MAPPING TO CONSERVE BIODIVERSITY

A HANDS-ON AND DIGITAL HALF-EARTH MAP DESIGN CHALLENGE

half-earth project

Unit Title

Mapping To Conserve Biodiversity Half-Earth Project
A hands-on and digital half-earth map design challenge

Subject(s)

Biology, MS Science, Geography, Introductory GIS,
AP Biology, AP Environmental Science

Technology Use

- In- person group work is supported with printed paper maps and transparencies.
- Map files are also provided for online work
- In-class and at-home access to the online Half-Earth Map is desirable, maps.half-earthproject.org.

Time Allocation

Two 45-minute class periods. The core activity is designed to take two class periods, although an additional class period would be useful for preparing students for the activity and for using the online maps. Additional time should also be allocated for facilitating recommendations for being more inclusive.

Activity Overview

Student-centered team-based design challenge with supporting slides and maps.

Designed for two class periods:

- *Prep day optional – key concepts and vocabulary review*
- Day 1 – Entry ticket; Whole class map-thinking warm-up; measuring protection activity, protecting a patch activity.
- Day 2 - Protect half the US activity; Peer evaluation session; Exploration of digital map resources.
- *Extension options – stakeholder version; Inclusion and equity discussion; Additional maps on local, state, regional scale: Additional exploration of Half-Earth Map.*

This mapping design-challenge engages students in evidence-based biodiversity conservation decisions. Student teams use maps on the distribution of biodiversity, protected areas, and human impacts in the US. They will engage in authentic group work to devise conservation solutions, communicate solutions and ideas, while evaluating the work of their peers consistent with NGSS standards, as well as AP Biology and AP Environmental Science frameworks. The activity supports learning based on student inquiry and ownership of their learning and has been effectively used at the middle school and college levels. Approaches for making the activity inclusive are featured. The data-driven online Half-Earth Map and Map of Life are used for open-ended extensions of the activity.

Learning Objectives

- Engage students in authentic group work that guides them to ask questions and generate ideas about biodiversity, maps, and land use in the context of the grand global challenge to save the earth's biodiversity.
- Develop map thinking based on a combination of printed maps and digital maps.
- Stimulate discussion and debate among students while encouraging them to turn to data and information for resolution.
- Raise student awareness of the availability of The Half-Earth Map and other resources to use for research and presentations, especially to link local biodiversity conservation to global efforts.
- Provide a well-structured framework for teachers to use directly or modify and extend to serve their classroom practice.

Student Performance Standards

- Explain biodiversity in terms of where species live.
- Use maps to show species ranges and to illustrate conservation biology decisions.
- Demonstrate an understanding of how diverse kinds of information can be layered onto a map for analysis.
- Contribute to authentic group work, through discussions, drawing conclusions from evidence, forming solutions, persuading and compromising.
- Articulate the complexity of making conservation decisions and the need to incorporate diverse disciplines and perspectives that inform conservation, including ecology, geography, agriculture, forestry, and urban planning.
- Construct an explanation of the multiple impacts that humans have on biodiversity.
- Use interactive research tools that are dynamically updated to reveal global and local species distributions and changes in human land use.

Preparation

Make decisions about your student teams. Field-tests have shown teams of 3-5 to be most effective. Do you want an even number of teams for peer evaluation?

Authentic group work is engaging and a great opportunity to address equity in learning from a perspective of diverse student abilities and backgrounds. It is well worth investing time to compose your teams, with an eye to balancing racial and ethnic identities, gender and sexual orientation, temperament, and cognitive abilities. Ideally each team will have diverse styles, opinions, and perspectives. In this document, diversity notes have been highlighted blue, and placed in the blue right-hand column. Every student should have role and you might consider assigning notetaking and reporting out roles for example to balance typical classroom patterns of quiet and outspoken students.

Decide on how much time you want to spend on providing background before the activity. , Concepts to review could include biodiversity, conservation biology, and protected areas.

Have a look at Appendix 4 Supporting instructional slides and decide how you might use them to support running the activity in your classroom.

Print maps for each team, including the transparency – larger maps (11 x 17) are better for group work, but printing 8 x 10 maps are less expensive and can be successfully used. Consider laminating large size maps for re-use and use erasable markers so that grid transparencies can be re-used. Field tests indicate that students respond better to maps printed in color rather than monochrome.

INSTRUCTOR TIP

Consider using page protectors to reuse the maps as an alternative to lamination. Student work can be photographed before erasure.

Materials (one set for each team)

1. United States map with 110 square kilometer grid (for printing 8.5 x 11) or United States map grid in 2 halves: US grid E and US grid W taped together for 11 x 17 size maps (black and white on transparency).
2. Map of US protected area (black and white on paper)
3. Map of US population density by county (color best, can work B&W)
4. Map of US agricultural lands by county (color best, can work B&W)
5. Map of US forested lands by county (color best, can work B&W)
6. Dry erasable markers so that students can modify work in progress and for re-use of transparencies.

Images in a separate file from this document as ***Appendix 3: map files***

INCLUSION NOTES

Consider:

- grouping students to increase the diverse perspectives that can be shared during this mapping activity.
- discussing land use in general and acknowledging previous land history and use by native and indigenous communities, before diving into the mapping project.

There are many ways to foster collaboration with faculty in other content areas, especially history and social studies. Many students find this dimension of conservation important and interesting; it's a powerful way to incorporate diverse perspectives.

Building a connection to local history, local land-use patterns, and perhaps their own multi-generational family history may increase student engagement and investment.

See related activity, "***What's in a Name?***"

Importantly, some students have not had the opportunity to connect with or feel a part of nature. Whether growing up in urban, suburban, or even rural settings, they may not have a strong connection to natural environments and biodiversity. You or students might research the work of Deja Perkins or Richard Louv.

Students from socially and economically marginalized settings in particular may not feel connected to nature, making it difficult for them to feel invested in the preservation of land for biodiversity. Before or after this activity you might facilitate a class discussion. You might start out with students taking the Connectedness to Nature Survey, bit.ly/NatureConnectionSurvey

Lesson Sequence and Instructions: Day One

Day One Summary

Students will be challenged to develop their thinking about biodiversity, land-use, conserving nature, and the use of data and maps. Working in teams they will address two mapping challenges that scaffold toward a grand challenge to place half of the contiguous United States into protection for biodiversity.

Entry Ticket (Optional)

Estimated time up to 10 minutes

Show the class the short (2:47) Half-Earth Project video (youtu.be/6fGJafDDCks). The video can be used to launch the lesson, including as an entry ticket. Slides 2 and 3 from the instructional support slides (*Appendix 4*)

1.What is the name of the project that the video presented?

2. What is the main goal of the Half-Earth Project?

3. What is the Half-Earth Project mapping?

Map-Thinking Warm-Up Activity (Optional)

Estimated time 7 minutes

This warm-up gets students moving and thinking about maps. Use the four walls of your classroom to represent the cardinal directions: North, South, East and West (Slide 4 *Appendix* 4).

- Tell students that the classroom represents the United States. Point to North. You could tape **N, S, E, W** signs on the walls. As an alternative you could focus this activity on your state or even on your city or town.
- Ask students where in the room (being used as map) their school is. Does everyone agree on how the room can represent the US or any other place?
- Ask them to think about the first place that they lived in the US (or state or town) and tell them to go there. They should greet others in that part of the room to share where they are.
- Now ask them to think of their favorite place ever visited in the US, or the state, or your city/town. They should go there and share with someone nearby where they are and why. You can also give students the option of going to a place they'd LIKE to visit because they saw a photo, or video, or heard about the place.
- Ask students to raise their hand if their favorite place has something to do with nature.
- List out some places that students name.

INCLUSION NOTES

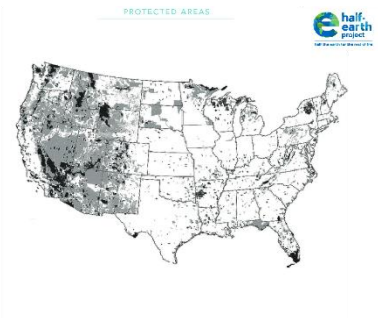
Some students have not had the chance to travel and their geography and map knowledge may be very limited. Students should be comfortable and have fun in this activity, so you might consider making asking general geography points, such as: What country is to the North of the US? What country is our immediate neighbor to the south? Name a state that's on the Pacific Ocean. Name a state on the Gulf of Mexico. Where are the Great Lakes? Consider having a reference map posted or projected.

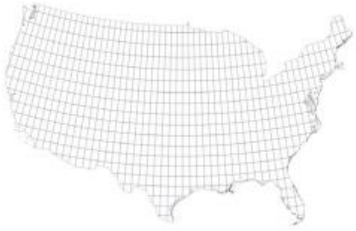
To support and encourage students that have not spent much time in nature, consider facilitating a conversation about natural places. Point out that school grounds, parks, and street trees are pockets of nature where species live. Ask students about their thoughts on nature. This could be a great way to build engagement around why learning this information is so important in communities that have historically been marginalized. It's generally true in cities that marginalized neighborhoods have fewer trees. Do your students think that's fair?

The Design Challenge

Conserve Half of the US for Biodiversity – 3 sequenced maps

Facilitate a discussion of protected lands (slides 5-9 from Appendix 4). What does the term Protected Area or Conserved Area bring to mind? Students need to have a basic understanding of a protected area.





Mapping Challenge 1 – How much US land is currently protected?
Estimated time 10 minutes

Map challenge 1 is to determine how much conserved land the US has now.

- Work as a team.
- Find your black and white protected areas map.
- Find your US grid map transparency
- Place the transparency over the protected areas map and make sure they line up (Slide 12)
- The protected areas are shown in dark gray and black and represent areas that have the highest category of protection for biodiversity (see appendix 2).
- Using a dry-erase marker, mark each cell that is over protected land.
- Count how many cells you've marked.
- There are 738 cells covering the contiguous United States.
- Calculate the percentage of lands currently protected in the United States.

INSTRUCTOR TIP

Consider providing supports, such as formulas, definition of fractions and ratios for students that may need math support.

- Teams share out their results (slide 13).
- Discuss the range in answers and reasons for differences - how to count partial cells, hurrying, miscounting, etc. (slide 14)
- Protected lands in the US is estimated to be about 14%
- Clearly there's a long way to go to get to half of the US protected.

Instructor note: Consider tabulating results to facilitate discussion.

INCLUSION NOTES

Consider taking time to engage students in the topic of just land use more deeply. What does ownership of land mean? What's the difference between private, government, & community lands? Who originally owned US lands and who controls ownership of lands and waters now? Answers to these questions have a deep history in our county worth exploring. What do students think about displacing people from lands in the past, and now for conservation goals? For example, our national parks– although providing valuable species protection– were not chosen for that purpose. In general, park lands were considered less productive but highly scenic. In most cases native peoples living on or using those lands were pushed out, displaced. In recent years in Washington State and Minnesota, native peoples have battled to preserve their traditional rights to forage, fish, and hunt on park lands.

In the long course of history, questions of land tenure, ownership, and control are complicated. For example, Central Park in New York City was originally used and occupied by native peoples (Lenape and others), then colonized by Europeans, and African descendants settled in the park in an area called Seneca Village. These Black Americans and others were in-turn displaced to remake central park into a gentrified version of nature.

Today the park is an important urban nature oasis, full of species, and enjoyed by millions each year. But the history of the park represents important issues of equity and justice that can in turn frame students thinking for global scale conservation. Other parks and "green spaces" across the US and other countries have similarly important histories. A deeper dive into these issues could be excellent for student projects and extensions to this mapping design challenge.

Mapping Challenge 2 – Pick a parcel of land to protect
Estimated time 10 minutes

For Map Challenge 2, look at your map and the current distribution of protected lands and think about choosing more land to put under protection.

- Each person on the team chooses one cell to add and mark it with a dry erase marker on the team map.

INSTRUCTOR TIP

You may want to have students assume roles for this activity, such as a Park Ranger, City Planner, or Town Mayor, and create a scenario where they are responsible for selecting land to be preserved. This role playing may be carried on throughout the next steps of the project as well. These roles may also help students consider which cell to add based on what's important to their role.

- Think about why you picked this cell to protect, then share reasoning with teammates (Slide 15).
- Teams share their results with entire class (slide 16)
- Brief wrap-up conversation could cover take-home messages from map challenges 1 & 2, and anticipation of the next challenge, to put half of US land into conservation.

INSTRUCTOR TIP

Implementing a clear time frame for students to pick and share, helps keep the lesson moving & students energized. Consider using a timer for each students turn and even assigning who will pick in what order to eliminate that discussion among groups and save time.

Instructor note: You might want to create a simple form for students to log their answers and questions.

INCLUSION NOTES

Assigning students roles in their teams can support equity and inclusion in several ways, and generally it makes students more energetically engaged.

Consider 2 main strategies for roles. These strategies can also be blended.

- Character Role: Having students play the role of different stakeholders helps them think about and identify with differing perspectives on a given conservation decision. Be creative about these roles. A realtor, factory owner, farmer, fisherman, politician, native American, water utility employee, garden supply worker, or school superintendent will likely all have different perspective and priorities. The challenge and joy of this approach is the research into defining the roles and the unpredictability of how students will in habitat the roles. You will also need to help teams strategize on resolving differences, finding consensus, and making final decisions.
- Responsibility Role: Some students like to write, others talk, draw, sleep, or daydream. Consider assigning each student on a team a specific role such as note taker, map marker, reporter, timer and progress checker. The challenge of this approach is defining and enforcing the importance of each role. This approach can be powerful for shifting status of the students in your classroom, emphasizing a diversity of student skills & talents, while perhaps encouraging some students to develop new skills and learn to respect differences in each other.

Lesson Sequence and Instructions: Day Two

Day Two Summary

Students extend their thinking on biodiversity, land-use, conserving nature, and the use of data and maps from the previous mapping challenges. Working in teams they will place half of US land into protection and support their decisions. Then they will use online maps to validate, modify, and further explore their design solutions.

The Design Challenge

Conserve Half of the US for Biodiversity – 3 sequenced maps

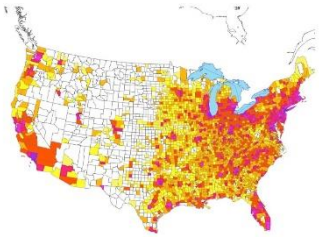
Brief Discussion of Challenges 1 and 2

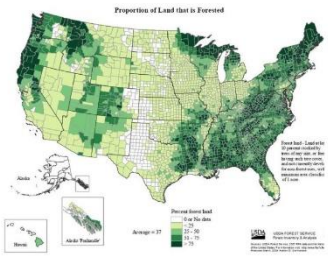
Estimated time 5 minutes

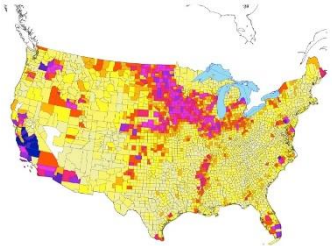
What did you learn from the last design challenge? Have you been thinking about how you would put more land into conservation? What kind of information would you like to have? (Slide 17 from Appendix 4 can provide context of discussing the various ways that we use land.)

Show Slide 18 of the agricultural intensity, population density, and forest cover maps. (Slides 19-21 show each map alone)

Note: These US maps are "heat maps" representing data for the more than 3000 US counties. How many counties does your state have? In a heat map, color or color intensity is used to represent magnitude. In the case of the forest cover map, the deeper green areas have more forest cover. In the case of the human impact maps --urban density and agricultural intensity-- purple represents the highest concentration, then reds, yellow, and finally white the least. Heat maps are versatile and can be used to display data ranging from economics to molecular biology data. See Appendix 2 for more information on the maps used for this activity.







INCLUSION NOTES

Additional Maps

The maps chosen for this activity are critical to for starting to make biodiversity conservation decisions, but many additional maps and data are available and important for making successful, equitable, and just decisions. Some students may find it interesting and revealing to look at maps that show the distribution of people by racial background, immigration status, or income. Such maps may challenge some students pre-conceived notions, while raising questions and provoking students to form new explanations and hypotheses.

For example, higher concentrations of Black Americans live in the southeastern US compared to other regions such as the Northwest . What are the likely explanations for this map pattern? Might such a population pattern effect conservation decision-making or communication? The US Census Bureau has many useful maps, see ***"References and Online Resources"*** at the end of this document.

Sentence starters can help facilitate analysis, such as: "this map is similar to our map in the following ways", or "this map is different from our map in the following ways."

Mapping Challenge 3 – Place half of the US lands into protected status
Estimated time 15 minutes

- Your team is designing a Half-Earth solution for the contiguous US
- The goal is to maximize biodiversity while maintaining human sustainability
- Look at your maps, and determine which provide information related to biodiversity and which for human needs and impacts.
- Mark all the grid cells that you want to protect to get to half US protected.
- As a team, discuss your choices, the trade-offs, and how you arrived at consensus.

Instructor note: You might want to create a simple form for students to log their answers and questions.

INSTRUCTOR TIP

Review the roles suggestions covered in Mapping Challenge 2. Those same roles could be implemented here.

Evaluate Another Team's Map
Estimated time 10 minutes

- Trade maps with another team (Slides 22 & 23).
- Observe the overall patterns of the map, how different from your group's map?
- Are the conserved areas on the map likely to protect and benefit biodiversity?
- How does the map impact people, both short term and long term?
- Pick a cell where biodiversity was optimized while meeting human population needs.
- Pick a different cell where you feel the costs outweigh the benefits.
- Share out some of the reasons for the cells you chose.
- Discuss some of the reasons why different team solutions came out so different.

INSTRUCTOR TIP

You could organize this as a gallery walks where the maps are placed on the wall and can be compared and discussed in a rotating forum.

Digital Map Exploration
Estimated time 20 minutes

E.O. Wilson writes in his book ***Half-Earth: Our Planet's Fight for Life:*** *I've stressed species as the unit in the hierarchy of biodiversity that can and must be studied most thoroughly with the practical aim of saving the whole…When we allow one species to die, we erase the web of relationships it maintained in life, with consequences that scientists seldom understand. In displacing wilderness, our actions are ignorant and permanently destructive. We break many threads and change the ecosystem in ways still impossible to predict.* – pg. 105/106

One outcome of doing this mapping design challenge is the realization that more data and information is needed to make good conservation decisions. Your students have produced maps based on very limited information. To support communities to make the best conservation decisions, we need to maximize protection and restoration of biodiversity, and that means a focus on species. Two websites associated with The Half-Earth Project are useful for learning more about species distributions, conservation lands and waters, and human impacts (**Slide 24**).

- The Half-Earth Map, https://www.half-earthproject.org/
- The Map of Life, https://mol.org/

Instructions to Students
In your exploration of The Half-Earth Map and MOL consider how your team's map did for protecting or helping to recover species.
Consider these guiding questions:

- What did my team's map accomplish for protecting biodiversity?
- How well did my team's map do in terms of the near-term needs of human populations, especially concerning food supply and living space?
- How does the size (resolution) of a mapping grid effect solutions and decision-making? For the hands-on activity, the grid size was 110 x 110 kilometers? Is that small enough, what would be the effect of finer resolution, say 20km?
- What other sources of data would you like to aid in your conservation decision-making?
- Does it make sense to look at one species at a time, or one parcel of land at a time?
- Who are some of the stakeholders that should be considered in making conservation decisions?

The following guided exploration provides some basic instructions for exploring the Half-Earth Map and the Map of Life to engage thinking about the distribution of our planet's species and protecting areas toward the goal of saving half of the earth for biodiversity. A series of guided explorations are available on the Half-Earth Project Educator Ambassador webpage, www.half-earthproject.org/half-earth-project-educator-ambassadors/, including in-depth lessons featuring hummingbirds.

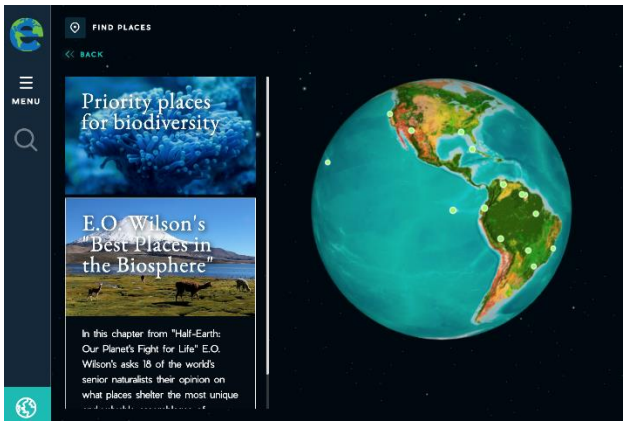
INCLUSION NOTES

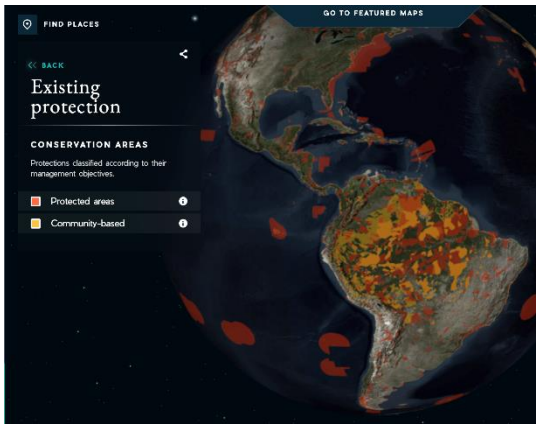
Making E.O. Wilson's Ideas Inclusive
The ideas and writing of E.O. Wilson have been enjoyed by all sorts of people for many decades. He ranks with Aldo Leopold, Rachel Carson, and others as an inspirational leader in nature conservation. In December of 2021 Dr. Wilson died at the age of 92. His legacy lives on in people of all ages and backgrounds.

Here's a sample of writers inspired by E.O. Wilson

- Lauret Savoy – author of ***Trace***
- Ben Goldfarb – author of ***Eager: The Surprising , Secret Life of Beavers and Why They Matter***
- Drew Lanham – author of ***The Home Place: a Colored Man's Love Affair With Nature***
- Dominque Goncalves - see gorongosa.org/e-o-wilson-a-tribute
- Janisse Ray – author of ***Ecology of a Cracker Childhood***
- Doug Tallamy – author of ***Nature's Best Hope***

Exploring Biodiversity with the Half-Earth Map

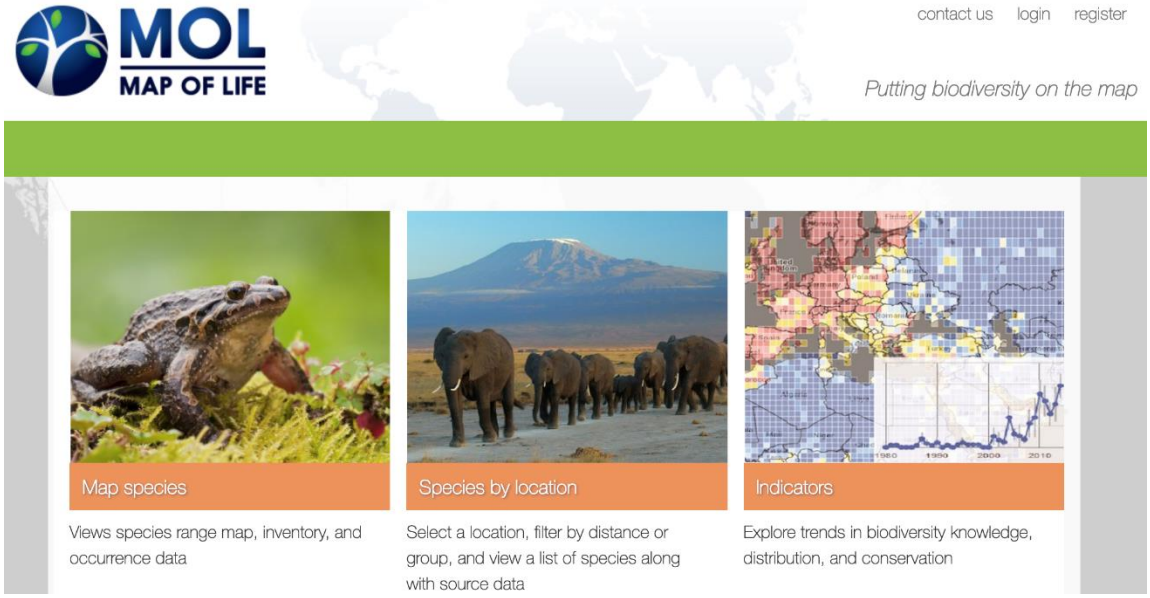




Go to www.half-earthproject.org and click on "explore maps" on the left

- Click the green "LAUNCH MAPS" button.
- Explore the highlighted "Priority places for biodiversity" use the buttons to focus on different groups of organisms. Click on the dots on the map to get more information. Click on "ALL MAPS >" to explore E.O. Wilson's "Best Places in the Biosphere."
- Click on the "<< BACK" button, then click on the "GO TO EXPLORE DATA." The mapping menu will appear on the left.
- Rotate the globe and zoom in on the US.
- Expand the **Mapping biodiversity** tab on the left and select different organism groups to see where they are on the map. What's the difference between richness and rarity?
- Zoom in on an area that you chose to conserve. How does species richness and rarity look in this area? Did you make good conservation choices with your map solutions?
- Expand the **Mapping human activities** tab on the left and explore how that might affect areas you chose for conservation.
- Expand the **Mapping conservation areas** tab and explore that layer by moving around the US and zooming in and out.
- Zoom in closely and the view will change to higher resolution "landscape" mode that's similar to 110 square kilometer grid on the transparency. Explore the distribution of biodiversity, conserved areas, and human impacts in a particular area.
- You can also click on the "FIND PLACES" button on the upper left above the mapping menu. Enter any location, for example a town, or a park in or near an area you put into protection to zoom to that area. A widget on the left presents species to watch in this area, along with other important information on protection, human impacts, and conservation priorities.
- What overall patterns do you observe for the US? What species groups are most rich? Is there a good alignment of biodiversity, conserved areas, and human impacts?

Exploring Biodiversity with the Map of Life (MOL)



Go to www.mol.org

- Click on the "Species by Location" box and type in "United States" or drag and zoom to the US.
- You can click on individual states or select them from the dropdown. On the right will be a list of expected species by group.
- Click "amphibians" for example to get a list and access to explore the distribution of individual species.
- When you click on an individual species, for example the "tiger salamander" an information window will pop up, with some general information, a photo, and a range map for the species. Click on "view detailed information" at the top of the window, to get data records on expert drawn maps and inventories, point observations, and species checklists.
- You can also click on the species tab at the top, or from the main page.
- Alternatively, you can type a species name, for example "Bog Turtle," also known as *Glyptemys muhlenbergii.* Some species have various common names, and not all are recognized by MOL, so if you don't find a species, try an alternate common name or the Linnaean genus-species name.
- You will be taken to a "summary map" page with a photo, conservation status, and range map. Click on the "Detailed Map" tab or the "Projection" tab for additional information.
- Click on the **Locations** tab at the top. On the right-hand side, click on the Mountain Ranges link and type in "Appalachian Mountains." The map on the left will highlight the mountains ranging through several states in the Eastern US. Alternatively, try "Sierra Nevada," "Cascade Range," or "Front Range" for example in the Western US.
- Click on the "Species" tab to get a list of expected species in the region. Click on a group such as "turtles" or "cacti," and explore the list of species. You can also download group species lists.
- Explore the list of species. Are you surprised at how many there are? Are you surprised by some of the species that can reside in the area you're exploring
- This page allows you to explore the world's mountain ranges, mol.org/regions/?regiontype=mountains

Appendix 1 - NGSS Planning Rubric

This page is a general planning tool that can be used for any reference or activity including this mapping activity. Following is a list of NGSS correlation for this mapping activity.

Identify the strongest cross-cutting concepts

☐ Patterns
☐ Cause & Effect
☐ Scale, proportion, & quantity
☐ Systems & system models
☐ Energy & matter
☐ Structure & functions
☐ Stability & change

Notes:

Identify the most relevant science and engineering practices

☐ Asking questions & Identifying problems
☐ Developing & using models
☐ Planning & carrying out investigations
☐ Analyzing & interpreting data
☐ Using mathematics & computational thinking
☐ Constructing explanations & designing solutions
☐ Engaging in argument from evidence
☐ Obtaining, evaluating, & communicating evidence

Notes:

Disciplinary Core Ideas in the 4 NGSS domains – table of top-level themes

ETS: Engineering, Technology, and Application of Science

ETS1: Engineering Design

LS: Life Science
LS1: From Molecules to Organisms: Structures and Processes
LS2: Ecosystems: Interactions, Energy, and Dynamics
LS3: Heredity: Inheritance and Variation of Traits
LS4: Biological Evolution: Unity and Diversity

PS: Physical Science
PS1: Matter and Its Interactions
PS2: Motion and Stability: Forces and Interactions
PS3: Energy
PS4: Waves and Their Applications in Technologies for Information Transfer

ESS: Earth and Space Science
ESS1: Earth's Place in the Universe
ESS2: Earth's Systems
ESS3: Earth and Human Activity

Phenomena that will drive student research, investigations, and model building

Notes:

NGSS Connections for Map Design Challenge

High School:

Interdependent Relationships in Ecosystems

- HS-LS2-1: Use Mathematical or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2: Use Mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems at different scales.
- HS-LS2-6: Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7: Design, evaluate, and refine solutions for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in: 1) increases in the number of individuals of some species, 2) the emergence of new species over time, and 3) the extinction of other species.
- HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse of impacts of human activity on biodiversity.

Human Sustainability

- HS-ESS3-3: Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
- HS-ESS3-6: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Earth's Systems

- HS-ESS2-7: Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on earth.

Middle School:

Interdependent Relationships in Ecosystems

- MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organism and population of organisms in and ecosystem
- MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- MS-LS2-4: construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystems services.

Human Impact

- MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform development of technologies to mitigate their effects.
- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- MS-ESS3-4: Construct and augment supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Appendix 2 – Mapping Activity Options, Extensions, and References

Independent Student work and modeling
Estimated time up to several days

Your students have engaged with important concepts in this lesson, including: biodiversity distribution, species richness and rarity, human impacts, protected areas, conservation strategies, and mapping. The hands-on component has engaged them in authentic group work, challenged them to understand data, and design conservation solutions.

This is a good set-up for further investigation of the online mapping tools:

- The Half-Earth Map - www.half-earthproject.org/maps
- The Map of Life – www.mol.org

Extension Ideas:
Have students refine and annotate the maps they created in class in a short report.
They could:

- document whether they actually got to half US
- identify grid cells where they took significant land out of agricultural production
- identify where their solution requires people to move where they live or work.
- Use the Half-Earth Map and Map of Life to choose some species or groups (taxa) to focus on to see how well their maps supported saving habitat for those species.

Students could use the maps they produced to make a poster that:

- Features the map as a central figure
- States the purpose of their design
- Highlights key features of their map design
- Discusses the pros and cons of aspects of their solution

Have students research and produce maps of your area, state, or region. Both the Half-Earth Map and the Map of Life can be used as resources to draw these higher resolution maps. Many states produce their own maps that feature species distributions, human impacts, and protected areas, see References below for some examples. To support inclusion, encourage students to consider maps that look at racial and ethnic data, economic data, water & air quality data, traffic accidents and roadkill data, for example.

Have students select 2 different places on the globe to compare in terms of biodiversity, human impacts, and protected areas. Perhaps they could choose a place near home and a place on another continent.
Questions to consider for their analysis include:

- Do the two areas have some common and some different species?
- How does species richness compare between the areas?
- What are some of the rare species in each area? How about threatened or endangered?
- How do the areas compare in terms of human impacts and protected areas?
- Would you want to make a case for protecting the biodiversity in one are but not the other?
- Which area might be easier to bolster biodiversity protection and why?

Appendix 3: Map files for printing - linked on blog https://www.half-earthproject.org/mapping-design-challenge/
Appendix 4: Supporting instructional slides - linked on blog https://www.half-earthproject.org/mapping-design-challenge/

Optional Versions of the Activity

The mapping activity is designed to be flexible and open-ended, thus easily adaptable to instructor or student modification. Following are some ideas for modifying the activity.

Stakeholder version: In teams of 3 students start out with the team working together to estimate how much land is already in protection. Then each student is responsible for one of the three maps of Population Density, Agricultural Intensity, and Forest Cover. Each student could be given an assigned role such as Urban Planner for the population map, Farm Economist for the agricultural map, and Chief of the US Forest Service for the forest map. During the design process each student is responsible for how their map is used in negotiating what grid cells to place into protection. Other variations of a stakeholder version could be designed with roles such as farmer, hunter, governor, land trust member, or bird-watcher, and used with bigger teams, for example. Consider enlisting students to identify and define roles. Incorporating stakeholder roles is an excellent opportunity for making the activity more inclusive.

Connectivity version: The design challenge of putting half of US land into full protection for biodiversity could be modified to emphasize connecting and improving already protected lands. The Half-Earth Project approach to conservation emphasizes prioritizing protection for the most species while taking advantage of complementarity. The principal of complementarity means that as we protect more land for species and connect parcels of land we get a magnified biodiversity benefit, including for species those yet to be discovered. Once students have estimated the total amount of protected lands, challenge them to connect as many of these lands as possible using the forest, population, and agriculture maps as guides. It would probably be helpful to introduce the Half-Earth Map and Map of Life before starting the map challenge or right after they estimate US protection, so that students can use the online information to guide their connectivity designs. Part of their corridor solutions could also be recommendations on invasive species to eliminate and native species to re-introduce, backed up by evidence from the Half-Earth Map, Map of Life, and other resources (see Reference list below).

More maps version: There are many additional maps readily available that could be used in the map design challenge. Candidate maps include ecoregions, biomes, climate or rainfall, and range maps for focal species. The maps provided in the map files (appendix 3) we used a common projection. For additional maps that you are your students might add, you just need to be sure that the same projection is used and that the maps are then printed to the same scale (see References for some examples). As mentioned previously, adding additional maps, makes students aware of the diversity of information important for making conservation decisions, while also affording good inclusion opportunities.

References and Related Online Resources

Biodiversity distribution data

- Half-Earth Project's data team, the Map of Life group, curates expert range maps, and direct observation of species (incidence records). www.mol.org/datasets/.
- The Global Biodiversity Information Facility (GBIF) is the principal international collector and curator of data on species locations www.gbif.org.

Protected Areas - The International Union for the Conservation of Nature (UICN)

- IUCN defined categories of protected areas, https://www.iucn.org/theme/protected-areas/about/protected-area-categories.
- World Protected Areas Database, www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas.
- IUCN Green List (www.iucn.org/theme/protected-areas/our-work/iucn-green-list-protected-and-conserved-areas) of protected areas.
- IUCN Red List (www.iucnredlist.org) of threatened species.
- US Geological Survey PAD-US, www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/protected-areas, the database of US protected areas, data provided to World Protected Areas Database.
- New York Protected Areas Database NYPAD, nypad.org/, example of state data.
- Vermont Biofinder, anr.vermont.gov/maps/biofinder, example of state data.
- California BIOS, apps.wildlife.ca.gov/bios, example of state data.
- Wisconsin, DNR maps, dnr.wi.gov/topic/landscapes/maps.html#coaMaps.

Human Impact – European Space Agency, large scale satellite monitoring of earth systems

- Urbanization,www.esa.int/Applications/Observing_the_Earth/Benefiting_Our_Economy/Urban_monitoring
- Forest cover, www.esa.int/esearch?q=forest+cover
- Agriculture, www.esa.int/Applications/Observing_the_Earth/Agriculture

Hands-on map sources:

US Forest cover map is from the United States Department of Agriculture (USDA)
Forest Service

- The map shows the percentage of forest cover in each US county where data was available. The deepest green represents counties more than 75% forested, then 51-75%, 25-50%, under 25%, and no data.
- The data is from the Forest Inventory and Analysis Program, www.fia.fs.fed.us/tools-data/maps/2007/descr/yfor_land.php.
- The map was created in 2007, www.fia.fs.fed.us/tools-data/maps/2007/national-100/yfor_land_national_rpa_2007_100.pdf.

Agricultural Intensity maps are also sourced from the USDA

- Value of crops per farm is the map provided in the maps file, and the scale is $750,000 of crop value per farm down to under $10,000 per farm. www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/Ag_Atlas_Maps/Economics/Market_Value_of_Agricultural_Products_Sold/12-M013.php
- Plotting data by the value of crops per acre changes the heat map and could be used as an alternate map, or extension map for the activity, https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/Ag_Atlas_Maps/Economics/Market_Value_of_Agricultural_Products_Sold/12-M016.php

- Cattle grazing is another big use of land in the US, www.nass.usda.gov/Publications/AgCensus/2007/Online_Highlights/Ag_Atlas_Maps/Economics/Market_Value_of_Agricultural_Products_Sold/07-M029.php

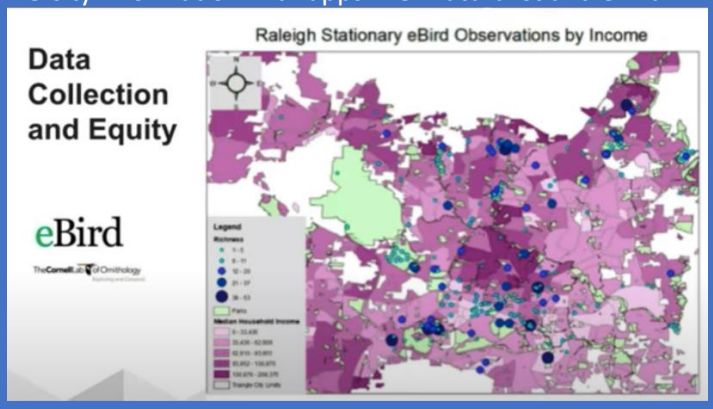
Population Density by County – From the US Census Bureau

- The map shows the population density of US counties. The scale is from over 1000 people per square mile, 500-1000, 100-500, 10-100, less than 10. This map was chosen for the activity because it emphasizes population concentration in urban areas.
- The map data are from the 2000 US Census, Texas Tech version of the map with scale, external-preview.redd.it/lx5CzDJHkNle5HEdb26EGgT_bJa9-c3Cbfa5WgK5ZJk.jpg?auto=webp&s=540a929c31b93f9091cc4ab0cf9a15e2e9a0aacd
- This 2010 data map shows, how changing the scale of the heatmap changes the way the color intensity distribution and impression, www.census.gov/library/visualizations/2010/geo/ua2010_urban_pop_map.html

Old Maps Online – mapping has been recording and changing the world for hundred of years. Explore this site for a broad appreciation of what maps can convey. www.oldmapsonlin.org.

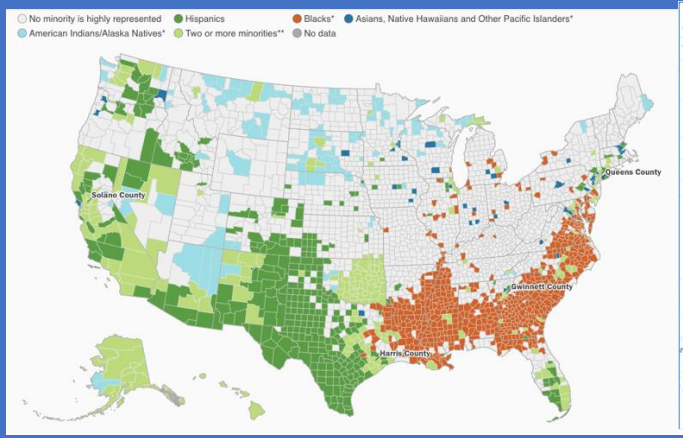
Maps to support thinking about equity and inclusion

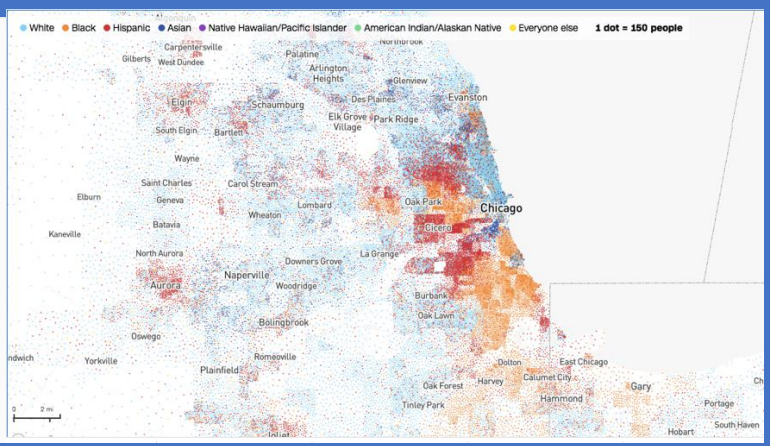
Deja Perkins maps bias in collecting biodiversity information with apps like iNaturalist and eBird.



djperkins9012.wixsite.com/perkins in this 5 minute video she talks about what she's found

View the entire video here, youtube.com/watch?v=ZFhiRAtTPV4





Brookings Institute expanding racial diversity CNN Race & Ethnicity Across the Country

CNN Race & Ethnicity Across the Country –interactive map presents high resolution census on any US location, able to zoom down to neighborhood level. cnn.com/interactive/2021/us/census-race-ethnicity-map/

Brookings Institute America's Racial Diversity – a good demonstration of how filtering and parsing data can change your perception of the meaning of the statistics. brookings.edu/research/americas-racial-diversity-in-six-maps/

2020 Census Demographic Data Map Viewer – interactive map using US census data. mtgis-portal.geo.census.gov/arcgis/apps/MapSeries/index.html?appid=2566121a73de463995ed2b2fd7ff6eb7

Most of the above data comes from the US Census Bureau, start with this summary page on racial and ethnic diversity in the US. bit.ly/USCensusDiversity

Justice Map from Sunlight Foundation and Energy Justice Network – presents the key indicator of income to compare against race. www.justicemap.org/

Half-Earth Map National Report Cards – a measure of how well the world's nations are doing at protecting the species they have stewardship over. The wealthiest nations are not necessarily doing the best. half-earthproject.org/national-report-cards-summarize-conservation-efforts-at-national-level/

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