BAMS In Box

Using Tree-Ring Research to Introduce Students to Geoscience Fieldwork

Clay S. Tucker, Jill C. Trepanier, Pamela B. Blanchard, Ed Bush, James W. Jordan, Mark J. Schafer, and John Andrew Nyman

ABSTRACT: Environmental education is key in solving environmental problems and for producing a future workforce capable of solving issues of climate change. Over the last two decades, the Coastal Roots Program at Louisiana State University (LSU) has reached more than 26,676 K–12 students in Louisiana to teach them environmental science and has brought them to restoration sites to plant 194,336 school-grown trees and grasses. The codirectors of Coastal Roots are continually searching for opportunities to enrich the experience of teachers and students in connecting school subjects, Coastal Roots, and stewardship. In school year 2018/19, students in five local schools entered a pilot program to learn how tree-ring science informs environmental science broadly. During their scheduled restoration planting trips, students were asked to collect the following tree data: tree cores, tree height, tree diameter, tree species, and global positioning system location points. Data were given to scientists at LSU for preliminary analysis, and graphical representation of the data were shown to the students for their interpretation. Results from this program indicate that bringing students into the field and teaching them a new scientific skill improved their understanding of environmental science and their role in coastal restoration, and tree-ring data showed significant correlations to various climate parameters in Louisiana. Additionally, we find that bringing this knowledge to teachers allows the knowledge to spread for multiple generations of students. Here we present tree-ring data from this project, lessons learned during the pilot program, advantages to student-based citizen science, and recommendations for similar programs.

KEYWORDS: Coastlines; Paleoclimate; Education

https://doi.org/10.1175/BAMS-D-20-0096.1
Corresponding author: Clay S. Tucker, ctucke8@lsu.edu
Supplemental material: https://doi.org/10.1175/BAMS-D-20-0096.2

Publisher's Note: This article was modified on 15 September 2021 to correct the spelling of the name of author Mark J. Schafer.

In final form 16 March 2021

AFFILIATIONS: Tucker and Trepanier—Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana; **Blanchard**—School of Education, Louisiana State University, Baton Rouge, Louisiana; **Bush**—School of Plant, Soil and Environmental Sciences, Louisiana State University, Baton Rouge, Louisiana; **Jordan and Shafer**—Department of Sociology, Louisiana State University, Baton Rouge, Louisiana; **Nyman**—School of Renewable Natural Resources, Louisiana State University, Baton Rouge, Louisiana

Louisiana's citizens are familiar with environmental threats to the coastal zone including landfalling tropical cyclones (Trepanier and Scheitlin 2014; Trepanier et al. 2015), inland inundation from heavy precipitation events (van der Wiel et al. 2017), and coastal land loss (Couvillion et al. 2011). On average, a wetland area the size of a football field is lost to open water every 100 min in Louisiana (Wright et al. 2019). Understanding and preventing coastal land loss is increasingly important in the state, and this is reflected in the K–12 Louisiana Student Standards for Science (LSSS; Louisiana Department of Education 2020). These newly adopted Louisiana science standards are closely aligned with the Next Generation Science Standards (NGSS; Pruitt 2014) and address erosion and coastal changes, climate, and weather (Table 1). The Louisiana State Department of Education's vision for environmental literacy is to "cultivate a Louisiana citizenry that understands, feels connected to, and is inspired to protect, preserve, and restore our environment for present use and future sustainability" (Louisiana Department of Education 2020, paragraph 2). Thus, the environmental topics of erosion and coastal land loss, climate and weather, are taught across many grade levels and high school courses.

While there may be a vision to have an environmentally literate citizenry, Louisiana has yet to adopt an environmental literacy plan while 20 other states have written, adopted, and begun to implement their environmental literacy plans (North American Association for Environmental Education 2019). The purpose of having an adopted environmental literacy plans is to support knowledge building, workforce development, and civic engagement (North American Association for Environmental Education 2019). Civic engagement includes both environmental (or ecological) stewardship as well as citizen science. The goal of environmental (or ecological) stewardship is to "sustain the capacity to provide ecosystem services that support human well-being under conditions of uncertainty and change" (Chapin et al. 2010, p. 241). Citizen science is defined as "those [science projects] that typically involve nonscientists (i.e., people who are not professionally trained in project-relevant

Table 1. Louisiana Student Standards for Science that focus on erosion and coastal changes, climate, and weather (Louisiana Department of Education 2020). The first digit or abbreviation in the code represents grade level (MS = middle school; HS = high school). The remaining alphanumeric code represents the science discipline (ES = Earth and space science; LS = life science; EVS = environmental science), core idea, and subidea.

Erosion and coastal changes	Climate	Weather
4-ESS2-1	3-ESS2-2	K-ESS2-1
4-ESS3-2	5-ESS2-1	K-ESS3-2
5-ESS3-1	7-ESS2-6	K-ESS2-1
7-MS-LS2-5	7-MS-ESS2-6	3-ESS3-1
8-MS-ESS2-2	7-MS-ESS3-5	3-ESS2-1
HS-EVS1-2 (HS Env Sci)	HS-LS2-1 (HS Biology)	5-ESS2-1
HS-EVS1-3 (HS Env Sci)	HS-LS2-6 (HS Biology)	7-MS-ESS2-5
HS-EVS2-3 (HS Env Sci)	HS-LS4-4 (HS Biology)	8-MS-ESS3-2
HS-ESS2-1 (HS Earth Sci)	HS-LS4-5 (HS Biology)	HS-ESS3-1 (HS Env Sci)
HS-ESS2-2 (HS Earth Sci)	HS-ESS2-2 (HS Env Sci)	
HS-ESS2-5 (HS Earth Sci)	HS-ESS2-4 (HS Env Sci)	
HS-ESS3-1 (HS Earth Sci)	HS-ESS3-1 (HS Env Sci)	
	HS-LS2-1 (HS Env Sci)	
	HS-ESS3-5 (HS Env Sci)	

disciplines) in the processes, methods, and standards of research, with the intended goal of advancing scientific knowledge or application" (Jenkins et al. 2020). Dickinson et al. (2012) state the goal of citizen science leads to three types of outcomes, one of which is related to the skills and knowledge gained by participants. Furthermore, Bonney et al. (2009) describe three types of citizen science projects: (i) contributory—participants assist with data collection; (ii) collaborative—scientists and participants work jointly on data analysis, interpretation; and (iii) dissemination of findings (Table 2). A search of two large databases, Federal Crowdsourcing and Citizen Science Catalog with 450 projects (CitizenScience.gov 2021) and SciStarter.org with 1,548 projects (SciStarter 2021), turned up 7 and 10 citizen science projects, respectively, focusing specifically on "forest" (i.e., focused on tree data and not just taking place within a forest and focusing on pollinators or invasive species, etc.) while a search on the terms "dendrochronology" and "tree ring" returned 0 projects.

Louisiana's coastal and environmental problems are serious. Its citizens and future workforce need to be environmentally literate—to understand the problems facing our coast so they can make informed personal decisions about the fate of Louisiana's coastal lands and the serious environmental issues they face. This contributory citizen science pilot project engages teachers and students in the scientific process of tree-ring and climate science using Louisiana State University's (LSU) already established environmental stewardship project, the LSU Coastal Roots (CR) Program, by piloting an enhancement and expansion of the CR Project to include a citizen science aspect, the CR Tree Ring Core Collection (TRCC).

Involving teachers and students in environmental stewardship: The Coastal Roots story. An increasing number of environmental stewardship programs exist around the United States and the world, some of which have a similar restoration focus as the CR Program and welcome K–12 participation. For instance, in *Bay Grasses in Classes* (Maryland, beginning in 1998), students learn about native Chesapeake Bay grasses, grow their own grasses, and participate in a restoration trip in the estuary (M. Lewandowski 2005, personal communication). Tampa Bay Watch's *Bay Grasses in Classes* beginning in 1994 is very similar to the Maryland program, but students grow smooth cordgrass for their restoration trips (J. Creneti 2005, personal communication). Another environmental stewardship program focusing on native tall grass prairies in Wisconsin is *Earth Partnership for Schools* (L. McCann 2005, personal communication). There are environmental stewardship programs that grow native fish instead of plants: *Salmonids in the Classroom* (British Columbia, Canada; D. Demontier 2005,

Table 2. K–12 citizen science projects aligned with Bonney et al. (2009) level of participant participation. Information includes year of initiation, science focus, and URL.

Citizen science project types based on level of participation	Example citizen science projects
Contributory	Monarch Watch (1992; tagging program and milkweed distribution; www.monarchwatch.org/; open to K–12)
	Globe at Night (international; focus on light pollution; www.globeatnight.org/; open to K–12)
	Project Budburst (phenology of plant life cycle events; http://budburst.org/open to K–12)
	Galaxy Zoo (2007; categorizing morphology of one million galaxies; www.zooniverse.org/projects/zookeeper/galaxy-zoo/)
Collaborative	Nature's Notebook (2009; phenology focus; local groups set research agenda/goals; www.usanpn.org/nn/welcome; open to K–12)
	Cornell Bird Laboratory's Birdsleuth (2004; bird count; school-based research projects; www.birds.cornell.edu/k12/citizen-science/; open to K–12)
	Earth Day: Forest Watch Program (tree health, sample and data collection and analysis; see Rock and Lauten 1996)
Cocreated	Reclaim the Bay (focus on growing shellfish from "seed" to reestablish healthy shellfish populations; https://reclamthebay.org/)

personal communication) and *Native Fish in the Classroom* (Louisiana; D. Lindstedt 2005, personal communication), in which Louisiana students grow paddlefish.

The LSU CR Program began in 2000 with the efforts of LSU faculty as an outreach program for the Louisiana Sea Grant College Program. What began in six schools back in 2000 now involves teachers and their students at 45 schools from grades 2 through 12 across 20 parishes (i.e., counties) throughout southern Louisiana. The overarching goal of the CR Program is to provide a K–12 environmental stewardship opportunity aimed at connecting classroom content to what is happening within the coastal zone. This includes the constructive (e.g., delta building, vegetative plantings to slow erosion on beach dunes and marshes, and coastal forest restoration) and destructive processes (e.g., erosion due to storm damage, interruption of water flow through and across the wetlands, invasive species damage, rising sea level, flooding due to tropical storms and large rain events, and climate change). The CR Program has grown and evolved over the last two decades (Table 3). In 2005, Louisiana was hit by Hurricanes Katrina and Rita, resulting in major disruptions to coastal school systems as students and their families were displaced from their homes due to flood and wind damage. The hurricanes also damaged many of the existing 24 school nurseries, reducing the participating schools to 18 the following academic year. These two hurricanes resulted in a flood of interest from K–12 teachers who were interested in helping their students learn about the coastal problems Louisiana faces. Additionally, teachers saw a need for their students to take action to remedy the widespread damage caused by the storms. In 2009, the National Oceanic and Atmospheric Administration's Bay Watershed Education and Training (BWET) grants were finally expanded to the Gulf Coast region and a 5-yr grant was awarded to the CR Program to expand and enhance already existing elements of the program. Since 2009 and the beginning of the BWET grant, each year there have been at least 1,500 students participating in more than 30 restoration trips (Table 2). BWET funding provided partial reimbursement of field

Table 3. Coastal Roots restoration trip information by academic year.

Academic year	Total trips	Total native plants transplanted	Percent ES students	Percent MS students	Percent HS students	Students participating in restoration trips	Teachers and chaperones
2000/01	2	25	0	67	33	45	2
2001/02	10	1,388	0	62	38	355	19
2002/03	9	515	11	48	41	230	10
2003/04	15	1,615	11	71	18	569	50
2004/05	13	402	17	76	8	417	43
2005/06	0	0	0	0	0	0	0
2006/07	6	290	0	98	2	277	35
2007/08	16	2,846	3	87	10	574	95
2008/09	20	4,709	20	72	9	1,078	156
2009/11	31	6,738	18	56	26	1,516	265
2010/11	34	6,744	24	60	15	1,918	299
2011/12	32	5,479	32	57	11	2,070	403
2012/13	37	5,976	37	42	21	1,873	459
2013/14	43	5,759	43	40	17	2,529	680
2014/15	46	6,581	39	43	18	2,711	637
2015/16	35	4,912	36	38	27	1,940	337
2016/17	43	4,305	57	31	12	2,350	695
2017/18	40	4,024	42	39	19	2,551	607
2018/19	43	4,190	48	32	20	2,518	612
2019/20	20	2,502	33	35	32	1,199	264

trip costs for schools. Since 2016, reduced program funding has forced schools to become responsible for all field trip costs. Despite the costs, schools continue to participate in their yearly restoration trips.

The CR Program is organized at the school level, where individual public, private, and parochial schools self-select to participate. Interested schools contact the CR program director and are required to pay an affiliation fee of $1,500. This fee covers the cost of materials to build a school-based plant nursery in which the students can grow their native plants until ready to plant at a restoration site the following winter (trees) or spring (beach dune grass; Bush and Blanchard 2009). Restoration site managers identify native plant species that schools can grow, and each school is provided seeds or stem cuttings to be planted and grown over the next 9 months. Native plant species grown so far include tree species such as longleaf pine, loblolly pine, live oak, water oak, southern bald cypress, tupelo gum, southern wax myrtle, swamp red maple, common persimmon, common pecan, and catalpa, in addition to one beach dune grass, bitter panicum. Students bring their crop of 9-month-old saplings or grass plugs on their trip to their partner habitat restoration site that is usually located within an hour's drive from their school. Throughout the year, teachers use the CR Program to address related science standards and to bring attention to what is happening in Louisiana's coastal zone through lessons that they teach in their classrooms. Because of the tremendous pressure teachers experience to cover the assigned content standards for their grade level using state approved textbooks, there is no written curriculum suggested or required to be taught when a school joins the CR Program. Instead, it is left to the teachers' judgment as to how they integrate the growing of plants and the restoration trip into their teaching. Yearly CR Winter Workshops include exemplary lesson demonstrations and presentations of related coastal and horticulture topics to help broaden teachers' awareness of connections that can be made to the CR Program. Teachers are also provided a compendium of annotated online lessons that has been compiled based on topics related to the standards for each grade (Blanchard 2016). Teachers are trained in how to grow the plants and manage their school-based plant nursery at these yearly meetings and are guided by the CR Handbook (Blanchard et al. 2020) that describes monthly caretaker duties associated with growing a variety of native trees and grasses. The codirectors of the program are professors of geology, education, and horticulture, so the CR Program has strong connections to horticulture, Earth, and coastal science.

The directors actively look for opportunities to expand the connections teachers can make to the CR program within their subject areas. For example, CR schools have piloted horticulture lessons (Karsh 2005; Karsh et al. 2009), environmental literacy lessons (Somers 2005), environmental broadcasts over low-power AM radio antennas (P. Blanchard 2021, personal communication) and an attitude scale toward coastal environmental themes (Jones 2011) in order to enhance student knowledge and make students more aware of their role in the environment (LaChenaye 2014). A tree-tagging and mapping task was created by the CR program director because students asked if their trees were alive after flooding, drought, and tropical storm events. There are now global positioning system (GPS) kits for students to collect latitude, longitude, tree height, and stem diameter for those teachers and students who might wish to return to their planting site to see how many of the 24 tagged trees are still alive in later years. The TRCC pilot project described in this paper represents, for the first time, a contributory citizen science project piloted in the CR Program.

Tree-Ring Core Collection pilot program

The possibility of connecting a contributory citizen science project to the CR Program excited many of the teachers involved in the program as this project provided an opportunity for students to learn how to gather scientific samples (tree cores) and data (latitude, longitude, tree height, and circumference) while participating in their yearly restoration planting trip. We designed a pilot program involving five schools in the CR program to teach students and teachers how to collect tree-ring core samples and the connection between tree-ring research and weather events that are recorded in the rings. The TRCC project was purposefully narrow in scope and was limited to students collecting tree cores at their restoration sites. From past experience with the radio stewardship project—a technically difficult project for teachers and students to learn and master—this first foray into citizen science was created to be cautious and slow and result in a contributory rather than collaboratory citizen science project. While a collaboratory citizen science project is a long-term goal (tree core collection, preparation, and analysis), adequate training time and grant money must first be secured. Therefore in this paper we present our techniques for guiding the students and teachers in the pilot program of TRCC in the basics of tree-ring core sampling and the information tree rings can reveal to those who know how to look for patterns within the rings.

Tree-ring science (i.e., dendrochronology) dates back more than a century in the United States (Douglass 1909) because trees record their environment from year to year represented by measurable growth rings (Speer 2010; Fritts 2012). Through various environmental stressors, growth rates can change each year, and an environmentally driven pattern can be discerned from a tree's rings. For example, trees in coastal Mississippi have been shown to express declined growth following nearby hurricane landfalls (Tucker et al. 2018). More information regarding tree-ring science background information and methodology is included in the online supplementary material (https://doi.org/10.1175/BAMS-D-20-0096.2).

Tree-ring science field work and analysis is relatively inexpensive and efficient, which makes it an ideal science to introduce to students. It also offers an engaging and fun opportunity for students to work in the field, and experts can provide information about the applicability of the work to climate science and understanding climate change. Students involved in this pilot project collected various data (tree height, tree stem diameter, tree species name, and GPS coordinates) in mature forests near their planting sites (Fig. 1). Field site descriptions, items included in the Dendro Kit, dendrochronological methods, and overarching themes from the project are not the focus of discussion here and are discussed in the supplementary material. However, we do offer the following recommendations as a result of the Coastal Roots TRCC pilot program.

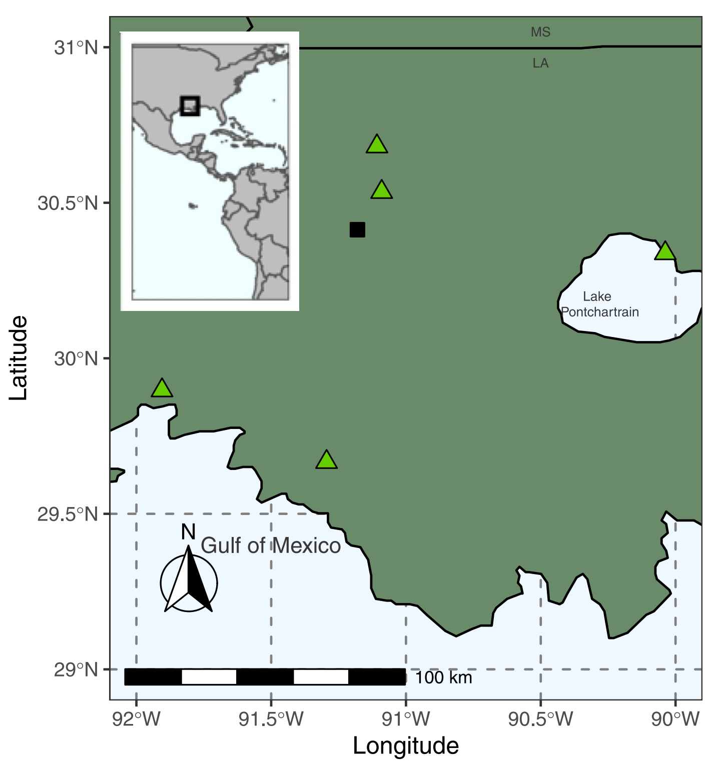

Fig. 1. The study area in South Louisiana with an inset showing global location. Louisiana State University (black square) and the coring/planting sites (green triangles) are shown.

Summarizing remarks for future best practices

Results of the TRCC pilot program show student learning gains in understanding of the scientific process (35%), of larger issues of coastal science (43%), and of their ability to pursue scientific careers (31%; Jordan et al. 2020, manuscript submitted to *J. Environ. Educ. Res.*). The TRCC shows that student citizen science can be a learning environment that enhances the behavior and self-efficacy of participants. Detail provided in this piece allows for duplication/adaptation for similar programs at other schools. Here we include a list of "best practices" compiled to make the process easier for researchers/teachers:

1) Working with an established program is useful for identifying schools with teachers and administration in favor of extracurricular projects. The institution likely already has interested students ready to become citizen scientists. The leaders of these established programs also have important insight for streamlining the process.
2) Simple, transparent instructions and data sheets are necessary for acquiring accurate, reliable data. See example data sheets in the supplementary material.
3) If working with students, forming a relationship with the teacher is important for bringing information to the classroom. We recognize teachers as the gateway to bringing new scientific knowledge into schools.
4) Bring all data and graphics back to the student-citizen scientists once the researchers have completed analysis. Multiple people looking at the same data proved to be useful in determining the potential breadth and depth of the environmental results. It also allows students to work together to discuss likely ideas for and implications of the results.
5) The citizen scientists should gather more than one type of data. This study initially aimed to collect only tree cores, but asking students to gather other data made them more invested and provided researchers a more robust picture of the environment.
6) Include student and teacher findings and comments in the reporting of the data graphics analysis.
7) After performing an initial program to assess student gains in knowledge, involve students more in the actual research process.

Acknowledgments. The work for this project was funded by as part of Program Project ID 2018_R/CEH-14 through the Louisiana Sea Grant College Program under the National Oceanic and Atmospheric Administration Award NA18OAR4170098. Institutional Review Board (IRB) approval was given by the LSU IRB office under Project 3926. The authors thank the schools, teachers, and students involved in collecting and discussing the data used in this study. The authors would also like to recognize and thank the staff and faculty at Louisiana Sea Grant College Program for guiding, assisting, and funding this project.

Data availability statement. Physical tree cores and non-tree-ring data are all stored in a common repository in the Department of Geography and Anthropology at Louisiana State University. Upon completion of the funding opportunity, tree-ring width data will be uploaded to the open-access International Tree-Ring Data Bank (ITRDB) housed online by the National Centers for Environmental Information (www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/tree-ring).

References

Blanchard, P. B., 2016: LSU Coastal Roots Program: Compendium of coastal, wetland, and restoration information for Louisiana educators. Louisiana State University School of Education, www.lsu.edu/coastalroots/teacher/index.php.

——, J. Fuller, B. Jones, and E. Bush, 2020: LSU Coastal Roots Program handbook: A year in the yard. 4th ed. Louisiana State University School of Education Doc., 76 pp.

Bonney, R., H. Ballard, R. Jordan, E. McCallie, T. Phillips, J. Shirk, and C. C. Wilderman, 2009: Public participation in scientific research: Defining the field and assessing its potential for informal science education. CAISE Inquiry Group Rep., 58 pp.

Bush, E. W., and P. B. Blanchard, 2009: Low-cost container yard for school-based restoration nurseries. *HortTechnology*, **19**, 818–822, https://doi.org/10.21273/HORTSCI.19.4.818.

Chapin, F. S., III, and Coauthors, 2010: Ecosystem stewardship: Sustainability strategies for a rapidly changing planet. *Trends Ecol. Evol.*, **25**, 241–249, https://doi.org/10.1016/j.tree.2009.10.008.

CitizenScience.gov, 2021: Federal crowdsourcing and citizen science catalog. U.S. General Services Administration, www.citizenscience.gov/catalog/.

Couvillion, B. R., and Coauthors, 2011: Land area change in coastal Louisiana from 1932 to 2010. U.S. Geological Survey Scientific Investigations Map 3164, 12 pp.

Dickinson, J. L., J. Shirk, D. Bonter, R. L. Crain, J. Martin, T. Phillips, and K. Purcell, 2012: The current state of citizen science as a tool for ecological research and public engagement. *Front. Ecol. Environ.*, **10**, 291–297, https://doi.org/10.1890/110236.

Douglass, A. E., 1909: Weather cycles in the growth of big trees. *Mon. Wea. Rev.*, **37**, 225–237, https://doi.org/10.1175/1520-0493(1909)37[225d:WCITGO]2.0.CO;2.

Fritts, H., 2012: *Tree Rings and Climate*. Elsevier, 582 pp.

Jenkins, L., K. Dibner, and M. E. Hannibal, 2020: Learning through citizen science: Enhancing opportunities by design. *2020 Annual Meeting*, Seattle, WA, AAAS.

Jones, R. M., 2011: Development of attitudes of children towards coastal environmental themes survey: Examining attitudes of Louisiana middle school students. M.Ed. thesis, Dept. of Educational Theory, Policy, and Practice, Louisiana State University, 84 pp.

Karsh, K. L., 2005: Integrating horticulture biology and coastal environmental issues into the middle school science curriculum. M.S. thesis, Dept. of Plant, Environmental Management and Soil Sciences, Louisiana State University, 219 pp.

——, E. Bush, J. Hinson, and P. Blanchard, 2009: Integrating horticulture biology and environmental coastal issues into the middle school science curriculum. *HortTechnology*, **19**, 813–817, https://doi.org/10.21273/HORTSCI.19.4.813.

LaChenaye, J., 2014: A mixed methods evaluation of the coastal roots program. Ph.D. dissertation, Louisiana State University, 163 pp.

Louisiana Department of Education, 2020: Louisiana student standards for science. Louisiana Department of Education, www.louisianabelieves.com/resources/library/academic-standards.

North American Association for Environmental Education, 2019: State environmental literacy plans 2019 status report. North American Association for Environmental Education, https://naaee.org/eepro/resources/state-environmental-literacy-plans-2019.

Pruitt, S. L., 2014: The next generation science standards: The features and challenges. *J. Sci. Teach. Educ.*, **25**, 145–156, https://doi.org/10.1007/s10972-014-9385-0.

Rock, B. N., and G. N. Lauten, 1996: K-12th grade students as active contributors to research investigations. *J. Sci. Edu. Technol.*, **5**, 255–266, https://www.jstor.org/stable/40188562.

SciStarter, 2021: SciStarter: Science We can do together. SciStarter, https://scistarter.org/finder.

Somers, R. L., 2005: Putting down roots in environmental literacy: A study of middle school students' participation in Louisiana Sea Grant's Coastal Roots Project. M.A. thesis, Dept. of Education, Louisiana State University, 155 pp.

Speer, J. H., 2010: *Fundamentals of Tree-Ring Research*. University of Arizona Press, 333 pp.

Trepanier, J. C., and K. N. Scheitlin, 2014: Hurricane wind risk in Louisiana. *Nat. Hazards*, **70**, 1181–1195, https://doi.org/10.1007/s11069-013-0869-6.

——, K. N. Ellis, and C. S. Tucker, 2015: Hurricane risk variability along the Gulf of Mexico coastline. *PLOS ONE*, **10**, e0118196, https://doi.org/10.1371/journal.pone.0118196.

Tucker, C. S., J. C. Trepanier, G. L. Harley, and K. L. DeLong, 2018: Recording tropical cyclone activity from 1909 to 2014 along the northern Gulf of Mexico using maritime slash pine trees *(Pinus elliottii* var. *elliottii* Engelm.). *J. Coastal Res.*, **34**, 328–340, https://doi.org/10.2112/JCOASTRES-D-16-00177.1.

van der Wiel, K., and Coauthors, 2017: Rapid attribution of the August 2016 flood-inducing extreme precipitation in south Louisiana to climate change. *Hydrol. Earth Syst. Sci.*, **21**, 897–921, https://doi.org/10.5194/hess-21-897-2017.

Wright, L. D., W. Wu, and J. Morris, 2019: Coastal erosion and land loss: Causes and impacts. *Tomorrow's Coasts: Complex and Impermanent*, Springer, 137–150.