

An interdisciplinary framework for evaluating 19th century landscape paintings for ecological research

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Abstract

As we contemplate the future of forest landscapes under changing climate conditions and land-use demands, there is increasing value in studying historic forest conditions and how these landscapes have changed following past disturbances. Historic landscape paintings are a potential source of data on preindustrial forests with highly detailed, full-color depictions of overstory and understory environments. They display key details about forest community composition, microhabitat features, and structural complexity from a time well before the advent of color photography. Despite these paintings' potential, their scientific applications have been impeded by questions of validity. *How truly accurate are the images portrayed in these paintings? How much of an image is an artist's manipulation of a scene to best illustrate an allegory or romanticized view of nature?* Following an established assessment model from historical ecology for evaluating resource validity, we demonstrate how scholarship on art history can be integrated with ecological understanding of forest landscapes to follow this model and address these questions of image veracity in 19th century American art. Further, to illustrate the potential use of these historic images in ecological studies, we present in a case study assessing microhabitat features of 10 different paintings. While this paper explores 19th century landscape art broadly, we focus our art historical review in particular on Asher Durand, a prolific and influential artist associated with the so-called "Hudson River School" in the mid-1800s. Durand left clear records about his perspectives on accurately depicting nature, and from a review of images and writings of Durand, we find support for the potential use of many of his paintings and sketches in historic forest ecology research. However, we also identify important caveats regarding potential ecological interpretations from these images. More broadly, because 19th century landscape paintings are not always directly transcriptive, and because regional art cultures differed in the 1800s, we cannot within this paper speak about landscape image veracity across all 19th century landscape art. However, in

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following established methods in historical ecology and integrating tools from art history research, we show that one can identify accurate historic landscape paintings for application in scientific studies.

KEYWORDS

artwork, Asher Durand, Catskill Mountains, climate change, ecocritical art history, forest, historical ecology, Hudson River School, microhabitat, Thomas Cole, White Mountains

INTRODUCTION

As we enter a period of unprecedented global change, understanding historical landscapes and how ecosystems have responded to past disturbances—both natural and anthropogenic—can provide useful and potentially unexpected insights for the future (Jackson & Hobbs, 2009; McClenachan et al., 2015; Swetnam et al., 1999). Historical ecology has developed as an important sub-field in ecology, drawing on empirical evidence from a range of methodological approaches including documentary records and land surveys, field notes, lake sediment cores, and dendrochronological reconstructions to study the dynamics of historic landscapes and their changes through time (Beller et al., 2017; Southgate, 2019; Swetnam et al., 1999; Szabo, 2015). In North America, much of our understanding of forests during the 17th and 18th centuries is derived from land surveys, which have been used to effectively reconstruct important aspects of early forest conditions during European expansion (Foster & Aber, 2004; Foster et al., 1998; Knight et al., 2020; Paciorek et al., 2021; Thompson et al., 2013). We have learned a great deal directly and by inference about the structure and composition of pre-industrial forests from these early surveys as well as from the paleo-ecological records and observations of the few remaining primary forests in this region (Cogbill, 2000; Cogbill et al., 2002; McIntosh, 1962). However, these assessments still miss many key features of past forests, particularly complex structural attributes of the forest as well as features in the understory and surrounding landscape (Schulte & Mladenoff, 2001). Historic paintings can provide another lens of “seeing” the historic forest, with the potential to yield rich information about forest systems and provide a more nuanced understanding of these environments as a whole (Kusserow & Braddock, 2018). Despite the potential of early landscape painting to provide information about historic forest and landscape conditions, their scientific applications have been impeded by questions of validity and reliability: *How truly accurate are the images portrayed in these paintings? How much of an image is an artist’s manipulation of a scene to best*

illustrate an allegory or romanticized view of nature? In this paper, we join the expertise of art history scholars with those of ecological scientists to address these questions.

Although historical paintings have been used to document land-use changes in geographical and geological fields (Devrani & Singh, 2014), they are rarely used in ecological research to explore long-term changes in the forest (Balkova et al., 2020; Gaynor & McLean, 2008; Jan Lacina, 2015). Indeed, paintings remain largely absent from reviews and methods papers about historical ecology (Egan & Howell, 2005; McClenachan et al., 2015; Santana-Cordero & Szabo, 2019; Southgate, 2019; Szabo, 2015; Vellend et al., 2013). The absence of early US landscape and forest paintings from ecological studies is likely due to a number of factors. For one, art history is recognized as a high-context subject, given general understanding among viewers that artists often respond to the work of prior artists and to allegorical impulses as much as to the environment as seen. For example, a work like Thomas Cole’s *Mountain Ford* (1846; Figure 1) is understood to have more to do with his well-established admiration for European artists (and particularly the Italian painter Salvator Rosa [1615–1673], who also commonly presented human figures on riverbanks framed by gnarly and twisted trees), than it has to do with the rendition of observed forest conditions in the Catskill region where Cole worked (Barringer et al., 2018; Bindman, 2015; Ellwood, 1988; Novak, 1980; Wallach, 1994). *Mountain Ford* engages viewers in the drama of the horse’s reluctance to cross the foreboding river, a theme linked with Cole’s career-long interest in the darker places of the psyche. Similarly, Albert Bierstadt’s (1830–1902) ebullient wall-sized western landscapes freely change the location of mountains, trees, and geological features to produce dramatic—and evidently counterfactual—renditions, as in *The Rocky Mountains: Lander’s Peak* (1863) (Figure 2). Painters like Bierstadt have been rightly understood as driven by their ideological content rather than by anything approaching scientific accuracy (Kusserow & Braddock, 2018; Miller, 1993, 2001). His huge canvases offered 19th century audiences an image



FIGURE 1 Thomas Cole (American, 1801–1848). *The Mountain Ford*, 1846. Oil on canvas, 71.8 × 101.8 cm. Metropolitan Museum of Art, bequest of Maria DeWitt Jessup, from the collection of her husband, Morris K. Jessup (15.30.63).

of manifest destiny, dramatically presenting how the sun would shine on a western landscape—even as, in the United States at the moment Bierstadt was working, colonial settlers driven by these ideologies were forcibly expanding westward at the cost of Indigenous lives, homelands, and livelihoods. Because works like *Mountain Ford* or *The Rocky Mountains: Lander's Peak* (1863) tend to hold prominent positions on museum walls, and because art history in the past several decades has been attentive to the relationships between ideology and cultural power, the counterfactual, romanticized, or otherwise allegorical tendencies of 19th century art have tended to appear definitional. However, the 19th century landscape tradition in the United States (and also in Europe at this time) also includes a large corpus of images painted on site (*en plein air*) or painted with direct reference to *plein air* pencil and paint sketches. Artists such as Jervis McEntee, Josephine Walters, Worthington Whittredge, Susie Barstow, and Asher Durand are also known for the so-called “forest interior” paintings that stressed forest details (Figure 3). These

more intimate works, often held in storage rather than placed on view, dispense with bombastic or explicitly narrative elements in favor of closer study of the forest and its understory, and it is these latter paintings that we highlight here as particularly promising for historical ecology research. Indeed, artists in the United States began to enter the forest to paint outdoors and to capture specific landscape scenes (working *en plein air*, sometimes in pencil but also with oil on canvas) as early as the 1820s (Harvey, 1998). A variety of factors drove this development. For one, the development of readily accessible steamship transportation from New York City up the Hudson River valley brought wilderness spaces into easy reach for summer sketching trips (Myers, 1987; Strandling, 2007). In addition, artists of this era were heavily influenced by 18th and 19th century approaches to natural history, which focused on direct observation, specimen collection, and morphology (Bedell, 2001; Harvey, 2020; Myers, 1998). Given the complexities of the art historical record, we suggest that understanding early 19th century visual material requires transdisciplinary work to



FIGURE 2 Albert Bierstadt (American, 1830–1902). *The Rocky Mountains, Lander's Peak*, 1863. Oil on canvas, 186.7 × 306.7 cm. Metropolitan Museum of Art, Rogers Fund (07.123).

disentangle what may be considered “nature” (understood, as Tim Morton has proposed, as a romanticized idea born at a particular place and time) from “ecology” (understood as a set of interdependencies that may be anthropogenically impacted but that are not fundamentally human projections) (Ellison, 2013; Faison, 2015; Morton, 2009).

In this initial assessment, we make two related propositions: (1) the criteria laid out by Forman and Russell (1983) for evaluating the validity of historical records for ecological research can be usefully applied to early landscape art practices as they emerged in the northeastern United States; (2) using sketches to inform interpretations of the full-scale compositions can bring to light the historical ecology suggested by those larger pictures. The second claim has been noted as a potential tool by Faison (2015), and has been applied in some environmental contexts (Haeberli, 2008; Nussbaumer & Zumbuhl, 2012; Zerefos et al., 2014; Zumbuhl et al., 2008), but is still largely absent from ecological research. It also requires a particular commitment to including methodologies from both humanities and the ecological sciences. To that end, we present here a broad interdisciplinary assessment of 19th century American landscape art and then provide an in-depth case study evaluation of Asher Durand's work.

REFRAMING THE QUESTION OF ACCURACY IN 19TH CENTURY LANDSCAPE ART

We focus here on the period of time in the United States from about 1830 to about 1880. Extensive forest clearing was conducted at this time in the northeast, primarily for agricultural purposes, yet predated clearing in more remote regions and the introduction of many exotic forest pests and pathogens (Cronon, 1983; Foster, 1992). These pathogens ultimately led to functional extirpations of some keystone tree species, including American chestnut (*Castanea dentata*), ash (*Fraxinus*) species, and American elm (*Ulmus americana*), as well as declines in large American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), and eastern white pine (*Pinus strobus*) (Lovett et al., 2016). This time period coincides with the settlement and treaty period in what is today the United States. It was during this period, landscape painting exploded in popularity in North America and became a dominant genre of 19th century American Art (Ferber, 2009; Novak, 1969; Schuyler, 2012). Prior to this era, the dominant modes of fine art painting in the colonies and the early United States were portraiture and a class of narrative-centered works collectively known as



FIGURE 3 Example of a Forest Interior painting by nineteenth century landscape artist, Asher Brown Durand (American, 1796–1886). *Group of Trees*, c. 1855–7. Oil on canvas, 61 × 45.7 cm. New-York Historical Society, purchase, the Louis Durr Fund (1887.8).

“history painting” (but which included mythological and Biblical subjects in addition to occasional renditions of actual historical events). In the late 1820s, however,

and especially in the period between 1830 and 1860, landscape painting first emerged and then became the dominant popular genre of painting in the United States,

a phenomenon that has been thoroughly studied by art historians and that often structures how museums present the history of art in the 19th century (Harvey, 1998, 2020; Novak, 1980; Wallach, 1968).

The northeastern United States, our focus in this paper, was one of the epicenters for an emerging confluence of art and natural history. Although artists from the United States traveled to other regions and realistic-appearing landscape painting developed as a transatlantic phenomenon (Thomas, 2000), travel to Europe took the better part of a year, and therefore, the primary access to artworks from other regions was either through prints—with a limited number of canonical works—or through painted copies. Therefore, while the methods we apply here to evaluate artists and artwork are broadly applicable, extrapolating specific findings to all 19th century landscape art around the world are not appropriate. Study of the art of the 19th century requires significant knowledge about the kinds of travel and access enjoyed by artists of a given region. We focus here on the 19th century American landscape art with artists that have been deeply studied by art historians and in a region that was experiencing profound ecological change.

The enthusiasm for landscape paintings in the United States had its origins and roots in New York State and the Hudson River Valley, where many of the pioneers in the genre lived and worked. Today, the 19th century landscape tradition in the United States is often described as the “Hudson River School,” although it should be noted that the term describes not an actual school or formal institution but rather an ethos shared by painters in the region. This inspired a set of working practices both in and beyond the Hudson River Valley itself. These painters—including Cole, Durand, Frederic Church (1826–1900), Sanford Gifford (1823–1880), Thomas Doughty (1793–1856), McEntee, and many others—commonly traveled on sketching trips in the Catskills and Adirondack Mountains, as well as throughout New England (especially in the White Mountains), in the American West, Europe, and South America. Concerns about anthropogenic impacts on the forest were often top of mind for Hudson River School painters. Much of their work depicted a forest experiencing profound and rapid change, from hemlock harvesting for the tanning industry in the Catskills to lumber extraction, agricultural clearing, and harvest for charcoal and acid wood factories (Kudish, 2000). Cole issued the sharpest written screeds against extractive industry, decrying how “the beauty of [untouched] landscapes are quickly passing away—the ravages of the axe are daily increasing—the most noble scenes are made desolate, and oftentimes with a wantonness and barbarism scarcely credible in a civilized nation” (Cole, 1836). But

paintings could serve as visual screeds as well, and in these kinds of works, the allegorical point dominates any usefulness of the works for the nuanced assessment of forest conditions. An example is afforded by a near-propagandist composition like Sanford Robinson Gifford’s *Hunter Mountain, Twilight* (1866), in which the word “twilight” describes not just a time of day but a moment in history (Harvey, 2012). The painting depicts a denuded landscape in a place where the tanning industry resulted in the widespread destruction of hemlock forests, a feature Gifford appears to use to comment on the ravages of the just-ended Civil War (just as the trees in the painting are chopped down, so too were so many soldiers on battlefields).

However, for every painting that shouts a larger-than-life point about the wholesale transformation of the forest, there are just as many (or more) visual representations that present direct field observations in more nuanced environments. Painting and sketching on site formed a critical part of the identity and philosophy of mid-19th century artists in the Hudson River School (Georgi, 2018; Harvey, 1998; Strazdes, 2009). Arts leaders like Durand, who wrote his famous *Letters on Landscape Painting* (1855) on this topic, were adamant that paintings should originate in the close observation of nature and of forests, landscapes, and waterways as they were seen and studied on site (Durand, 1855). As one of the founders of the major arts magazine *The Crayon* and President (1845–1861) of the National Academy of Design, the leading formal organization for artists in the United States, Durand commanded major platforms for spreading the importance of *plein air* practices founded in accurate observation.

Given his status and influence on early and mid-19th century American art as well as the wealth of images that he personally painted and sketched, Asher Durand is an ideal focal artist to evaluate in the context of forest image accuracy and “truth” (see case study below). Durand began as an engraver, largely working on banknotes and commercial subjects, but was inspired to move beyond this field to work in and draw inspiration from nature by Thomas Cole, widely considered as one of the originators of the Hudson River School style. In 1837, Cole prescribed the equipment Durand would need (stool, umbrella, easel, colors, and brushes) and took him on his first major field expedition, into the Adirondacks, to paint what he saw in front of him. Despite a lack of precision in some of his early painted compositions (as noted above), Thomas Cole was a strong advocate for accuracy in field sketches, and he passed on this passion to Durand (and later to his only formal student, Frederic Church). Cole’s field notebooks offer extraordinary evidence of the accuracy he sought. For instance, the

sketch that Cole made of Crawford Notch in New Hampshire contained detailed handwritten information, recorded in cursive, about the species on various slopes and exposures (Figure 4A). Although the final product from this sketch, *A View of the Mountain Pass Called the Notch of the White Mountains (Crawford Notch)*

(Figure 4B) shifted the location of a building and slightly altered the foreground stumps, the forest composition illustrated here is a product of the detailed notes that were taken to ensure accuracy of this composition. Asher Durand's notebooks, many of which are in the physical possession of the New York State Library in Albany and



FIGURE 4 Sketch and completed final work for *A View of the Mountain Pass Called the Notch of the White Mountains*. (A) field sketch, Thomas Cole (American, 1801–1848). *Crawford Notch*, 1839. Graphite on paper, 28.4 × 43 cm. Princeton University Art Museum, gift of Frank Jewett Mather Jr (1940–78.4r) and (B) final composition of Cole, *A View of the Mountain Pass Called the Notch of the White Mountains (Crawford Notch)*, 1839. Oil on canvas, 102 × 155.8 cm. National Gallery of Art, Andrew W. Mellon Fund (1967.8.1).

have been microfilmed and digitized (<https://emuseum.nyhistory.org/people/4882/asher-b-durand/objects>), similarly include numerous pages with detailed studies of trees, streams, rocks, and landscapes, illustrating Durand's dedication to observing and capturing key images from nature. For Cole, Durand, and the artists who came in their wake, these observations then formed the basis of larger studio compositions. But beyond just emulating Cole, Durand also further developed Cole's methods, particularly in his use not just of the pencil but of oil paints in his *plein air* work. Indeed, with the technological innovation of the aluminum paint tube in the early 1800s, artists were able to bring pre-mixed oil paints into the field, a key precondition for the emergence of *plein air* painting both in the United States and elsewhere. After 1837, Durand executed many oil-on-canvas works in the field that are extraordinary works of art in their own right (Harvey, 1998) and as large as 18" × 24" (45 × 60 cm). Today, the residue of their origins in the field may be found in the surface itself, as the paint sometimes contains bits of insects or other detritus that settled on the surface as the work was drying (Harvey, 1998). The ethos of close observation that Cole espoused and that Durand popularized inspired a slightly younger generation of Hudson River School painters to truly awe-inspiring levels of particularity. A noteworthy example of this is Frederic Church's enormous painting *Heart of the Andes* (1859). The management agency that toured this work around the country supplied viewers with opera glasses to peer into the finest botanical details of the species spread out across the painted vista. Although the painting is an invented studio composition, conjoining many different observations rather than directly rendering a single or true-to-life scene, it was based on Church's travels in Ecuador in 1853 and 1857—trips inspired by the German naturalist Alexander von Humboldt's travels in the mountains, undertaken with the intent to derive first-hand observations of the relationship between vertical elevation and ecological composition (Harvey, 2020).

The major question related to the use of art for historical ecology in the 19th century thus involves not the most basic form of the question ("are 19th century works accurate renditions of a scene?") but a more nuanced one that requires a commitment to art history methodologies as well as ecological ones ("what is the relationship of the fields sketches to the larger studio compositions?"). While *plein air* paintings and sketches from the field are likely to be an accurate reflection of the scene or study in question (although they do carry potential bias in the scene depicted, as the particular location and angle of view may have been chosen for any number of reasons), the larger and more detailed landscape compositions need to be

assessed in relation to the rendered-from-life sources that inspired them (Harvey, 1998). In the remainder of this paper, we propose that the bombast of large-format works like *Heart of the Andes* and the evidently romanticized aspect of large landscape compositions should not prompt ecologists to discount the entire genre of landscape painting. Seated at their easels for hour upon end in the forest, day in and day out throughout seasons spent traveling into the landscapes they depicted, artists were close observers of forest conditions (Harvey, 1998), and their work therefore warrants consideration as a potential resource for historical ecology. Context is critical to understanding art and artists and their work, and in following our emphasis on the need to study art historical sources for ecology as individual and high-context (19th century landscape paintings, that is, are not "accurate" or "inaccurate" across the board of the genre), we turn to Asher Durand and his work from the mid-1800s as a case study for assessing the value of his sketches and compositions as data sources for research in historical ecology.

ASHER DURAND'S WORK, 1850–1870: A CASE STUDY FOR ART AND HISTORICAL ECOLOGY

Forman and Russell (1983) laid out four criteria (similar to those of Rymer, 1979) for evaluating the validity of historical records for ecological research (Table 1). Although these criteria were designed for written accounts, they can be applied equally well to 19th century art. Asher Durand is a particularly useful artist to study for the

TABLE 1 Assessment criteria laid out by Forman and Russell (1983) for evaluating the accuracy and potential application of documents, records, and other observations for historical ecology research.

Criteria	Assessment question
First- or Secondhand Observations	Did the author of a statement personally make the observation reported, or was it learned second hand from the actual observer, or is it third hand information, even written long after the event?
Author's Knowledge of the Subject	Did the author have the necessary ecological and taxonomic knowledge to make the statement?
Context of the Statement	What was the broader historical and ecological context in which the statement was made?
Purpose or Possible Bias of the Statement	Did the author of the statement have a special interest or bias which may have colored the statement?

reasons defined above. Across his writings, sketches, and studio works, Durand offers a large data set for future ecological analysis by researchers. In addition, he both learned and promoted the value of direct observation, which provides a valuable historic record. To inspire trust in data derived from forest images, as well as to suggest how this process might be best approached, we assess Durand's corpus against each of the questions defined by Forman and Russell.

First- or Secondhand Observation: Did the author of a statement personally make the observation reported, or was it learned secondhand from the actual observer, or is it thirdhand information, even written long after the event?

Research in art history has clearly demonstrated the interest of artists and the art-viewing public in *plein air* oil sketches, typically produced on long summer trips (Harvey, 1998). Asher Durand, in particular, wrote compellingly and in detail about the importance of an artist's observation of nature in his letters to a hypothetical art student that were published in a leading art journal of the time, *The Crayon*.

I would urge on any young student in landscape painting, the importance of painting direct from Nature as soon as shall have acquired the first rudiments of Art. If he is imbued with the true spirit to appreciate and enjoy the contemplation of her loveliness, he will approach her with veneration, and find in the conscientious study of her beauties all the great first principles of Art.

(Letter I)

A knowledge of integral parts is essential for the construction of a whole that the alphabet must be understood before learning to spell and the meaning of words before being able to read.

(Letter II)

Durand's summer travel itineraries reflect the depth of his commitments. Durand lived and worked in New York City from 1820 to 1869. Throughout this period, however, fieldwork outside of the metropolis formed the basis of his practice. Following his transformative trip with Cole to the Adirondacks in 1837, Durand spent September of 1838 sketching in the Catskills (particularly around the Shawangunk Mountains) and June and

July of 1839 traveling to the White Mountains of New Hampshire and the Green Mountains of Vermont. Between 1840 and 1842, he traveled in Europe. Upon his return, his sketching itinerary during the heyday of his career gave a sense of his activities (Snook, 2007; Figure 5). Almost all of his trips were taken with other Hudson River School artists invested in the same methodologies, including John Casilear (1811–1893), John Frederick Kensett (1816–1872), and Christopher Pearse Cranch (1813–1892). Most were at least several weeks long (including significant travel time on steamboats, trains, horse-drawn carriages, and on foot into remote locations), and in many years, he spent two to three months in the field.

Durand's studio compositions track the locations to which he traveled in summer and early fall and were generally produced on the basis of the field sketches during the following winter and spring. In some cases, he would become interested in observed phenomena, sometimes over multiple years, and track that theme through multiple works; between 1845 and 1847, for instance, Durand was captivated by the relationship between beech and oak trees, returning in multiple pictures to sketches as well as compositions depicting beeches growing in the shade and from the same area as oak species. Durand's very large pastoral composition *The Beeches* (1845) (Figure 6) was based on a field sketch from that year, but the following season, he made a *plein air* work based on similar relationship that inspired two more monumental compositions with beeches and oaks intertwined at the roots: *Landscape Composition, Forenoon* (1847) and *Landscape Composition, Afternoon, In the Woods* (1847). Durand's vigorous travel itinerary, artistic practice, and the rhythms of the relationships between sketches and compositions strongly suggest that the images that appear in Durand's paintings at this time are a product of direct observation.

Author's Knowledge of the Subject: Did the author have the necessary ecological and taxonomic knowledge to make the statement?

The concept of ecology in the epistemology of western science, founded on the interdependence of constituent parts within an environmental whole, did not yet exist in Durand's era. Indeed, as (Kusserow & Braddock, 2018) have shown, it was not until the 1860s that art history began to show sustained engagement what we might recognize as ecological sensibility, one concerned with the ramifications of effects across a system. That said, Hudson River School painters were highly influenced by the

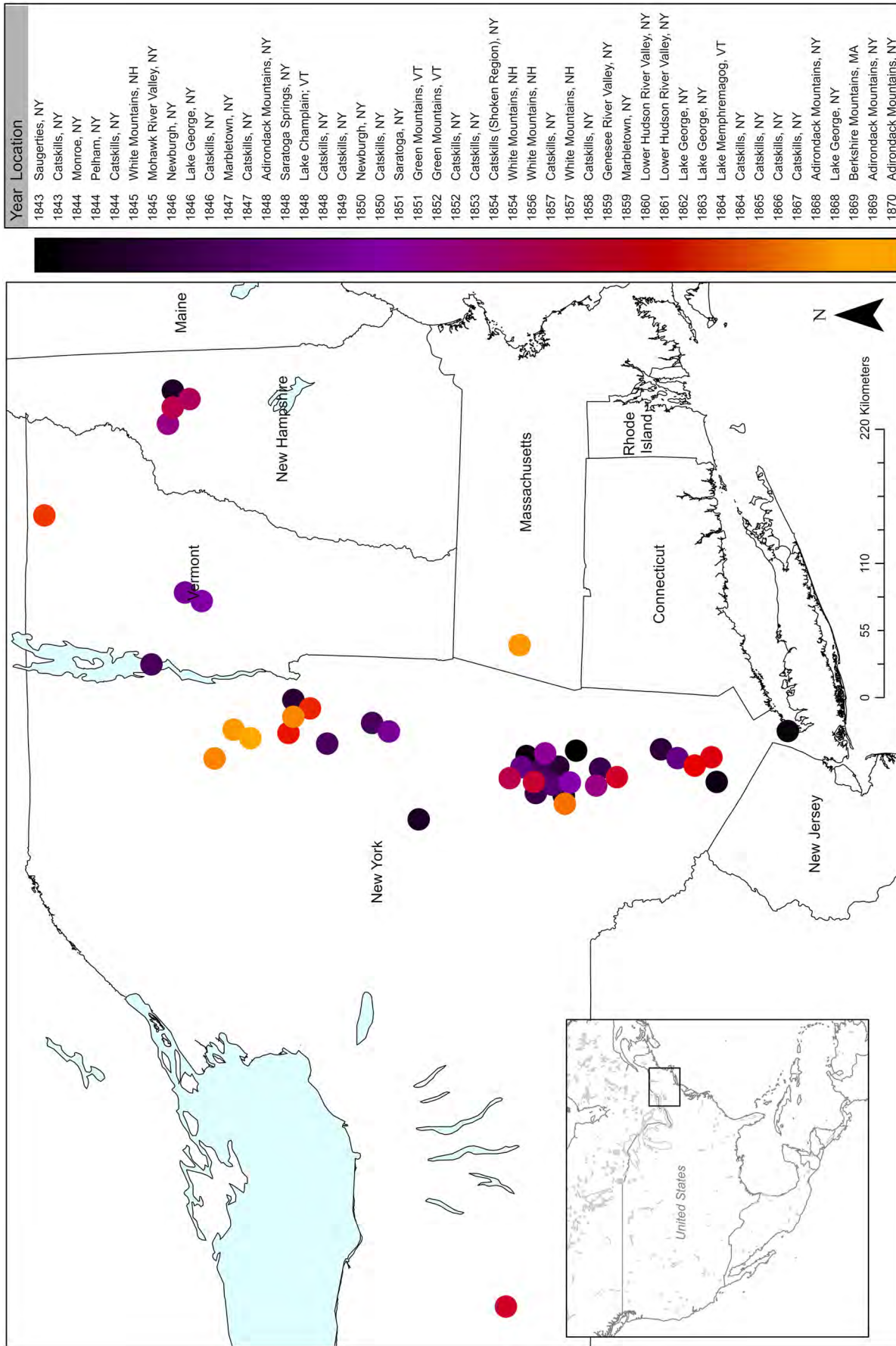


FIGURE 5 Map of approximate location of sketching trips for Asher Durand between 1843 and 1870. In some cases where specific towns or locations are not well-established (e.g., “Green Mountains,” “Berkshires” or “Adirondacks”), locations are placed with the region to illustrate the general location but do not indicate or suggest a specific sketching site. Color gradient reflects timeline with dark dots representing visits in earlier time periods and warmer colors representing visits in later time periods.



FIGURE 6 Asher Durand (American, 1796–1886). *The Beeches*, 1845. Oil on canvas, 153.4 × 122.2 cm. Metropolitan Museum of Art, bequest of Maria DeWitt Jessup, from the collection of her husband, Morris K. Jessup (15.30.59).

taxonomic efforts in botany, geology, zoology, and other areas that began in the 18th century (Harvey, 2020). Whereas the previously dominant modes of painting stressed either social identity (the majority of portraits were commissioned by well-off sitters who paid for painters to take the likenesses) or iconic scenes (as in history painting), landscape painting itself emerged in parallel to observational science as it was developing in the era. Natural history led the way, with writer-scientists like Comte du Buffon (1707–1788) formulating early concepts of ecological succession, geologists like Sir Charles Lyell (1797–1875) stressing lengthy gradual forces like erosion, and polymaths like Alexander von Humboldt (1769–1859) recording minute observations across various climate regions and paving the way for the not-yet-invented concept of ecology itself (Bedell, 2001; Harvey, 2020; Von Humbolt, 1850). The influence of these naturalists and scientists on the sudden popularity of landscape painting in the 19th century United States has been fully established in primary as well as secondary sources (Bedell, 2014; Harvey, 1998). In some cases, artists were invited on scientific expeditions in order to capture the organisms, imagery, and landscapes encountered (Glanz, 1982; Myers, 1998), a situation in 1832 exemplified by Prince Maximilian of Wied-Neuwied's hiring of artist Karl Bodmer on his scientific expedition to study the "natural face of North America" (Gallagher et al., 1996; Glanz, 1982; Kinsey, 1992) or, later, by Thomas Moran's embedment on John Wesley Powell's 1872 expedition (Kinsey, 1992). In other cases, artists maintained close correspondences with scientists, attended their lectures in public forums, or collected and read their written works; Cole, to take only one example, collected geological specimens, maintained a friendship with the scientist Benjamin Silliman (who urged painters in general to study science to attain "verisimilitude, depending on physical laws," in their work), and used his notebooks as much as field notes as an artistic portfolio (Bedell, 2014). In all cases, the shift from the society genre of portraiture to the outdoor genre of landscape emerged contemporaneously with—and driven by—the urges to catalog, classify, and represent the natural world.

In Durand's case, these urges expressed themselves primarily in his methods, especially after the mid-1840s. His *Letters on Landscape Painting* were written as if sent directly to a student who had applied to study with him. Durand refused, insisting that the student adopt the natural world as a teacher, emphasizing close study of natural forms, truthful renditions, and verisimilitude. As was typical of his era, Durand understood the aim of such truthfulness as typological: sketch, he urged the student, until "you shall have learned by heart the characteristic forms of *all* objects," a formula that reflects contemporary

passion for the encyclopedic cataloguing of characteristic specimens (Durand, 1855). In addition, Durand advised the letter's recipient to focus first on larger foreground elements (rocks and downed trees) and only afterwards move into foliage, grassy banks, and branches; Durand's specific concern was that a neophyte's efforts to represent these hard-to-paint details would compromise what Linda Ferber, a scholar who has worked in great depth on Durand, calls his effort to produce "botanical precision" (Ferber, 2007). Durand practiced what he preached, producing sketches of tree trunks and of hills, acclivities, and slopes with various levels of represented forest canopy rugosity (the three-dimensional roughness, leaf density, and surface complexity of a forest's canopy; Fahey et al., 2015), as driven by the species composition at that site. Given the degree to which landscape painting itself emerged hand-in-hand with observational science, and given that Durand embodied this development and fully embraced the emphasis on detail in nature, we feel it can be safely assumed that he possessed the necessary "taxonomic knowledge" as defined by Forman and Russell. Indeed, Durand painted tree structure in a way that clearly reflects close observation of the forest. The complexity of bark, wounds, vertical organization of leaves, epiphyte loads on branches and trunks, tree hollows, branch angles, and dead wood in the canopy as well as on the ground all accurately reflect conditions that can be found in eastern forests and that would have been impossible to create without extended close study and observation of these specific features.

Context of the Statement: What was the broader historical and ecological context in which the statement was made?

In addition to the scientific context and the fact that Durand's era witnessed widespread loss of forests and forest habitat, as discussed above, Durand's turn from an early career as a banknote and fine art engraver to a landscape painter reflected both personal and cultural forces that shaped his predilection for working from close observation. On the personal side, his experiences in cities during his one and only trip to Europe (1840–1841) contrasted with his state of mind when exploring the outdoors. In letters home, he described feeling visually overwhelmed by the conventional iconography of old-world painting that he experienced in museum after museum and found his mood lightened and improved when sketching scenery outdoors in Switzerland and Italy (Ferber, 2007). On the cultural side, the period of Durand's emergence as a *plein air* painter coincided with the early development of an "environmental

consciousness” in the arts, literature, and sciences in the United States. For some of the leading voices in this tradition—including Henry David Thoreau and Walt Whitman—the spiritual potency of the environment was not articulated in denominational terms. For others, including Durand and William Cullen Bryant (his close friend and one of the most popular poets of the age), Christian spirituality drove their desire to find signs of God’s omnipotence in sublime, individual experiences deep in the forest, as well as to chronicle human domination of the landscape (Harvey, 1998; Stillman, 1901; Strazdes, 2009). After 1850, a period that coincides closely with the appearance of such texts as Thoreau’s *Walden* (Thoreau, 1854) and Whitman’s *Leaves of Grass* (Whitman, 1855), Durand emphasized what have come to be called “forest interiors” over pastoral or cultivated landscapes.

Durand’s career thus reflects a movement toward less cultivated environments (in the European settler colonial sense), mirroring Thoreau’s maxim that “in wildness is the preservation of the world” and capturing the organization of a nascent environmental ethic around practices of close, accurate observation. As president of the National Academy of Design from 1845 to 1861 and a key voice in *The Crayon*, Durand articulated a preference for accurate rendition that mirrored the interests of some of the most influential voices of the era.

True art teaches the use of the embellishments which Nature herself furnishes, it never creates them.

(*The Crayon*, Letters on Landscape Painting; Letter I)

[Idealism’s] legitimate action is not seen as creating an imaginary word, as some would suppose... It is sufficient if we have arrived safely at the conclusion, that all the element with which the imagination deals, and on which idealism is based, exist visibly in nature, and are, therefore, not separate creations of art.

(*The Crayon*, Letters on Landscape Painting; Letter VII)

This view of Idealism does not propose any deviation from the truth, but on the contrary, demands the most rigid adherence to the law of its highest development.

(*The Crayon*, Letters on Landscape Painting; Letter VIII)

Foremost among the other champions of this perspective was the English art critic John Ruskin,

whose works inveighed against the over-modification of natural materials and natural forms. For Ruskin, whose works were tremendously influential on both sides of the Atlantic, the level of resistance of natural materials to over-shaping by the artist constituted the measure of their authenticity. Urging stoneworkers to find the hardest material they could (that is, the material least amenable to transformation beyond its state when found), Ruskin also rejected elaborate studio compositions in favor of more spontaneous and direct-from-nature works. In the United States, Ruskin’s thinking percolated into the art world and joined the emergent environmental ethic flowing through philosophically oriented literature and underlaying the *crie de couer* of works like Gifford’s *Hunter Mountain, Twilight*, George Inness’ *Lackawanna Valley* (which also shows a field of stumps), and Cole’s dystopian five-part series *The Course of Empire*, which depicts how great civilizations colonize and then destroy the natural landscape before collapsing under the weight of their grandiose aspirations. In this context, art critics and writers explicitly called for artists to capture and depict forests in landscape before they were cut:

[Landscape painters] have a high and sacred mission to perform... The axe of civilization is busy with our old forests, and artisan ingenuity is fast sweeping away the relics of our national infancy... It behooves our artists to rescue from its grasp the little that is left, before it is too late. This is their mission.

(*Literary World*, March 15, 1847)

Purpose or Possible Bias of the Statement: Did the author of the statement have a special interest or bias which may have colored the statement?

In evaluating whether 19th century landscape paintings can yield accurate data on early forest landscapes, the issue of bias is the greatest hurdle. A blanket statement on this criterion, unlike the other three, is not possible. Instead, each painting must be judged in the context of the conditions under which it was produced. The potential for bias or embellishment in these historical painting may be ranked from (1) very low (but not absent) in sketch books and many *plein air* works to (2) moderate in larger compositions of forest interior and/or landscapes, which are generally based on multiple sketches, and (3) high in certain commissioned or obviously allegorical works that were produced to emphasize identifiable messages, people, structures, or iconic and

romanticized sites. The remainder of this essay considers (1), the simpler case, and (2), the more high-context one that requires correlation of the sketches with the composition itself.

Sketches and *plein air* paintings

Plein air sketches have clear applications for an art-based form of historical ecology. Although sketchbooks were used by artists to depict larger landscapes (as in Cole's notebook image in Figure 4A), they were also commonly used for detailed studies of particular elements, a practice that reflects Durand's injunction in the *Letters on Landscape Painting* to focus on larger foreground features. Durand's field sketches were drawn on site, and while many show distant landscapes or the shapes of hills, many others represent individual studies of specific features (a decomposing tree, for instance) that would be incorporated into later studio paintings. While a limited study in isolation may not provide information about larger forest structure, they do provide detail about the subject at hand and, assessed in terms of the criterion involving bias or special interest, they clearly demonstrate Durand's interest in accurately capturing detailed aspects of the forest that were incorporated thoughtfully and accurately into a larger composition. It is important to be aware that not every *plein air* study was completed entirely in the field. Because art materials had to be transported on site, and because it took time for paint to dry, detail was occasionally added in the studio (Harvey, 1998). In addition, bias may be introduced as a matter of visual perspective, that is, where the artist chose to set up and sketch. The 19th century corpus of *plein air* works includes frequent images of ledges, lakes, streams, and landscape edges obviously chosen for their picturesque location. The selection of a particular scene to meet an aesthetic expectation or to ensure optimal light conditions could introduce a bias regarding the community (edge/disturbance prone), disturbance history, or the growth pattern of canopy trees; however, the scene itself is likely to be faithfully reproduced in a *plein air* sketch. And, while there could in some cases be a bias toward edges, Durand himself often chose forest interior locations. Many of his sketches and *plein air* paintings depict the interior depths of a forest, that is, scenes from within a forest stand and away from an edge, such as a cutting block or a cliff without large ledges or edges. Selecting these locations can themselves be a product of the artist's intent but if they are accurately portrayed, they nonetheless provide a unique picture of pre-industrial forests. Art historical research on Durand in particular suggests that his *plein air* sketches and paintings may generally be

considered accurate and that they lack gross bias or embellishment (Harvey, 1998).

Forest compositions

Due to their high level of detail and often very large size, landscape and forest composition paintings have great potential as an historical resource. But because they are not created on site, they are more subject to potential aesthetic bias and warrant greater scrutiny. We suggest, however, that although an image may not be a perfect reproduction of a specific site, it can still be a highly accurate representation of the forest in a given region, understood in general or typological terms. And as such a composition can provide information about forest communities and structural features (gaps, standing dead trees, microhabitats, and understory density) in the larger landscape. Durand walked extensively through the forest for the specific purpose, and with finely honed skills, of capturing observations. He completed sketches and paintings *en plein air* and used the sum of his work, in his grand painted compositions, to convey the character of the forest. His *Letters on Landscape Painting* both name this goal and provide a definition of accuracy itself, as typological, that accords with the notion that the forest compositions should be seen as visual overview of the system.

As a case study for the notion of the composition as a composite typology, consider Durand's *In the Woods* (1855) (Figure 7A). This image is obviously a composition—for one, it is much too large (154.3 × 121.9 cm) to have been easily transported into the field. Secondly, archival sources reveal that it was painted in Durand's studio in New York City during the winter of 1855, after he had spent the summer of 1854 walking and sketching throughout the eastern Catskills (Figure 5). That said, it is also clear that Durand incorporated components of what he saw, sketched, and painted during the summer trip into this winter work (Figure 7). Three *plein air* sources informed *In the Woods* (Ferber, 2007). The most obvious source is *Woodland Interior* (1854; Figure 7B). *Woodland Interior* was likely done wholly or partially *en plein air*. The size (slightly more than 24" × 16") comports with other field paintings made by Durand, and the effect of the painting—lacking obvious open space for the eye—suggests a limited level of modification that would correspond to norms for large studio compositions. The level of finish on this work is much higher than on other *plein air* sketches, suggesting that it had significant retouching and deepening in the studio and that details may have been modified. However, the essential origins of this work were most likely done in the forest, not in the studio.



FIGURE 7 Final composition painting, (A) Asher Durand (American, 1796–1886) *In the Woods* - 1855. Oil on canvas, 154.3 × 121.9 cm. Metropolitan Museum of Art, gift in memory of Jonathan Sturges by his children (95.13.1), with two examples of *plein air* paintings or sketches by Durand from the previous summer that were used in the composition: (B) *Woodland Interior*, c. 1854. Oil on canvas mounted on fiberboard, 60.2 × 42.7 cm. Smith College Museum of Art, purchased (1952.107); and (C) *A Brook in the Woods*, c. 1854. Graphite, gouache, and white lead on paper, 35.2 × 25.4 cm. New-York Historical Society, gift of Ms. Nora Durand Woodman (1918.129). The central stream-side beech tree in *In the Woods* is also based on a tree in one of Durand's *plein air* sketches of a forest scene (*Landscape, Wood Scene (Sketch in the Woods)*, image available at: <https://collections.brandywine.org/objects/5307>).

Woodland Interior is missing large beech trees, which were common in Catskill forests at this time (Cogbill, 2000). Whether or not that fact reflects an intentional omission, or the actual composition of the particular forest stand Durand was painting, it is significant that Durand used a beech tree from another *plein air* sketch (*Landscape, Wood Scene (Sketch in the Woods)*, image available at <https://collections.brandywine.org/objects/5307>) to introduce that species into *In the Woods*. Given the relatively low level of finish and the travel size of the

canvas (again 24" × 16"), *Landscape, Wood Scene (Sketch in the Woods)* was certainly a work done in the field. The beech from this sketch is visible in the middle left foreground of *In the Woods*. Durand fit this tree accurately within the forest structure in the full-scale painting, and he also flipped and inverted the beech from the sketch. In flipping the beech, he locates it exactly at the place, on a sharp turn in the riverbank, with the undercut portion upstream and visible to the viewer, where the depicted watercourse would have caused root-exposing

erosion on the streambank. The conflation of two sketches into the composition thus combines two field studies to capture the *typical* rather than the *photographic* condition of the forest as Durand experienced it in 1854. Durand clearly understood how trees interacted with the local environment, as well as the signature presence of the beech species in the Catskill forest (a point that, as discussed above, had also captured his interest in the 1846–1847 studies of oaks and beeches).

A third sketch also shapes *In the Woods*. The large tree in front of the beech, on the left side of the work, is derived from another 1854 field sketch, *A Brook in the Woods*. Durand transposes the details of this graphite sketch carefully, including the tree's placement upon the streambank and the branch structure that articulates into the open space created by the stream (Figure 7C). The full-size composition now includes a wider range of forest structure and forest composition than is necessarily present in the specific scene captured from *Woodland Interior*, but it aggregates the character and composition of the forests that Durand was visiting in 1854.

Beyond its representation of a rich, biodiverse forest, *In the Woods* also includes detailed depictions of the forest floor, downed wood, epiphytic mosses, and fungi, which are clearly and accurately depicted in a manner consistent with ecological expectations. For example, upon close examination, the fungi on the oak bole in the lower left of this image can be identified as *Fomes fomentarius*, a fungus associated with dead hardwood trees and placed accurately in the painting on a dead tree trunk (Figure 8A). Similarly, we see a conifer log in the foreground with the distinctive cubical decay of brown rot fungus that frequently occurs on dead conifers (Figure 8B). We see moss accumulating on the upslope side of a leaning tree or at nodes along the trunk, where water may be held slightly longer and therefore promote the development of bryophyte mats (Figure 8C). In the forest canopy, we see structural components that align with fundamental ecological processes in which tree canopies grow into the gap over the stream. For instance, we see an apical rearticulation (an abrupt, 90° vertical turn) of an upper branch over the stream. Originating from breakage in a limb, this growth form is more common in areas like stream edges where access to light can stimulate asymmetric crown growth (Figure 8D). None of these details alone assures the veracity of this image, but collectively they support the idea that this painting, even as a composition, is an accurate depiction of a complex late-succession (“old growth”) forest ecosystem, which Durand understood intimately.

Returning to the fundamental fourth criterion of the schema proposed by Forman and Russell, the purpose or

possible bias of the statement, it is clear that Durand's *plein air* sketches accurately represent the image that lay before him. In the composition *In the Woods*, he presents not a perfect reproduction of a single location in the forest but a credible representation of a complex Catskill forest from the mid-1800s. Within this painting, we have a high degree of confidence in the detailed accuracy of individual trees, mosses, fungi, and logs, and his methodological conflation of multiple sites ties closely to his comments about the comprehensive nature of accuracy (that is, Durand's injunction to artists to capture the totality the objects visible in a landscape environment) in *Letters on Landscape Painting*. Given his attention to detail and his self-professed commitment to accuracy, we are confident that this conclusion can be extended to many of Durand's paintings during this period. In evaluating accuracy of the larger forest composition *In the Woods*, our conclusions about accuracy rely in part on the artist's ability as a naturalist and observer to include relevant information (i.e., data) in these images. An art historical assessment of Durand suggests that we should indeed trust this ability (Harvey, 1998), and so we argue that in addition to the use of *plein air* sketches, these finished compositions also have particular value for studies in historical ecology.

It should be noted that not all images are available or relevant for this work. A substantial number of finished compositions from this period are clearly not accurate. For example, Durand's 1850 painting *Landscape: Scene from Thanatopsis* is primarily a narrative, rather than an environmental, work. Inspired by William Cullen Bryant's poem “Thanatopsis,” this composition presents a clearly fictitious place that includes a cathedral at the center, in the shade of which we can glimpse a funeral, likely a representation of Durand's grief over Thomas Cole's early death two years prior. The painting contains a number of references to Cole's work that make its elegiac aspect clear; just as Bryant's poem “Thanatopsis”—a Greek neologism meaning “view of death”—offers a model for soothing the terrors of death, Durand's painting poetically integrates Cole's death into a soothing forest scene.

CASE STUDY OF MICROHABITAT FEATURES IN HUDSON SCHOOL PAINTINGS

This case study represents an example of how these paintings can be used by ecologists to define features of old growth forests in the northeastern United States. In an ecological context, details in a painting or sketch are not simply visual embellishments but also provide



FIGURE 8 Detailed features of the forest from *In the Woods* (Figure 7A). Specific identifiable ecological features in Durand's forest interior in painting, *In the Woods*. (A) Conk of fungi, *Fomes fomentarius*. (B) Distinct cubic form of a brown rot fungus on a stump. (C) Moss on the "uphill" side of an angled tree. (D) Apical rearticulation of a branch in the canopy.

information on key microhabitat features in a forest. Larrieu et al. (2018) define microhabitat features as “a distinct, well delineated structure occurring on living or standing dead trees that constitutes a particular and essential substrate or life site for species or species communities during at least a part of their life cycle to develop, feed, shelter, or breed.” Whether the structure is a woodpecker cavity or a complex of climbing vines, these features are the very details with which artists such as Church, or Durand filled their canvases. Not only do they provide optical foci, but they also illustrate the specific microclimatic and substrate conditions that specialized organisms need in order to shelter, forage, or breed. Because microhabitat features provide an essential habitat component to a variety of organisms, they can also demonstrate potential for species presence in a forest (Asbeck et al., 2021).

To assess the presence and variety of microhabitat features in landscape paintings of the Hudson River School, we compiled a list of microhabitat features, adapted from the features and definitions proposed by Michel and Winter (2009) and Larrieu et al. (2018) (Table 2). The list of 25 individual features was ordered into 7 groups as structured in Larrieu et al. (2018): cavities, fungal fruiting bodies, tree injuries, twig tangles, epiphytic structures, dead wood, exudates, and bark separation. While exudates, which include sap run, resinosis, and resin drops, were recognized by both Michel and Winter (2009) and Larrieu et al. (2018) as a distinct group, they were not clearly identifiable in landscape paintings. Because we could not distinguish, with a reasonable amount of confidence, a clear depiction of exudates from a stipple of dark paint or the texture of an artist's canvas, we excluded that category from our overall assessment.

Using the list generated from Michel and Winter (2009) and Larrieu et al. (2018), we then analyzed a set of 10 landscape paintings (listed in Appendix S1) completed between ca. 1855 and 1870. This suite of paintings is not only dominated by Durand but also includes a few other artists from this period who produced highly accurate paintings of forest interiors. This case study analysis is intended to illustrate the potential of these paintings to yield specific quantifiable details about preindustrial forests and is not intended to be a full-scale assessment of forest interior complexity. The paintings were analyzed for the overall presence/absence of different microhabitats and for the abundance of microhabitat features (Tables 2 and 3). Presence/absence was assessed within the entire composition, but the abundance of features was assessed only in the three most visible foreground trees in each painting. Regarding epiphytic structures, our tendency was to ignore small patches of moss and

aggregate moss into total clumps to ensure high confidence in its presence. For all features, we did not mark their presence unless we were reasonably confident in its depiction; however, in all cases, there cannot be absolute confidence.

These forest images were selected based on image accessibility (we could not visit original artwork in most cases and therefore relied on electronic access to high-resolution images) and our knowledge about the artist creating the work. All images are highly detailed such that minute microhabitat features can be discerned across multiple trees in the same work. For instance, in Durand's *Group of Trees*, the foreground tree on the far left displays a litany of injuries, twig tangles, and epiphytes: a historic branch attachment is indicated by the bulging branch collar about two-thirds up the right side of the trunk; on the left side of this tree, two epicormic shoots snake their way to the edge of the composition; and throughout this side of the trunk, thick mats of moss blanket the tree from base to canopy. By contrast, *The Adirondacks* does not depict a forest interior, although a variety of microhabitat features are depicted in equal profusion. The dark, shaggy tree leaning from the right foreground toward the center of the composition displays nine fungal fruiting bodies at its base with a liana vine creeping diagonally across the trunk. Higher along the trunk, two dead branches protrude at opposite angles as a smaller epicormic shoot sprouts between them. The shaggy bark creates several bark pockets, while portions of its exterior are covered in mats of moss. While the presence of wildlife is not a microhabitat feature in and of itself, it is noteworthy that *In the Adirondacks*, as well as *Woods of Ashokan*, *A Creek in the Woods*, *The Old Hunting Grounds*, and *In the Woods*, together comprising half of the works analyzed, depicts wildlife, reinforcing the idea that these compositions represent structurally complex forests that provide essential substrates to support such wildlife.

Through the analysis of microhabitat features across this set of case study works, we found that all works contained over half (4 or greater) of the microhabitat groups identified in Table 2. An average of 29 individual features were exhibited in the three most visible foreground trees (Table 3). Epiphytic structures were the most common group, representing 117 structures across the 10 paintings. In a study of French mixed hardwood-conifer forests, Vuidot et al. (2011) found that there was an average of 1.58 microhabitats per living tree across forest types and microhabitat features increased with tree size. Another study in France reported a median frequency per living tree of between ~0.2 and 0.6 microhabitat features (Larrieu & Cabanettes, 2012), and in general, old growth forests have many more

TABLE 2 Presence/absence of microhabitat features in a case study assessment of 10 forest interior paintings completed between ca. 1855 and 1870 (paintings listed in Appendix S1).

Title	<i>Forest in the Morning Light</i>	<i>Group of Trees</i>	<i>Woodland Glen</i>	<i>A Creek in the Woods</i>	<i>In the Woods</i>	<i>The Adirondacks</i>	<i>In the Woods</i>	<i>Woods of Ashokan</i>	<i>The Old Hunting Ground</i>	<i>The Trout Pool</i>
Artist	Durand	Durand	Durand	Durand	Durand	Hart	Walters	Whittredge	Whittredge	Whittredge
Microhabitat										
Cavities										
Woodpecker cavity		x			x					
Woodpecker activity/marks			x				x			x
Insect bore holes										
Sapsucker galleries					x					
Fungal fruiting bodies										
Fungal conk					x	x				
Tree injuries										
Broken crown				x						
Cracks			x	x	x		x			x
Splintered limb	x		x	x	x	x		x		x
Exposed basal wounds	x	x		x	x			x	x	
Broken snag (standing dead)	x	x	x	x						
Branch stub	x	x	x	x						
Historic branch attachments	x	x	x	x			x	x		
Twig tangles										
Epicormic shoots	x	x	x	x		x	x	x	x	
Witch broom										
Epiphytic structures										
Distinct (large) clumps of moss	x	x	x	x	x	x	x	x	x	
Lichens						x		x		
Ferns										
Dead wood										
Crown dead wood	x	x	x	x	x	x	x		x	x
Dead wood on forest floor		x	x	x	x	x	x	x	x	x
Bark separation										
Bark sloughing		x	x		x			x		
Bark pockets			x					x		x
Exposed sapwood	x			x						

TABLE 3 Abundance of microhabitats by group for the three closest foreground trees in each painting in a case study assessment of 10 forest interior paintings completed between ca. 1855 and 1870 (paintings listed in Appendix S1).

Title	<i>Forest in the Morning Light</i>	<i>Group of Trees</i>	<i>Woodland Glen</i>	<i>A creek in the Woods</i>	<i>In the Woods</i>	<i>The Adirondacks</i>	<i>In the Woods</i>	<i>Woods of Ashokan</i>	<i>The Old Hunting Ground</i>	<i>The Trout Pool</i>
Artist	Durand	Durand	Durand	Durand	Durand	Hart	Walters	Whittredge	Whittredge	Whittredge
Microhabitat										
Cavities										
		1	1		3		1		2	1
Fungal fruiting bodies										
					2	9				
Tree injuries										
	12	6	7	16	9	15	15	16	3	1
Twig tangles										
	2		1	4		1	1		1	
Epiphytic structures										
	10	18	25	9	15	7	21	7	5	
Dead wood										
	2		2	3	4	3			3	
Bark separation										
	1	1		1		8	2			
Total	27	26	36	33	33	43	40	23	14	2

microhabitat features than young or managed stands (Michel & Winter, 2009).

Overall, the case study of microhabitat features in these landscape paintings revealed high quantities and varieties of features across paintings. These microhabitat features are the same details that provided 19th century viewers with ecologically centered entertainment and supported the primeval character of America's wilderness identity. When studied as individual microhabitat features, rather than as a collective suite of details, landscape paintings from the Hudson River School can show characteristics of northeastern old growth forests through the presence of structural complexity.

CONCLUSIONS

Understanding forests of the past helps us to understand current forest ecosystems and how they may change in the future. Paintings of landscapes and forests from the 19th century that provide a realistic representation of the forest have the potential to reveal information on the complex structure and composition of late-successional (i.e., mature and old growth) forest communities prior to industrialization and the loss of most late-successional forests in this region. Many stand characteristics, such as large downed wood debris, forest microhabitats, large tree densities, canopy disturbances, understory structure and composition, and more (Table 4), typically not well characterized in other historical ecology methodologies,

can be identified and ultimately quantified in these images. For example, in our abbreviated case study of microhabitat assessment from a set of 10 paintings, we documented an average of over 25 individual microhabitat features across the three dominant trees in each painting. These pre-industrial forest images also capture a forest landscape that still held such key tree species as American chestnut and American elm, now functionally extirpated from the eastern North American landscape by the introduction of pathogens in the early to mid-20th century.

Although there are unquestionably allegorical and political messages embedded in many early 19th century forest images, we suggest that this does not necessarily detract from their veracity or their potential use as a tool in historical ecology. Inclusion of insights from art history scholarship, alongside a critical evaluation of artists' notes, sketches, and compositions, shows the skill of these artists as naturalists and the degree to which they were responding to trends of the era (Kusserow & Braddock, 2018). This is particularly true for artists subscribing to *plein air* philosophies in the Hudson River School. Further, the Hudson River School painter's advocacy for wilderness remains timely. North American forests at their time were threatened by industrialization, and while much of the landscape has reforested, these forests continue to face threats. Ex-urban land-use changes are encroaching on regenerated forests and the direct and indirect effects of globalization are leading to environmental change, which has promoted the introduction of

TABLE 4 Forest features and characteristics portrayed in the 19th century landscape paintings that could be used in ecological studies with some examples of ecological processes for which these characteristics may provide insight into historic forests.

Feature or characteristic	Ecological process or insight
Variation canopy outlines and surface topography	Canopy variation (and rugosity in particular) has been linked to ecosystem processes Emergent canopy trees as key forest features
Standing dead (snags)	Microhabitat assessments Fire, disease, or windthrow disturbance history
Downed wood	Variation in decay classes of down wood reflecting disturbance legacies
Live tree microhabitat features	Complexity within and among trees
Relative size class distributions, vertical organization trees	Overstory forest structure
Vertical structure of understory trees, shrubs, and herbaceous layers	Understory forest structure Potential grazing (or lack thereof)
Morphology of crowns on large, old trees	Disturbance history
Are extirpated trees present?	Place (and at least structural role) of extirpated species in the forest
Presence/density of large, old trees	Structural complexity and historic densities of large trees
Stream channel features such as debris dams, large wood, side channels, and sinuosity	Historic wood loading and food function in forested streams Historic floodplain interaction and overall channel morphology
Type, intensity, extent, etc. Windthrow, gaps, fire	Disturbance history and aspects of stand regeneration following disturbance

invasive insect pests, pathogens, and plants. While not a true baseline to pre-colonial forests, because these paintings were created ~100 years after Euro-American settlers arrived and during a period where the influence of indigenous cultural practices was fading from the eastern landscape, paintings from the 19th century represent a quasi-baseline representation of what forests might once have looked like. In this respect the paintings are a valuable resource for restoration efforts focused on recreating the stand structural and microhabitat complexity of forests before the introduction of contemporary silviculture, loss of keystone species, or changes in stand structure or understory composition caused by the exotic beech bark disease complex (Keeton et al., 2018). This represents an alternative perspective, supplementing other historical ecology methodologies and enhancing our understanding of long-term forest change and the preindustrial forest ecosystems (see, e.g., Barton & Keeton, 2018).

Taking an interdisciplinary approach in reviewing the content and context of the material—which is an inherent part of nearly all historical ecology (Szabo, 2010; Szabo & Hedl, 2011)—we can identify artwork that can be used for the ecological assessment of preindustrial

forests. A review of the writing, context, and works of Asher Durand, the case study we chose for this article, indicates that many of his paintings and sketches contain valuable information about forest structure, composition, and ecology of pre-industrial forests from the northeastern United States. We stress, however, that while paintings may be accurate representations of the system, the art was not created to generate data, and one cannot universally accept all works as a direct measure of the system. The specific images used for ecological analysis will depend in part on the questions being asked. For example, *In the Woods* may be well suited for exploring forest composition, understory structural complexity/composition, and microhabitats on individual trees, but it may not be optimal for a strict quantification of downed wood loading or forest basal area. Paintings also notably depict forests that already bore some of the marks of suppression of indigenous cultural stewardship practices, which can affect the nature of questions asked with these paintings. Similarly, one may have a different set of questions for canopy rugosity than for epiphyte loads or forest composition, which would affect not only the images assessed but also the evaluation of image veracity to meet the needs of the study.



FIGURE 9 Worthington Whittredge (American, 1820–1910). *Foothills Colorado*, c. 1870. Oil on paper, 29.8 × 50.2 cm. Denver Art Museum, gift of the Houston Foundation in Memory of M. Elliott Houston and Museum Exchange (1969.160). Photograph courtesy Denver Art Museum.



FIGURE 10 (A) William Trost Richards (American, 1833–1905). *Rhode Island Coast: Conanicut Island*, c. 1880. Transparent watercolor with touches of opaque watercolor on cream, moderately thick, slightly textured wove paper, 25.4 × 36.7 cm. Brooklyn Museum, Bequest of Mrs. William T. Brewster through the National Academy of Design (53.229). (B) Martin Johnson Heade (American, 1819–1904). *Newburyport Meadows*, c. 1876–81. Oil on canvas, 26.7 × 55.9 cm. Metropolitan Museum of Art, purchase, Mrs. Samuel P. Reed Gift, Morris K. Jesup Fund, Maria DeWitt Jesup Fund, John Osgood and Elizabeth Amis Cameron Blanchard Memorial Fund and Gifts of Robert E. Tod and William Gedney Bunce, by exchange (1985.117).

Beyond Asher Durand, the Hudson River School and forests of the northeastern United States, historic artwork may have similar potential in other regions and for other scientific fields. For example, a number of prominent artists from New York and the eastern seaboard traveled west to the mountain and intermountain regions as well as north to Labrador. As evidenced by work on glacial

dynamics in Europe (Haeberli, 2008; Nussbaumer & Zumbuhl, 2012; Zumbuhl & Nussbaumer, 2018; Zumbuhl et al., 2008), there is clear potential for inference about changes in mountain ice cover from early paintings, and environmentally inclined art historians have already used some of the most northern works to explore the idea that art can be used to understand the historical extent, size,

and morphology of glaciers (Gambino, 2013; Gapp, 2017). Western works from the 19th century that incorporate mountain scenery may have similar potential in evaluating isolated glaciers, and paintings from this period of prairie and river landscapes of the western United States have potential in exploring these areas before major agricultural efforts dominated the landscape (Figure 9). To be sure, we must acknowledge that components of the images were implicitly or explicitly designed to advertise and encourage travel to the west; they reflect a white, Christian, and often imperialist notion of manifest destiny in regard to people, animals, and places (Keck, 2013). However, many of these early artists from a western culture (such as Worthington Whittredge [1820–1910] and Sanford Robinson Gifford) were active in the communities and cultural systems that helped define the Hudson River School, and they valued careful observation in their landscape images. Coastal shorelines and salt marshes were also frequently painted scenes by many landscape artists in the 19th century who subscribed to the importance of creating paintings in close alignment with nature as observed (e.g., William Trost Richards [1833–1905] and Martin Johnson Heade [1819–1904]; Figure 10). Where a verifiable interest in accuracy can be identified in the artist and where the archival record presents evidence of *plein air* sketching, these images have the potential to tell us about historic shorelines, marsh habitat loss, and coastal plant communities that have been and will continue to be impacted by changes in ocean conditions and land use. Examining all of these paintings and their artists following the criteria of Forman and Russell (1983) outlined above is beyond the scope of this paper; however, we suggest that the analysis and review presented here provides a framework by which other works can be evaluated and ultimately used to generate new knowledge about past environmental conditions from 19th century landscape art.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

No data were collected for this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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