



Incorporating lessons from women naturalists to support biodiversity education and under-represented students

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Abstract

Contributions of women naturalists have enriched our scientific understanding of the natural world since the seventeenth century. However, this analysis of natural history compilations shows far more entries from and about men rather than naturalists while often including none or no more than two or three contributions from women naturalists. For life science education, lack of such information limits student exposure to a diversity of naturalists at a time when greater emphasis is placed on reaching under-represented students, with increasingly diversified backgrounds and perspectives. This article first explores evidence and explanations for this absence using a bibliometric mapping analysis (which in and of themselves supply information for meaningful teaching moments) and secondly, explains why availability of such would help engage students to meet concerns regarding biodiversity declines needing correction by 2050. These two analyses taken together form the framework used to consider the compiled information from an educational perspective. From 2022 until 2050, only 12 years remain for students to complete secondary science, move onto higher education, and emerge eligible for work. Including lessons about women naturalists could help reach under-represented students by allowing student-to-lesson affinities to occur based on either the topical nature of the naturalist's research; the geographic/cultural inclinations, or the era of the naturalist's work. Research to address matters described here begin with a pilot scoping review and bibliographic analysis, revealing lists of natural history compilations (publications). In closing, a group of selected women naturalists from this study serve as examples for inclusion in life science curriculum.

Keywords Naturalists · women gender studies · Scoping review · Education · Biodiversity · Curriculum planning · E.O. Wilson

“The right way to create a young scientist who’s going to be on fire by the time they’re in college is to let them pick something ... that has really excited them.”

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—E.O. Wilson [Tyson C (2019) *A legendary scientist sounds off on the trouble with STEM. The chronicle of higher education.* <https://www.chronicle.com/article/a-legendary-scientist-sounds-off-on-the-trouble-with-stem/>. Accessed 7 May 2019]

Introduction

Critical decision points have been identified to sustain life on planet earth, with one global estimation focused on accomplishments by 2050 (Dyer 2005). Within that time, beginning in 2022 until 2050, only 12 years remain (until year 2034) that students can begin school, complete secondary school, receive a 4-year higher education degree, and be eligible for work. As suggested by Dr. E.O. Wilson (Tyson 2019), during these years, the life science curriculum should incorporate biodiversity units as part of their lessons, thus beginning preparation for scientific challenges identified in the *Millennium Ecosystem Assessment Synthesis Report*. This approach would prepare students for such challenges by providing them a solid foundation in biodiversity-centered science, as well as introducing scientists to whom they can best relate, helping to reverse the lack of diversity seen in science even today (Editorial Nature 2021).

This implies the need to reach not only those students seeing success in science as a way to college, but also those from under-represented groups who may be put off by the rigors and vocabulary of science instruction. As will be presented, and serve as timely examples, are lessons derived from women naturalists which provide an array of possible *affinities*¹ for students which otherwise would not be present (Hecht and Nelson 2021), due by default to units almost exclusively focused on accomplishments from white mens.

Such opportunities to learn from the life's work of a scientist to which they felt akin would be one way to help overcome findings regarding under-representation of students (women students, or those of color), occurring for eventual college enrollment (U.S. Department of Education 2016). Incorporating individuals of science to whom students can form affinities can also combat disparities by helping students lock onto "like minded scientists."

Part I. Rationale, methodology, and data

Reasons for conducting this study

The year 2031 will mark the 200th anniversary of the HMS Beagle's departure from Portsmouth, England, taking a novice geologist named Charles Darwin on a global adventure. However, upon studying Fig. 1, Maria Sibylla Merian left Amsterdam for

¹ Here, affinities are possibilities for bonding between student and women naturalist subject matter, including: the topic of the naturalist's concern; the geographical/cultural background of the naturalist; or the time or era in which the naturalist worked, where affinities could form due to the topic.

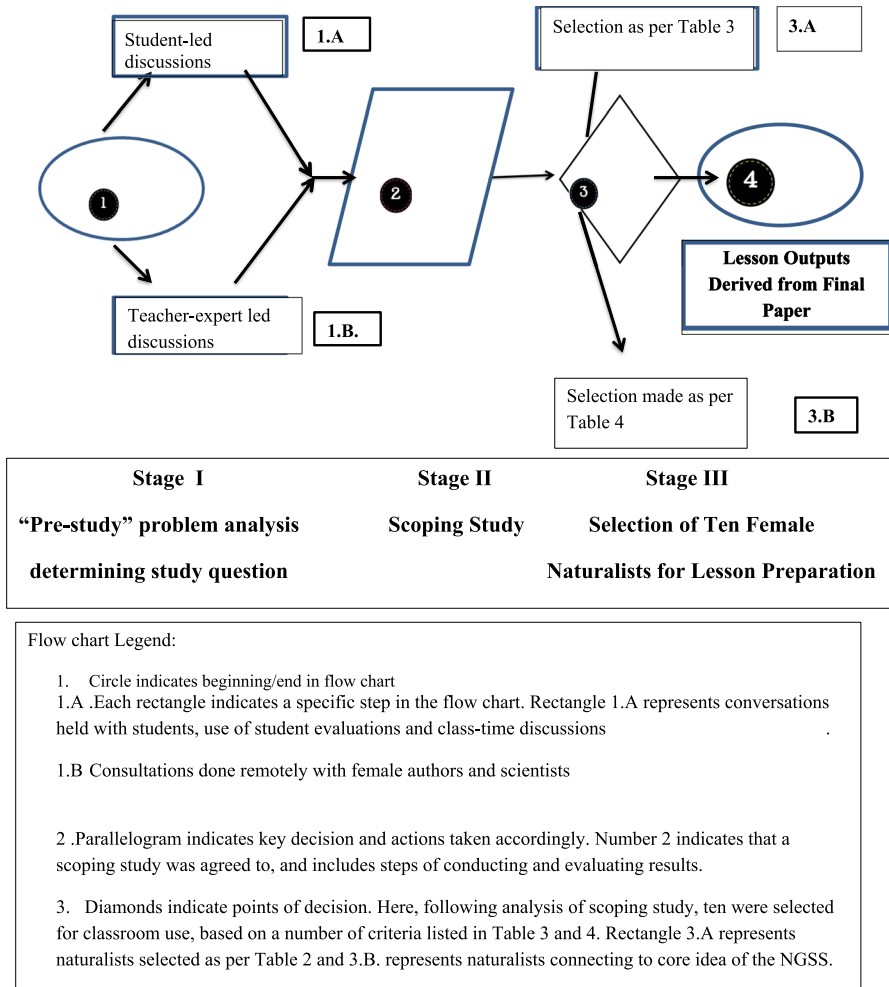


Fig. 1 Flowchart using symbol to trace steps followed in this study to identify extent of literature available on women naturalists and finalize a choice of representative group of naturalists for use in classroom

the Surinam tropics over a century earlier, in 1699. At 52 years old, Merian was a single mother traveling with her daughter, working in the heat of the forest to capture its animal, insect, and floral diversity (Lack 2007). Even though she left England almost 132 years before Darwin and almost sixty years before Linnaeus published his *Systema Naturae*, Merian’s name and legacy is still relatively obscure.

Beginning in Surinam and the tropics, Merian virtually single-handedly undertook the classification and taxonomy, collection, representation, and publication of her collected works. By contrast, when Darwin returned to England, he had a cadre of experts working on his collections, with much credit due to George Stevens Henslow for organizing such an effort (Desmond and Moore 1991). These challenges

faced by Merian—a paucity of resources, exclusion from scientific circles, and lack of recognition for her work—(Todd 2007; Bowcutt and Caulkins 2020) are echoed by the experiences of other women selected for this study. Despite their accomplishments they have been overlooked in the historical and scientific records (See Table 2 for examples), and generally absent from educational pedagogy.

For today's science teachers, one of the most important goals comes from one's responsiveness to the increasing diversification of students in the classroom, and capturing the attention of under-represented groups, including women and minority students (Arif et al. 2021). To promote scientific study to a diverse student body, incorporating a diverse set of scientists (differing, for example, in gender, cultural background, or nationality; Hecht and Nelson 2021) throughout the curriculum gives minority students scientists to whom they can more readily relate (Bowcutt and Caulkins 2020). Incorporating the work of women naturalists, as will be shown in this paper, is one way to help science teachers meet diverse student needs. Students can then learn simultaneously about a naturalist's contributions while examining the specific societal and historical constraints placed upon this individual. Presenting naturalists in this light acknowledges their work (Bowcutt and Caulkins 2020) while providing individual models for positive identification among women students.

Among under-represented student groups, there is a wide-spread interest to encourage women student participation in science (FIST 2013). This led the study to also reflect on the observation that there was a lack of women scientists, or naturalists, featured in available publications, textbooks, and libraries or the curriculum. This search revealed what prior publications had reported, being that there were clear signs of what is referred to as either “overt or unconscious gender bias in science,” (Nature 2013).

One example of such is the collection compiled by W. Bebe (1944), which includes only one women naturalist, Rachel Carson, out of a total of 46 authors. Discussions with students surrounding the initial search led to a wide array of questions regarding the scientists identified. An initial inability to fully answer such questions led to a “pilot study,” conducted to offer a more detailed explanation of the gender unevenness found in natural history anthologies.

Second, distinct from but related to the imbalance in current science curricula is the continuing under-representation of women in all areas of science. This ongoing shortage of women, either in publications, on relevant internet sites, or in high-level positions (Chiumkanokchai 2019), also exists in the scientific community of naturalists, as noted by Gould (1993).

These findings also call attention to times when a scientist who, having produced a meaningful body of work, is worthy of recognition in publications and collections, yet judged to be without merit. This focus makes this study more vital, as other quantitative studies on this subject were not found. A third reason is the fact that recently, both scientists and interested amateurs have begun turning toward “the observational practice of the naturalist,” (Hannibal 2019) as a way of studying the natural world. Such opportunities exist to become citizen scientists, supply data on local species, and participate in BioBlitz activities. If this trend is on the rise, ensuring under-represented students are included in the growing populations of what are

called “contemporary naturalists” (Hannibal 2019) reinforces the need for familiarity with naturalists of interest.

A final reason for the urgency of conducting this study is derived from recent comments by E.O. Wilson (Tyson 2019) regarding STEM (science, technology, engineering, and math) education. Instead of STEM inspiring students, Wilson said they are “presented with an intellectual triathlon in order to go into science.” This “triathlon” occurs rather than education providing opportunities to identify and follow their own interests in biodiversity.

Research question: introducing the paper’s theoretical framework

The leading question, addressed in this paper from various perspectives is “When, where and why did women naturalists not receive the attention that their accomplishments warrant?” The follow-up research question, addressed in the second half of the paper, is, “What resource are available to deepen teacher understanding of these naturalists and how might they be used in the classroom?” Responding to the initial query began with a scoping review and its bibliometric analysis (Tlili et al. 2021) based upon searches and personal compilations of naturalist literature.

Once such collections had been read and evaluated, as stated in the secondary question, it remained to determine what could be drawn from them of importance to secondary curriculum. Importance here means that students early on can consider their affinities with specific naturalists of interest, and that based on these interests, prepare for either further research or jobs in biodiversity, wildlife management, and conservation, as only a few examples. In this manner, the relevant bibliometric studies were conducted first, with data used to address the above-mentioned theoretical research question.

This paper offers the first such scoping study on presence or absence of women naturalists in relevant compilations, books, anthologies and hosted web sites. It then takes these compilations as a starting point in identifying naturalists and literature that would help introduce such naturalists to secondary and undergraduate education (Parts I and II). Subsequently then, the argument is made for increasing such naturalist literature especially where it can be most used and appreciated among diverse student body classrooms.

Part II. Methodology for initial analysis and review of the literature

Pilot study framework: bibliometric analysis

The current study assesses the scope, availability, and educational utility of illustrative (as opposed to exhaustive) works by or about women naturalists and conservationists from the mid-seventeenth century to the present day. Figure 1 contains a flowchart for the study using standard icons to identify specific start points, action steps, key decision steps and decision points, leading to the final product. Stage 2 of the study involves a scoping review, as described further in Sect. Part II.

Methodology for initial analysis and review of the literature. First, books and articles from natural history collections and/or anthologies containing works from a naturalist's life were assessed from a gender perspective (Table 1; Fig. 1, Stage 1).

The scoping study's qualitative summary is presented in Sect. **Part III. Quantitative and qualitative findings of study**, which finalized features for screening women naturalists and conservationists for classroom lessons. The information for these final individuals is then taken directly from the publications in the scoping review. A companion article is also available for further details on naturalists and biodiversity in the classroom (Cohen 2021).

The three-stage study (Fig. 1) would ensure that each of the initial points and queries from teachers and students were addressed, especially by building upon and broadening the pilot review. Thus, a more detailed scoping review was planned (Stage 2), using search engine results, external recommendations, and receipt of other relevant lists to identify material (Table 2 contains full listing of final sources) germane to the investigation. The selections were then reviewed in historical order by publication date, resulting in a date range of 1944–2016, and classified by editor/author, applicability to curriculum, and the number of women naturalists included in each.

Each stage of the study led to a comprehensive, diversely authored list of publications that included reports on Women naturalists to support teachers with lesson inputs for diversifying classrooms. Based on this goal, four objectives were established, such that the study would:

- (1) Support the diversification of student identities in the classroom, beginning with the women students.
- (2) Highlight a programmatic emphasis for women-identified initiatives and other groups under-represented in science, such as women in Science and Technology (FIST 2013).
- (3) Identify print publications/exemplar scientists in historical (Fig. 2) context as candidates for inclusion in an enhanced curriculum, with internet-based resources identified separately.
- (4) Support students identifying with one of the selected naturalists, followed by their use as role models based on gender and other "alike" factors.

Scoping study methodology and framework

The methodology developed for the study's scoping review (Fig. 3) was adapted from the literature (Archambault et al. 2013; Grant and Booth 2009; PRISMA 2009) and used to identify and define a list of publications expected to include women naturalists. Building on material assembled for the pilot study, the final analysis gathered yet more information. Therefore, it had more quantitative data to provide for an accurate measure of women naturalists appearing in the identified publications. Then the scoping study could test as to whether or not women naturalists appearing in the data were increasing or decreasing over time. Following this quantitative review, a selective focus on some key publications and

Table 1 Sources for scoping review showing number of files used in final selection of material

Type of source	Name of report or other type of resource with entries to be listed in database	Total # lists ^a	# Final publication selected from lists
1	Search data report		
2	“	13	3
3	“	10	4
4	Responses to inquiry	10	4
5	Search data report	17	2
6	“	15	1
7	Web posting	23	8
8	Response to inquiry	10	10
9	Journal resource	19	19
10	Web resource	13	4
11	Web posting	1	2
12	Web posting	20	20
13	Search web links	1	1
14	Article resource	18	10
15	Book resource	1	8
16	Mega web searches ^b	1	25
17		172	121
18		2,700,000	Various sub-groups selected
		15,400	As above
		13,039	As above

Table 1 (continued)

Type of source	Name of report or other type of resource with entries to be listed in database	Total # lists ^a	# Final publication selected from lists
	Total for web mega search	2,798,439	

^aThese numbers are links, books, articles, resources that contain from 1 to 60 individual naturalists; they are not numbers of preliminary or final naturalists, which were later tabulated and shown in Fig. 2 and Tables 2, 3

^bUltimately, the three mega web searches were excluded from documentation, given that more useful sub-sets were extracted, with their entries used in 1–15 above

Table 2 Comparisons among key natural history anthologies for presence of chapters on/by women scientists

Row	1	2	3	4	5	6	7
Book citation	Author/ editor	Year published	End point of book	Total #	# Women naturalists	Name(s) of women naturalist(s)	
1	The book of naturalists: an anthology of the best natural history	William Beebe (Editor)	1944 (Reprint, 1988)	1960s	45	1	Rachel Carson
2	Famous naturalists	L. and M. Milne	1952	1945	14	0 (None)	-
3	Eco-feminism (concept)	Introduced	1975		N/A	N/A	(Park 2007)
3	The naturalist in Britain	David E. Allen	1976				
4	The naturalists—Pioneers of natural history	Alan C. Jenkins	1978	1900	45	0 (None)	-
5	Nature into art: a treasury of great natural history books	Handasyde Buchanan	1979	1978	38	10	E. Albin; E. Blackwell; Mrs. Sarah Bowdich, Mrs. E. Bury; M. Lawrence; Mrs. J.I. Loudun; M.S. Merian; Clara M. Pope; Mary E. Rosenberg; Elizabeth Twining
6	The Heyday of natural history	Lynn Barber	1980	1860s	25	5	Margaret Gatty, M. Anning, A.W. Griffiths; Charlotte Yonge; C. Owen (Wilson 1998)
7	Biodiversity (concept)	Introduced	1986				
7	Made from This Earth: American women and nature	Vera Norwood	1993	1990	50	18	Susan F. Cooper; Rachel Carson; Dian Fossey; Zora N. Hurston; Sarah Orne Jewett
8	Perspectives on biodiversity: genetic resource conservation	C. Potter; J.I. Cohen; D. Janezewski	1993	1995	24	3	Christine Padoch, Adriana Martini; Camila Montecinos
9	Voyages of discovery	Tony Rice	1999	1880	16	1	Maria Sibylla Merian

Table 2 (continued)

Row	1	2	3	4	5	6	7
Book citation	Author/ editor	Year published	End point of book	Total #	# Women naturalists	Name(s) of women naturalist(s)	
10	Median, mid-point year Finding order in nature— The naturalist tradition from Linnaeus to E.O. Wilson	Paul L. Farber	1999 2000	Subtotals: 257 21	38 (15%) 2	Elizabeth Gould; Rachel Carson; Annie Dillard	
11	In Nature's name	Barbara Gates	2002	69*	30*	S. Trimmer; A. Kingsford; L. Liese Schartau; M. Lemon; M. E. Shore; E.A. Maling; H. Martineau; A. Martin; G. Jekyll; M. Gatty; E. Twining; M. North; Louisa A. Meredith; E. Bright- wen; Jane Mareet; Mary Somerville; J. Loudon; A. B. Buckley; Ellis Ethelmer; A. B. Buckley; A. Boding- ton; S.B. Lee; E. Gould; J. Blackburn; E. Cook; A. Pratt; M. Fountaine; E. Olmerod; M. Stopes	
12	The naturalists—Scientific travelers in the golden age of natural history	Stephen R. Brown	2002	15	0	—	
13	Great natural history books and their creators	Ray Desmond	2003	23	3	Maria Sibylla Merian; Elizabeth Blackwell; Anna Atkins	

Table 2 (continued)

Row	1	2	3	4	5	6	7	
	Book citation	Author/ editor	Year published	End point of book	Total #	# Women naturalists	Name(s) of women naturalist(s)	
14	The great naturalists	Robert Huxley	2007	1900	39	2	Maria Sibylla Merion, Mary Anning	
15	Earth Heroes—Champions of the wilderness	Carol L. and B. Malnor	2009	2009	8	2	Wangari Maathai; Margaret Murie	
16	Earth Heroes—Champions of wild animals	Carol L. and B. Malnor	2010	2010	8	2	Rachel Carson, Jane Goodall	
17	Natural Histories—Extraordinary rare book selections from the American Museum of Natural History Library	Tom Baione (Editor)	2012	2011	37	1	Maria Sibylla Merian	
18	Explorers' sketchbooks—The art of discovery and adventure	Huw Lewis-Jones and Karl Herbert	2016	2010	70	11	Gertrude Bell; Adela Breton; Amelia Edwards, O. Tonge; Margaret Fountaine, F. Stark; Vivian Fuchs; Margaret Mee; Maria Sibylla Merian; Marianne North, N. Uemura	
<i>Averages</i>					—	290	53 (18%)	—
<i>Subtotal</i>					290	53 (18%)	—	

Time in Centuries	Periods defined by study	Name of Period	Key Event	Historic Period Number as used in article
1600	1600	Early Naturalism		I
1650				
	1699		Sibylla Merian departs Surinam	
1700				
	1750		<i>Systema Natura</i> by Linnaeus	
1750				
1800				
	1820	Heyday of Natural History	Darwin departs on HMS Beagle -1831	II
1850			Origin of Species - 1859	
	1870			
1900		Emergence of Specialized Disciplines	Decades affected by environmental and later, conservation concerns	III
1950		Developing Awareness of Environmental Concerns		IV
	1962		Rachel Carson - <i>Silent Spring</i>	
		1970		
	1975		Eco-feminism	First Earth Day
	1993		Internet	V
2000		Internet sites supporting female naturalists		

Fig. 2 Historical periods as defined by the study, relevant to the publication of key anthologies and online resources containing material from or about women naturalists

naturalists were uncovered. These and other details of the scoping review will be discussed in Section 3.

After presenting the naturalists in the qualitative summaries, issues faced by women naturalists are discussed, as found in the literature and as currently observable as gender bias. Then, what women naturalists accomplished is presented, despite the discrimination and diminution of work during their productive years. Finally, educational comments are offered, as per performance standards derived from the National Research Council of the United States (NRC 2012),

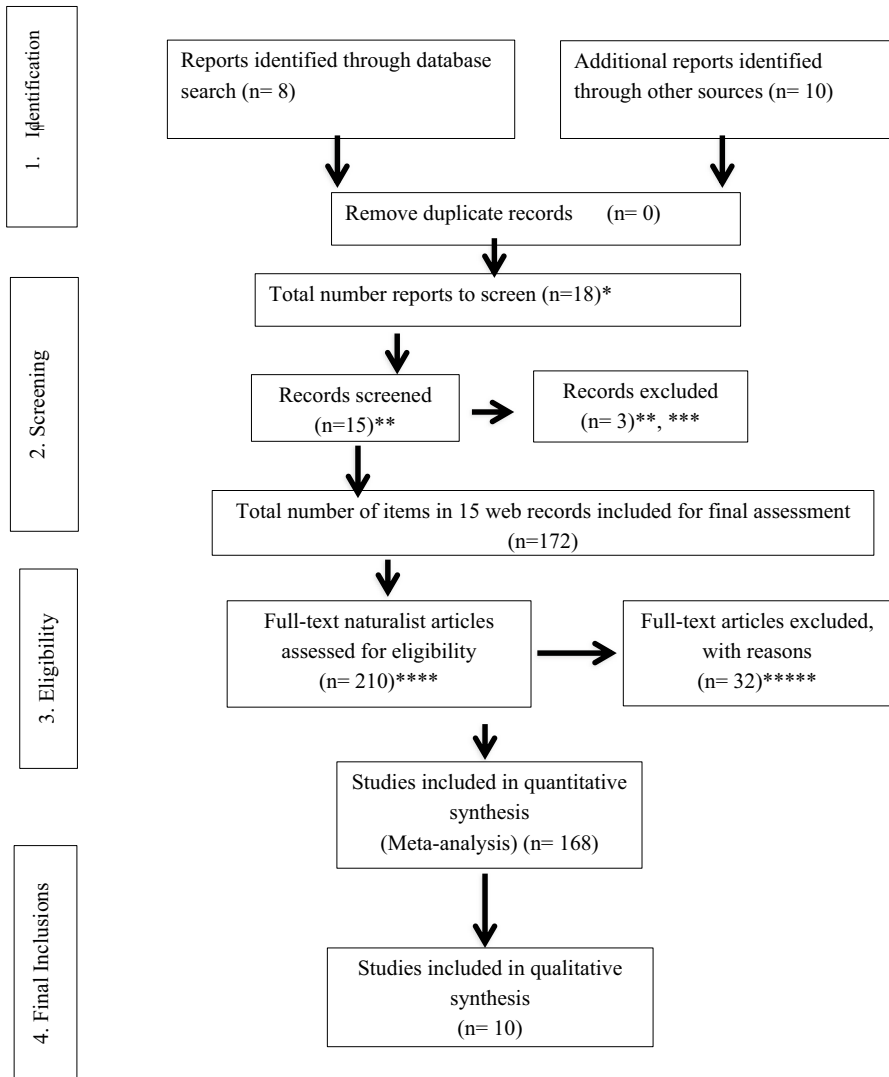


Fig. 3 Diagram of a scoping review to identify anthologies and collections containing the works of women naturalists. Records are mega-documents containing multiple items to screen in detail to arrive at final number of articles. (Modelled after PRISMA (2009) flow diagram. *Specific names of each of the 18 reports shown in Table 1. **Each sub group shown in Table 1. ***The large web search results shown in the text were excluded here, as smaller, useful sub-sets were extracted. ****Total of 210 comes from examination of each “naturalist resource,” to determine if suitable to purpose of search. *****Number 32 from duplicates or inappropriate articles due to lacking key details, artwork, or other reasons

and its Next Generation Science Standards (NGSS), in Sect. [In conclusion](#) (See Table 5 for examples).

Study qualifiers as applied from other studies

According to Grant and Booth (2009), scoping reviews can provide a “preliminary assessment of potential size and scope of available research literature. They aim to identify nature and extent of research evidence,” and are used when “a body of literature has not yet been comprehensively reviewed, or exhibits a large, complex, or heterogeneous nature not amenable to a more precise systematic review.” These qualifiers aptly describe the publications considered for this study, ranging from printed natural history literature and art to more recent biographies found on the internet. Because the lives and undertakings of the featured naturalists covered a span of hundreds of years—from the 1600 s to the twenty-first century—five chronological divisions were adopted to group information into more meaningful units (Fig. 2).

The scoping review consisted of four steps: Identification, Screening, Eligibility, and Final Inclusions. Each step began with a sample size value of n , from which material was selected for the analysis. Details for the outcome of these steps, and the values for each, are presented and described in the flow chart found in Fig. 3. The figure is modified from Grant and Booth (2009), and Archambault et al. (2013), and it contains all data from the scoping review. The methodology and data classification scheme were modified to fit the objectives of the current scenario.

The first step of the scoping review was the identification of relevant literature through a systematic and extensive selection process (Fig. 3; Step 1). This initial process of collection utilized search engines and personal communication results, with each item surveyed shown in Table 1. The search engines used are listed at end of Table 1. Numerous searching parameters were tested, using screens such as “women naturalist; naturalist; natural history; various names of naturalists, and time periods,” from which a final publication list was assembled, shown in Table 1, column 5. Each publication’s utility was considered by reviewing full documents, testing for reading skill levels, and ease of use in classroom situation. This resulted in a final list of publications, annotated by study-related discussion and questioning.

Part III. Quantitative and qualitative findings of study

Findings: quantitative synthesis of data

The analysis of publications (constituting a bibliographic analysis; Tlili et al. 2021) began with a broad-based approach, selecting literature anthologies, collections, reports, websites, and journal articles (Fig. 2; Table 1, column 4). The aggregate sum of items at this point consisted of 168 lists to be considered for full review. In the second step, more specific selection criteria were used to narrow the field from the lists described above, examining publication dates, editors, and contents that reflect the contributions of women naturalists to the scientific study of natural history and conservation. The reduced list of items is shown in Table 1, column 5, which specifies how many publications were selected from each list. The sum of the

Table 3 Key naturalists identified and shown over five eras of natural history, with major accomplishments highlighted

Time (50 years)	Key Societal, Scientific, or Historical Events	Five Historic Periods of Activity (as per Figure 1)	Illustrative Naturalist	Time Period: half-way point/life	Naturalist's birthplace and Country of Origin	Primary characteristic: artist, author, global, conservation, tropics, scientist, collector; birth-death
1600	The Enlightenment	I. 1600 – 1820				
1650		Natural History studies begin	Maria Sibylla Merian	1682	Free City of Frankfurt, Germany	Primarily artistic, entomology; metamorphosis; (1647-1717)
1700	18 th Century		Merian departs for Surinam	1699-1701		Two year journey
1750	1758: <i>Systema Naturae</i> by Linnaeus					
1800	19 th Century	II. 1820 – 1870	Mary Anning	1824	Lyme Regis, United Kingdom	Collector; paleontologist and fossil preparations (1799-1847)
	1831: Darwin departs <i>HMS Beagle</i>	Heyday of Natural History	Elizabeth Gould	1825	Ramsgate, United Kingdom	Artist; ornithology (1804-1841)
1850		III. 1870 – 1950				
1900	20 th Century		Margaret Fountaine	1915	Norfolk, United Kingdom	Butterfly collector; Global travel, collections, (1862-1940)
			Eva Mameli Calvino	1931	Sanremo, Italy	Scientific author, collector (1886-1978)
			Rachel Carson	1937	Springdale, Pennsylvania, USA	Scientific author, environmental impact, conservation (1907 – 64)
			Margaret Mee	1948	Chesham, United Kingdom	Artistic, conservationist, tropics (1909-1988)
1950		IV. 1950 – 1975	Dian Fossey	1958	San Francisco, California, USA	Author, Scientist, conservationist, (1932-1985)
	1962 – <i>Silent Spring</i> published	Rachel Carson's Effect				
	1970 – First <i>Earth Day</i>					
	1975 – "Eco-feminism"	V. 1975 - Present	Wangari Maathai	1978	Nairobi, Kenya	Scientist, Author, conservationist (1940-2011)
	1986 – term "biodiversity" introduced		Jane Goodall	-----	London, United Kingdom	Scientist, Author, primatologist, conservationist (1934-)
2000	2004 – Maathai first African woman to win Nobel Prize	Contemporary Naturalists				(Hannibal 2019) – term recognized in print
	2010 – 50 consecutive years at Gombe					

publications in this column is 122, the final total of individual titles identified for inclusion in the next phase.

Final selections were then made from these 122 publications. The numbers were reduced by considering that many of these works, while favoring naturalists and natural history, also contained chapters weighted to scientific work other than natural history and conservation. After the final round of selection, an illustrative (though by no means exhaustive) final list of 18 publications was obtained. The detailed description of this final group can be found in Table 3, which summarizes comparisons among key natural history anthologies and trends over time regarding the presence or absence of women naturalists.

The selected works were published over a period of more than 70 years, from 1944 to 2016. The computed averages and values (as tabulated in Table 3) showed that 1999 was the approximate mid-point year for total women naturalist inclusions across publications. The first subtotal included nine collections prior to that date, with a subtotal for diversity among naturalists that included 38 women (allowing for some duplication). This was the result for the collections published between 1944 and 1999, with two volumes featuring no women at all. This subtotal was then compared to the one for books published beginning in 2000.

The second subtotal found 53 women included in publications from the period of 2000 to 2016. Not only did gender diversification increase in this second group, but cultural and national diversification was also observed involving individuals outside of Europe or America. This later subtotal reflects an increase in women naturalist content over the first period by 15 individuals, many appearing for the first

time in the collection by Lewis-Jones and Herbert (2017). In this group, much of the increase was from the collection edited by B. Gates (1998), which addressed at least 30 naturalists. This collection grew from her earlier work, *Kindred Nature*, which focused on women from the Victorian and Edwardian periods.

The inclusion of works by Norwood (1993) and Gates contributed significantly to the totals of women naturalists found both before (Norwood) and after (Gates) the median year value of 1999. A similar effect will be noted later (Recent Developments), which discusses the impact internet sites have had in rapidly increasing the number of women naturalists for whom biographical and professional information is available.

Findings: qualitative data

For the qualitative synthesis of findings, ten illustrative women naturalists were chosen from the publications identified for review and shown in Table 2. These individuals were selected to: (i) maximize diversity regarding country of origin and background; (ii) ensure diverse approaches to the study of natural history; (iii) represent each of the five time periods of study, and (iv) highlight the period when the emergence of conservation awareness occurred. In refining the group to these ten candidates allowed increased opportunities to encounter and develop a fuller comprehension of naturalists representing diverse approaches in the investigation of natural history.

A common understanding for natural history studies began with Linnaeus and Georges Buffon. Their combined work set a course for what became modern natural history, with a common goal “to scientifically name, classify and order plants, animals, and minerals” (Farber 2000). It is from this historical vantage point that ten women were selected from the works reviewed. Tragically, five of the women met with an untimely death due to horrible accidents or illness, namely Mary Anning, Rachel Carson, Dian Fossey, Wangari Maathai, and Margaret Mee. Table 3 presents these ten women by era and in chronological order, with notes on their individual approaches to the scientific study of natural history.

During the heyday of natural history (1820–1870), women began to engage in greater numbers, choosing a variety of approaches in their studies and explorations. As per point (ii) above, the ten naturalists selected were chosen explicitly to showcase this diversity. Once these individuals were identified, it was seen that they could be placed in three categories, as defined by their way of investigating nature, each of which went far beyond the conventional image of women collecting butterflies or naturalize in their garden as a genteel pastime.

The first approach was exercised by women known primarily for their commanding artistic abilities; these include Maria Sibylla Merian, Elizabeth Gould, and Margaret Mee. The second group consists of those who excelled in the field, lab, and literary publication of findings. This group includes Eva Mameli Calvino, Rachel Carson, Dian Fossey, Jane Goodall, and Wangari Maathai. A third group is represented by some exceptionally gifted collectors, with Mary Anning being the earliest. She was followed by Eva Mameli Calvino, who assembled collections as part of her

scholarship, and Margaret Fountaine (1980), who collected over 20,000 butterflies from all over the world, publishing over 20 papers and leaving detailed diaries of her extensive travel.

Identifying and grouping these naturalists in such a manner became a keyway to determine when or if their story should be used in a classroom situation. For example, on the intersection between art and nature, Maria Sibylla Merian is an excellent choice, but there are other women as well, with different stories. This idea will be revisited in the section on education.

As shown in Table 3, some of these women naturalists undertook excursions and began collecting during the beginnings of field studies in earliest decades of genuine excitement in the field of natural history. Those so noted here include the global travels of Margaret Fountaine and Margaret Mee, with Africa-specific travel by Jane Goodall and Dian Fossey. While their increasing presence did not lessen the dangers they faced, gradually an atmosphere of acceptance and professional acknowledgment did occur. It did begin to foster an atmosphere of acceptance and participation. There were enterprising women who were recognized for their knowledge and skills as equal to men, especially seen with those who sought Mary Anning's judgment on the fossil record.

Others, such as Margaret Mee, were part of the scientific expansion of the British Empire, while the broader travels of women naturalists later became spread throughout different eras and continents. As for Rachel Carson, while her travels were more limited, the impact of her work on raising environmental awareness is undeniable, as is the Nobel Peace Prize awarded to Wangari Maathai. The fact that these women they did not arrive or function as a single, coordinated force of scientific explorers has made them easier to overlook. It is now time for them to be recognized and serve as models for student affinities, and their stories readily available in the student's literature.

Among the selected women there are several for whom conservation of natural resources became an issue of paramount importance, an outgrowth from their pioneering work as naturalists. In her own way, each became a spokesperson for "conservation awareness" long before the birth of national efforts (See Cohen and Altman 2021, on timing of conservation awareness). These four naturalists operated within the last two periods of time covered in Table 3, periods IV and V, and include Margaret Mee, Dian Fossey, Wangari Maathai, and Jane Goodall. These women pioneered the transition from naturalist research and art to a focus on conservation and advocacy for the prevention of human-related extinctions.

Part IV. Science without acknowledgment

Gender imbalances and obstacles to equality

Thus far, this paper has discussed how the politics of gender have historically affected women naturalists' ability to advance in their scientific capacity or to achieve full standing for these innovations and contributions. Given the constraints of this study, it is possible to highlight only a few significant items for each person

studied. Findings in Table 4 detail the specific impact of gender on the women studied. The table summarizes differences in educational opportunities and other barriers to success, ending with the intentional limitations imposed on women attaining academic records. In total, ten specific qualities were identified and expanded upon.

Given the current emphasis on, and agreement with, gender equity in the practices of biodiversity conservation (Lau 2020), lessons garnered from the experiences of these ten naturalists take on new meaning. Using their experiences in educational settings is not just one more researchable topic for women science students, but a way of achieving greater gender equity in conservation.

Despite the imposed limitations presented above, when women pursued field studies (Quality 8 in Table 4), they were as successful as men, or more so (See for example Fossey and Goodal, Table 4). However, women's work that focused on conservation, biodiversity, or protection of the environment were not well tolerated when they conflicted with the financial livelihoods of the local elite. Examples reinforcing this finding include the loss of Dian Fossey, the threats against Wangari Maathai, and the assaults on Rachel Carson's credibility. To date, Dian Fossey's killers remain unknown, but her death was most likely the result of ongoing disputes with poachers. Fossey said early on that, "Conservation of any endangered species must begin with stringent efforts to protect its natural habitat by the enforcement of rigid legislation against human encroachment into parks and other game sanctuaries" (Fossey 1983).

Wangari Maathai's experience deserves mention as well; her life was threatened repeatedly during the rule of former Kenyan President Daniel Arap Moi, and she struggled to obtain her education (Quality 1–3 in Table 4). She was also repeatedly arrested and, in one case, beaten unconscious. She explains in her own words, "It was easy to vilify me and project me as a woman, who was not following the tradition of a 'good African woman'" (Gilson 2005).

However, it was Rachel Carson who felt the full onslaught of a male-dominated industry that perceived her work as potentially damaging to their products, research, and integrity (Quality 10, Table 4). Unlike Fossey and Maathai, there was no village or family to support Carson. She was the sole author of the *Silent Spring* (Carson 1962) and initially its only defender, although support from others came later. While the book brought with it great fame, it also placed this heavy burden on Carson. It was only later when Steward Udall was able to put Carson's contribution into perspective by saying, "a great woman who awakened the nation by her forceful account of the dangers around us," (quoted in Lear 1997).

Maria Sibylla Merian, after all her detailed, arduous work, was forced to live almost vicariously, seeing her great talent displayed as the work and possession of others. Although her work outshone her husband's, it was kept a secret except from those in the family's inner circle. Merian excelled at entomology and metamorphosis, her gleanings from seeing species first-hand were almost unparalleled, but she was never able to fully join scientific society (Quality 2, Table 4).

Another constraint women frequently encountered was the inability to pursue active research. This may have been the most challenging issue to resolve, as many naturalists' work was difficult to find, often because such legacies were not left in print (Quality 3, Table 4). The problem for these women was not a lack of talent or

Table 4 Key professional needs and opportunities for naturalists, their availability to women relative to men, and relevant examples from literature

Professional needs, opportunities and qualities evaluated		Similarities or differences by gender	
Quality	Professional quality	Male	women (example provided)
1	Becoming a naturalist: formal education versus informal upbringing	Some courses offered in university; however, degree not offered; could be critical in assuming later post as vicar/naturalist	Education mostly through mothers educating their daughters; bonds established with emphasis on outdoor studies/hobbies; nature-writing (RCarson, JGoodall)
2	Scholarly societies	Able to participate and become full member	Unable to join or become member, but able to attend certain meetings (MAanning, EGould)
3	Pursuit of research, publishable results	Established professional identity and then worked to publish scientific reports	Not encouraged to do purposeful research or work leading toward publication (Conniff 2011; Allen 1976)
4	Presumed modesty around specimens dealing with reproduction and sex	Did not have to worry about modesty, language or study of sexual elements/organs of reproduction	Women expected to attain a false modesty to these matters; hence distancing themselves from their study/familiarity (Conniff 2011; Barber 1980)
5	Authorship	Able to publish serious scientific reports and books	Women's natural history publishing for young children; artists found difficulty in gaining support (MMerian)
6	Financial support	Able to obtain institutional, religious, and societal support and funding	Support obtained from offered positions, such as positions of "sorter classifier" (Tonn 2018)
7	Potential for scientific contribution	Equivalent between genders as shown by numerous examples, especially artistic	
8	Observational and field abilities	Equivalent	Widely demonstrated among all aspects of natural history (DFossey, JGoodall)
9	Routinely expected credit for work and/or collections done	Routinely issued credit for own work, and often assumed credit for contributions by women	Credit for contributions could not be expected; in fact, it was rare. (MAanning, EGould)
10	Academic chauvinism	Men assumed credit for scientific work, women generally perceived as unable	Women often unable to pursue their passion for nature studies recognized in academic circles

interest, but rather that opportunities for professional work were tightly controlled and not favored by inclinations of a Victorian upbringing. This situation did admit gradual improvement, however. There was no doubt that Margaret Mee, both artist and author, was honored in her time. And eventually, in Italy's Eva Mameli Calvino (Corradini 2020), we find a women scientist who began work in the cryptogamic laboratory, rising ultimately to become the Director of the Botanic Garden at the University of Cagliari and who, before retirement, had published over 200 professional papers.

The ability to locate publications and compilations of authors within scattered databases has seen a meteoric increase in the twentieth century. The work of Dian Fossey or Jane Goodall, for example, is now readily accessible. These two women, far from being forced into the background, have redefined the way humans see their relationships to the great apes and chimpanzees, a seismic shift affecting our position among the primates.

As was true for Margaret Mee, when women naturalists of the modern era (Table 3) began to gain renown as artists, it was often with a concomitant focus on conservation. Mee was one of those who sounded an early warning regarding the devastation occurring in the Amazon basin due to mining and deforestation (Mee 1988). Mee, like Jane Goodall, was able to gain support of environmentalists in a burgeoning movement, at a time when society's eyes were being opened to the approaching disaster in the tropics.

Ultimately, women overcame the Victorian threat to their "presumed modesty" posed by animals "in the flesh" (Barber 1980; Allen 1976) and went on to become adroit field observers. From the earliest times, women like Maria Sibylla Merian began to demonstrate their capacity to leave, study, collect, and return as ably as any man (Qualities 7 and 8, Table 4). But it was not until the generation of Fossey and Goodall that this was finally more fully recognized. Dr. Louis Leaky hired Jane Goodall, Biruté Galdikas, and Dian Fossey, referred to as 'the Trimates.' Together, they unlocked key insights about the connections between us and our great ape relatives. Leaky had decided to be on the lookout for "a fresh pair of eyes and a fiery spirit," and this non-gender-specific requirement ultimately led him to settle on these three talented women (Surujnarain 2019).

Accomplishments without acknowledgment

Previously, unwritten perceptions (as well as some actual, codified regulations) determined how, when, where, and to what degree women participated in natural history studies. As this work became popular in "refined society," it was deemed perfectly acceptable and even expected that women would enjoy this pastime by collecting shells across England's numerous beaches. If women wanted to do more than just collect, then basic classification was also acceptable.

To involve women in the more advanced scientific areas, including publication, was a different matter. Allen (1976), writing of women in the Victorian period in England, reflected that they were "left out, ignored, and only bought in on festive

occasions because they could scarcely be seriously interested, or else they were deliberately kept out, because science was man's business."

A women collector who wished to undertake and participate in the scientific side of natural history, join a scientific society dealing with shore life, or travel for research on far-flung beaches in remote locations would inevitably encounter obstacles. According to the wisdom of the day, these aspirations would place women in peril, and more importantly, would remove them from their positions of natural responsibility. As stated by Conniff (2011), during "the great age of discovery, women had been obliged to stay at home, doing little jobs about the house and not much else." This observation was supported by Barber's (1980) analysis, that "in natural history as in other fields, there was the usual obstacle that women were not expected to achieve anything."

However, despite the limitations on what was expected from women, many continued to pursue scholarship without reservation. The numerous awards earned by women naturalists are a testament to their accomplishments, raising the bar for scientific output by both the men and women who followed. Women working in the natural history museums of the day were particularly industrious and productive in one of the few scientific roles that were left open to them. Here, it was expected that such women "provided the labor foundational to natural history; the routine, messy, and tedious sorting, labeling and organization of specimens," (Tonn 2018).

As an example of a woman who worked through these types of challenges, consider Elizabeth Gould (nee Coxen). Her life illustrates the common complications for Victorian women of the day that were immensely talented but, for the most part, destined to remain unknown. In her case, it was because many perceived her as merely an assistant in her husband's business, rather than recognizing her hand in so many of his paintings (Quality 9, Table 4). Elizabeth was a very talented artist in her own right, but her professional approach went mostly without deserved acclaim. The lack of recognition was a direct result of her marriage to John Gould, who was well-known as an ornithologist, illustrator, and taxonomist. Early in his career, Gould benefitted greatly from an appointment as a naturalist to the Zoological Society, where he worked extensively on bird collections without having to travel abroad. Upon marrying Elizabeth, he gained an artist who could finalize his original drawings for plates needed for the process called "lithography" (Jenkins 1978).

Unfortunately, Elizabeth's beloved husband never gave her credit for her work. While he acquired most of his expertise through his professional exposure, Elizabeth was likely taught drawing and watercolor as part of what was expected of a woman in Victorian Britain. There were others who knew of her real talents, however. Most significant was Edward Lear, an artist in his own right, who also worked for and with Gould. He could see where the greater talent resided, commenting about John Gould that "he owed everything to his excellent wife and to myself, without whose help in drawing he had done nothing" (Barber 1980). In further high praise of Elizabeth, Barber would insist that "Mrs. Gould deserves to be ranked only just below Audubon as an ornithological illustrator."

Part V. Analyzing outputs for a science curriculum

Methodology used to analyze outputs from this study for life science education

Overview

Science teachers today are not concerned with pedagogy alone. On an equal or perhaps greater degree, teachers must ensure instruction meets the needs of a diversifying student population, presents a given lesson simultaneously across a county or district, and assures lessons are approachable to students in an inclusion classroom. Thus, adding new material to enrich classes presents a challenge, given the just mentioned criteria by which a teacher's performance will also be measured. In fact, school systems can upgrade technology in the classroom (such as adding Chromebooks) more quickly than they make curricular adjustments (Vigeant 2016).

In today's system, an educator who wishes to introduce a given women naturalist must make some difficult decisions. They first must decide whether sufficient time and resources are available to address the class's instructional needs, enhanced by inclusion of or more of the women profiled here. Then, even if these concerns are sufficiently addressed, they must still seek and obtain approval to deviate from the county curriculum.

For educators willing to go to these lengths, it would be useful to have an anthology or other research-ready material available with a focus on women naturalists. Individual instructors or the department could choose from this material to provide lessons. As class composition continues to change and science teachers wish to serve under-represented students, equitable modifications can be made regarding which naturalists are presented. A broad and well-curated selection of material, including copies prepared for students in need such that their reading level is accommodated.

Selecting the right naturalist(s)

Modifying the curriculum, while time consuming, can ensure students become acquainted with "the observational practice of the naturalist" when studying the natural world. As such, it would provide experience for students becoming citizen scientists or merely those who enjoy knowing what the area one chooses to live in. However, it is not possible to develop background documents on each of the scientists whose name came forward from the scoping study.

Therefore, in preparing for use in class, women scientists were identified whose work could most directly correlate with the four core ideas for life sciences and to a lesser extent, earth and space sciences by the Next Generation Science Standards (NGSS) (NRC 2012). This was accomplished by producing a matrix categorizing the primary naturalist pursuit of each scientist beach of the four core ideas. This resulted in specific combinations, for example, Rachel Carson was placed in the author/scholar category, supporting two specific components, ESS3C and LS2A (See Table 5).

Table 5 women naturalists and their suggested place in relation to Core Ideas of the NGSS for Life Science (LS) and for Earth and Space Science (ESS)

Historic era	Naturalist category	Naturalist name	NGSS core idea	Specific component to be addressed in lesson
Enlightenment	Explorer/naturalist; artistic renderings	Maria Sibylla Merian	LS1: Molecules to organisms	LS1.A: Structure and function LS1.B: Growth and development of organisms
		Elizabeth Gould	LS4: Biological Evolution: unity and diversity	LS4.C: Adaptation
	Field naturalist collector	Margaret Fontaine	LS4 Biological Evolution: unity and diversity	LS4.C: Adaptation
		Mary Anning	LS4: Biological evolution	LS4.A: Evidence of common ancestry and diversity
	Author/scholar	Rachel Carson	ESS3: Earth and human activity, and LS2 Ecosystems: interactions, energy, and dynamics	ESS3C: Human impacts on earth systems LS2A: Interdependent relations in ecosystems
		Eva Mameli Calvino	LS4 Biological Evolution: unity and diversity	LS4.C: Adaptation
	Field naturalist/conservationist	Jane Goodall	LS4: Biological evolution: unity and diversity	LS4.D: Biodiversity and humans LS4.A: Evidence of common ancestry and diversity
		Wangari Maathai	LS4: Biological evolution: unity and diversity	LS4.D: Biodiversity and humans
		Margaret Mee	LS4: Biological evolution: unity and diversity	LS4.D: Biodiversity and humans
		Dian Fossey	LS4: Biological evolution: unity and diversity	LS4.D: Biodiversity and humans

https://www.knowatom.com/blog/estimating-the-time-cost-of-new-science-standards?utm_term=estimating_the_time_and_cost_of_new_science

In addition, the final selection of naturalists included individuals whose work is complementary to the standards set by the county or school district. As for one county system, here is an example of their last section, Earth's History and Evolution. For this section, students will "study Earth's history, geological time, and explore how organisms have evolved. Students will examine the fossil record and construct explanations from mass extinctions. Students will explore the concepts of natural selection and adaptation and will learn that traits of an organism can change as a result of environmental conditions or a need for survival. Students will explore the similarities between organisms and use biotechnical processes, such as DNA fingerprinting, as means of identification." Thus, it is in the context of evolution as species change over time, and thus a naturalist would have to contribute to enhancing/extending the student's learning.

With these correlations done, teachers can more easily justify the inclusion of selected naturalists and their accomplishments to augment the topic being studied. For example, Core Idea 4 contains core component LS4.D, biodiversity, and humans. The five naturalists selected complemented each of the individual expectations of the lessons. These included field naturalists/conservationists Wangari Maathai and Jane Goodall, for human impact on the environment Rachel Carson and Margaret Mee were included and finally, Mary Anning on implications of the fossil record (Table 5).

These five women scientists provided a counterpoint to male scientists who often begin with Antony van Leeuwenhoek and Robert Hooke, Gregor Mendel, Charles Darwin, Alfred Russell Wallace, Jim Watson and Francis Crick. The students were able to couple the work of the women scientist into the last term project on whether the planet was experiencing what has been called an Anthropocene extinction event, and how can human response to such be measure (Cohen 2016).

New options for selecting naturalists

As mentioned previously, there is a renewed interest in the naturalist as an observer of nature, studying the natural world, leading to interests in what has been termed "contemporary naturalists" (Hannibal 2019). This trend is not an isolated event; recently, there have been calls for proper acknowledgment of the scientific contributions of modern-day naturalists (Crimmins and Crimmins 2012). In this case, naturalists were characterized as "individuals pursuing deeper awareness or knowledge of species and ecosystems as a passion rather than as an occupation."

As the trends toward a more diverse student body and more general interest continue, it will become even harder for science departments to justify maintaining a male-dominated lesson plan. The next section considers advances in women-naturalist-specific compilations available on the World Wide Web. In the absence of a comprehensive anthology, or when those available do not quite fit curricular needs, the sites below could assist.

Online resources

There are now resources available online, which students can access if time is allocated for such studies in the life science curriculum. One example, while not specifically natural history or conservation-oriented, is the recent e-book piloted by the Smithsonian Institute, *Stories of Women in STEM at the Smithsonian*, (<https://ssec.si.edu/women-in-stem>). For sites more specific to women naturalists, consult the list of resources in Table 5.

The list of sites in Table 6, as with all else in this article, is intended to be illustrative, not exhaustive. Topics range from the life of one naturalist (*Becoming Jane, The Evolution of Dr. Jane Goodall*), to sites relevant to general areas of natural history, such as the one on birds (*Seven Women Who Made the World Better for Birds and People*), to sites focused on a given region or art form. Together, these sites are part of a growing array that has come to form an anthology or collection of sorts, albeit one scattered across the internet rather than within a single volume. Unlike a physical book or library, the online collection of works will always have space for additional material. These existing resources may serve as motivation, encouraging other institutions to post their own sites showcasing women naturalists relevant to their particular work or mission.

As the trends toward a more diverse student body and more general interest continue, it will become even harder for science departments to justify maintaining a male-dominated lesson plan. The next section reviews advances in women-naturalist-specific compilations available on the World Wide Web. In the absence of a comprehensive anthology, or when those available do not quite fit curricular needs, the sites below could assist. These resources allow naturalists to act as “teachers” in the units on natural history selected while teaching biology (Krupa 2000).

women naturalists and eco-feminism

Placing women naturalists in a life science curriculum is a “positive” for students for reasons already discussed. However, teachers should prepare responses for questions regarding discriminatory actions that women faced in completing their individual accomplishments. As noted by Norwood (1993), the side-lining of women in the case of natural history comes from men asserting a real dominance over the science. However, this was just one of the challenges women faced during professional advancement.

Table 4 was constructed to summarize some of the major limiting factors impacting the work and professionalism of specific naturalists. When used in the classroom, for example, following the reading of individual bio-statements, students could choose to focus on qualities were most applicable to the naturalist they selected for study. Consider if their naturalist of choice had to contend with quality 2, for example, unable to join scholarly societies. Then the student could study how such restrictions affected that individual. Finally, when undertaking

Table 6 Illustrative examples of internet postings detailing women naturalists, including their work, historical settings, and chronology, along with other resources on natural history

Row/ URL number	Name	Year posted	URL
1	Becoming Jane, The Evolution of Dr. Jane Goodall	2020	https://www.nationalgeographic.org/tickets/events/being-jane/ National geographic
2	Great naturalist	2020	Santa Barbara museum of natural history. John and Peggy maximus gallery. https://www.sbnature.org/visit/exhibitions/66/great-naturalists
3	Library and archives, natural history museum	2020	www.nhm.ac.uk/library Search holding of the Natural History Museum, London, for a given naturalist
4	Her natural history: a celebration of women in natural history, BHL	2019	Biodiversity heritage library/Smithsonian institute https://about.biodiversitylibrary.org/get-involved/events/her-natural-history/ https://drive.google.com/file/d/14Nkq42_lzXBtUTQHSU8Ajs71DFMwXj/view https://www.flickr.com/photos/biodivlibrary/albums/72157662014417893
5	Natural history society of Northumbria: women naturalists of North East, UK	2018	http://www.northernbridge.ac.uk/media/sites/teaching/northernbridge/Place%20of%20opportunity%20-%20Natural%20History%20Society%20of%20Northumbria.pdf
6	Scenes and sketches: America's women naturalists	2017	https://medium.com/@sarahpedry
7	Seven women who made the world better for birds and people	2016	https://www.audubon.org/news/seven-women-who-made-world-better-birds-and-people
8	Women in nature: a gallery of influential and pioneering women naturalists	2015	https://www.sierracollege.edu/ejournals/jscrhmv6n1/index.html
9	Recognizing some contemporary (women) naturalists	2014	https://cornerofthecabinet.com/2014/10/29/recognizing-some-contemporary-women-naturalists/ Corner of the Cabinet
10	Botanical art and artists	2006	https://www.botanicalartartists.com/about-katherine-tyrrell.html

compare/contrast analysis, then students could consider how such qualities provided advantages to men over the women working in the same period.

Part VI. Study limitations, conclusion and acknowledgments

Study limitations

This study was not able to be conducted in a longitudinal manner, nor could it address specific classroom interventions incorporating women naturalists and their work, as the material for such is not readily available. In addition, due to the virtual nature of classes because of the COVID-19 virus, it was not possible to work one-on-one with students to personally evaluate their responsiveness to newly prepared material on specific accomplishments of some of the women featured here. Finally, it was not possible to provide a thorough gender-based analysis, as this is not the expertise of the author.

However, despite these limitations, the study provides numerous starting points for those willing to take its findings to the next level of detail, and/or construct case studies once suitable classroom materials are prepared. Here then is the foundational work; ready to be built upon for use with generations of students looking for role models with whom they can build affinities. It is such attachments that leads to lives wanting to reverse the loss of global and local biodiversity; to build conservation corridors, and to help in planet earth's restoration. We have no excuse for maintaining a climate of under-representation in science.

In conclusion

As is often the case, that which seems missing altogether was waiting to be seen. In 1699, a single mother ventured from Holland to Suriname at the age of 52 to study the life cycles of tropical insects. Maria Sibylla Merian crossed the Atlantic over a century before Darwin departed England; yet, for so long, the products of Merian's stay in Suriname remained virtually unknown while findings and artifacts from Darwin's voyage were celebrated. Despite Merian's lack of professional networks and colleagues of her equal, she learned to persevere while working on her paintings in comparative obscurity. However, not dismayed, she continued to produce until her death in 1717, and nowadays, her work is in great demand, is still being exhibited, and while it came out just a few years ago, a student-oriented, classroom-appropriate edition of her work was published (Pomeroy and Kathirithamby 2018).

Like Merian, other women naturalists had to proactively overcome the imposed limitations of their gender to follow their passion for the natural world. Together, they were responsible for a myriad of writings, collections, and artistry, and while some of this material was published individually, there is little available in comparison to the output of their male counterparts. Much has changed in the world since the seventeenth century; however, women naturalists remained rarely published in the 1940s and even as recently as the 1980s (Tables 2 and 3). Eventually,

as presented by Norwood (1993) and Gates (1998), with the rise of eco-feminism in 1975, the number of women naturalists increased. And, as they became more involved, there was a commensurate growth in the publication of their individual works and their presence in compilations.

With the advent of the internet (see Table 3, Era V), the creation of collections including women naturalists has undergone rapid growth. Table 5 gives recent examples of these, many of which now appear through national museum initiatives, regionally or locally sponsored, and compiled individually for publication (Jones and Seeley 2018). This grassroots growth is gradually filling in the details for eras II through V in Table 3 and may yet invite readers to stop and wonder at Maria Sibylla Merian, who made her perilous voyage hundreds of years before others in era I.

It is clear from this study that once women became involved in the production, editing, and composition of these collections, the number of acknowledged women naturalists increased. Why might this be? Was it an oversight on the part of previous editors, or were records of women naturalists not readily available? Was it a reluctance to devote the time and attention necessary to see that this imbalance was righted? No matter the reason for the delay, a wealth of work is now available, warranting further study and cataloging.

However, there is not yet a body of suitable ready-to-use lessons on women naturalists available for use in the classroom (One example does come from Pomeroy and Kathirithamby 2018). Encouraging the pursuit of science by sharing the story of how difficulties were overcome to obtain our current understanding, is a benefit that can facilitate success for both male and women students.

Despite the number of women included in this study, it still represents only a few of the individuals considered “women naturalists.” Moving forward, and to accompany the revised interest in natural history, there is now a place for anthologies on the discoveries of natural history from authors and under-represented peoples not previously included in these volumes. This is a challenge well worth taking up, both to honor individuals such as those mentioned here, to encourage the growth of emerging naturalists, and to recognize naturalists from countries not covered here.

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