). Why many U.S. biology teachers are 'wishy-washy.' *Science, 347,* 1054.

Navarro-Perez, M. & Tidball, K.G. (2012). Challenges of biodiversity education: a review of educational strategies for biodiversity education. *International Electronic Journal of Environmental Education, 2,* 13–30.

NGSS Lead States (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: National Academies Press.

Pimm, S.L., Jenkins, C.N., Abell, R., Brooks, T.M., Gittleman, J.L., Joppa, L.N. et al. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science, 344,* 1246752.

Potter, C.S., Cohen, J.I. & Janezewski, D. (Eds). (1993). *Perspectives on Biodiversity: Case Studies of Genetic Resource Conservation and Development*. Washington, DC: AAAS.

Waldron, A., Mooers, A.O., Miller, D.C., Nibbelink, N., Redding, D., Kuhn, T.S. et al. (2013). Targeting global conservation funding to limit immediate biodiversity declines. *Proceedings of the National Academy of Sciences USA, 110,* 12144–12148.

Wilson, E.O. (2006). *The Creation: A Meeting of Science and Religion*. New York, NY: W.W. Norton.

JOEL I. COHEN is a teacher in the Science Department of the Montgomery County Public Schools, 4610 West Frankfort Dr., Rockville, MD 20853; an Instructor for the Graduate School USA /Audubon Naturalist Society, Woodend, MD; and Instructor for John Hopkins University's Center for Talented Youth. E-mail: cohenji@comcast.net.