

TOWARD A CONCEPTUAL FRAMEWORK FOR ASSESSING THE HUMAN DIMENSIONS OF PALEONTOLOGICAL RESOURCES

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Abstract—Dinosaurs and other fossils capture the imagination of people of all ages from around the globe. An assessment of the wide range of human values associated with paleontological resources reveals strong and sometimes conflicting perspectives. Given the fact that fossils are non-renewable resources, decision-making relative to the use, conservation and stewardship of paleontological resources must recognize and consider the human dimensions of fossils. Scientific, educational, recreational, commercial and other human values may directly influence the motivations and behaviors of individuals as they relate to paleontological resources. The unauthorized collection of fossils from public lands, including theft and vandalism, entails a variety of legal, ethical, economic and social factors that need to be assessed in conjunction with the planning and implementation of public policy. The purpose of this review is to initiate the compilation of baseline information on the human dimensions of paleontological resources in order to develop a conceptual framework and more clearly identify the most crucial questions to address in future research.

INTRODUCTION

A fundamental topic in paleontology that has garnered little attention is an evaluation of the values that humans ascribe to fossils. Some examples of human values associated with fossils include scientific, educational, recreational, spiritual, commercial, and even aesthetic values. An assessment of the types and diversity of values that humans place on fossils should shed light on individual and societal attitudes, perceptions and even behaviors linked to fossils. Increased understanding of the human dimensions of paleontological resources may shed light on the motivations influencing human thinking and behaviors. In turn, social science research involving the human dimensions of fossils may help to better reveal the basis for some of the following questions, which highlight normative occurrences and historical events related to paleontology:

- Why are children so universally passionate about fossils? (And how can that enthusiasm about fossils be used to further children's interest in science?)
- Why are movies such as *Jurassic Park* and *Jurassic World*, which feature dinosaurs, some of the highest grossing box-office draws of all time?
- Why are some members of the public willing to pay millions of dollars to own an original skeleton of a prehistoric creature?
- Why do some individuals knowingly take the risk of stealing fossils from a national park or other type of protected area, when this action is illegal and subject to penalty?
- What human factors contributed to the disappearance of the paleontological resources at Fossil Cycad National Monument, South Dakota, resulting in this monument becoming abolished as a unit of the National Park Service?

This compilation is a first attempt to develop a conceptual framework for assessing the human dimensions of paleontological resources. The purpose of this conceptual framework is to lay the foundation for future research by beginning to identify and define the interrelationships between people and fossils (Fig. 1). Through future study, it will be important to identify whether there are basic social or demographic patterns which influence the human dimensions and values associated with paleontological resources. There is a general lack of data available regarding the range of human values, beliefs, perspectives, motivations and behaviors, which may result in either positive or negative impacts on non-renewable resources (Kim and Weiler, 2013).

It is important to recognize that fossils possess their own scientific and educational values and are often managed in accordance to laws and in the public trust. The impairment of paleontological resources due to human-related activities would result in the loss of the scientific and educational values these resources possess (Shimada et al., 2014). The data gained through targeted social science research may help inform scientists, educators, business owners, public land managers

and others to better understand and implement effective strategies for the enjoyment, use, management and stewardship of non-renewable fossils.

WHAT ARE PALEONTOLOGICAL RESOURCES?

In order to assess and understand the human dimensions of paleontological resources, it is important to define the scope of meaning applied to the resource. Based on the intent of this discussion we are using the terms paleontological resources and fossils synonymously and interchangeably. Although there are some subtle variations between the scientific and legal definitions for fossils, there is uniform consensus that paleontological resources are the non-renewable remains of past life preserved in a geological context.

The non-renewable nature of paleontological resources is an important consideration for science, education, resource management and other human dimensions associated with fossils. Despite the fact that fossils may be abundant or rare, fossils are finite in the geologic record. Therefore, for all extinct genera and species, the fossil record for these ancient organisms is limited to the physical remains that have been previously preserved in geologic strata deposited during the lifespan of a particular group of organisms. No additional remains from extinct fauna or flora will become fossilized once the group is extirpated. For example, the famous dinosaur *Tyrannosaurus rex* lived and became extinct during the Late Cretaceous. The skeletal remains of *T. rex* are preserved in several Upper Cretaceous geologic formations. Therefore, no fossil remains of *T. rex* have been preserved since the Late Cretaceous, and all *T. rex* fossils are limited to those that are still

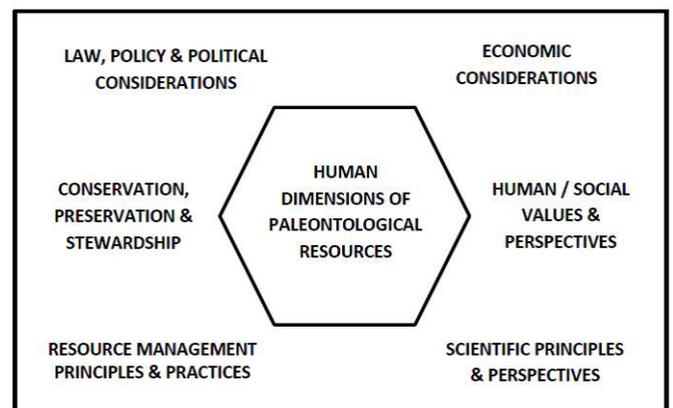


FIGURE 1. Conceptual model identifying the six primary factors defining the human dimensions of paleontological resources.

buried beneath the surface, are weathering at the surface, or have been removed from the geologic context and maintained in museum or private collections.

The non-renewable nature of fossils influences a variety of human dimensions pertaining to fossils. These include basic scientific principles and resource management practices involving fossils. The non-renewability of fossils may also influence the commercial interest and value of certain types of fossils in a “supply-and-demand” environment. Conversely, extant biological taxa are renewable resources because they have the potential to perpetuate themselves through reproduction. Recent successes through captive breeding of endangered species, including the black-footed ferret (*Mustela nigripes*) and the California condor (*Gymnogyps californianus*), show the potential to rescue species on the brink of extinction.

Paleontological resources include the fossil remains of the morphological components of once-living organisms including bones, teeth, hair, scales, shells, leaves, seeds, wood, pollen, amber and a wide variety of other physical components of organisms. Additionally, a category of paleontological resources referred to as trace fossils (ichnofossils) preserve some evidence of biological activity rather than the actual physical remains of the organism. Examples of trace fossils include fossil footprints, feces, root casts, burrows, nests, and other evidence of biological activity preserved in a geologic context.

It is important to recognize the similarities and differences between paleontological resources and archeological resources. The most important similarity is that both paleontological resources and archeological resources are non-renewable and represent old objects preserved at or near the Earth’s surface. Both paleontology and archeology are fields of study that employ similar methodologies and techniques for the excavation and removal of resources from within strata and soils. The principal difference between paleontological and archeological resources relates to the types of resources that are being studied and excavated. The study of archeology focuses on remains associated with human history and culture such as archeological artifacts, prehistoric and historic structures, petroglyphs and pictographs, and other human-related objects. The study of paleontology focuses on the evidence of past biological organisms and their activities preserved within geologic strata. It is worth noting that fossils can occur secondarily within a cultural resource context (Figs. 2-3), where fossils may be discovered within archeological sites or within the building stones of historic structures (Kenworthy and Santucci, 2006). The many facets of the fossil record have likely captured the attention of humans throughout the course of humanity.

PREVIOUS WORK AND LITERATURE REVIEW

The literature associated with the science of paleontology consists of tens of thousands of books, journal articles and other publications. These publications contribute to a greater understanding of the scientific aspects of fossils, including: systematics, taxonomy, biostratigraphy, paleoecology, evolution, paleobiogeography, taphonomy, functional morphology, ichnology, and a wide range of other subdisciplines in paleontology. The extensive scientific research associated with the field of paleontology is interesting to note, but beyond the scope of this publication. However, it is important to recognize that there are comparatively few research publications devoted to social science and fossils.

Archeological evidence indicates prehistoric people encountered, observed and sometimes collected fossils for thousands of years (Mayor, 2005, 2007, 2011; Kenworthy and Santucci, 2006). The history of early fossil discoveries and the birth of the science of paleontology

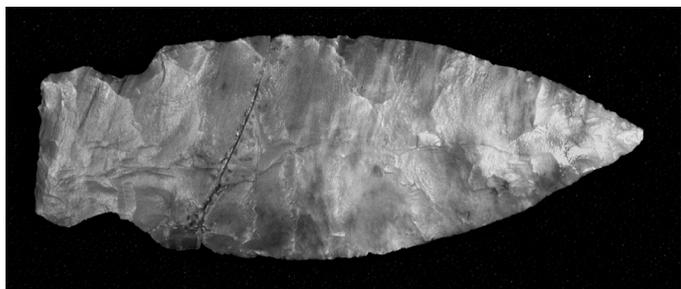


FIGURE 2. Projectile point made from petrified wood discovered at Petrified Forest National Park Arizona (NPS Photo).

include wonderfully rich narratives of the human experience and evolving intellect within natural philosophy and science (Rea, 2001). Despite this history, specific empirical research and scientific literature assessing the human dimensions of paleontological resources are nearly non-existent.

An extensive and growing body of literature, including both natural science and social science research, focuses on the relationships of human activities and behaviors associated with natural resources (Decker et al., 1996; Manfredo et al., 2004; Enck et al., 2006; Leong et al., 2013). Many publications specifically examine the impacts to natural resources based on human behavior and activities (Wise, 1982; Gramann and Vander Stoep, 1987; Johnson and Vande Kamp, 1996; Muth and Bowe, 1998; Decker et al., 2001; Gavin et al., 2010). Additionally, there is also an abundance of research focusing on the use of education and interpretation in promoting natural resource stewardship (Olson et al., 1984; Helens, 1992; Daniels and Marion, 2005; Marion and Reed, 2007).

A review of the literature associated with depreciative behavior and natural resources yields more targeted studies that have some relevance and transferability to the assessment of human behaviors involving paleontological resources (Bradford, 2005; Lawhon, 2013; Lawhon et al., 2014; Sheffield, 1988). Beginning during the 1990s, researchers at Virginia Polytechnic Institute undertook evaluations of visitor attitudes and perceptions to better understand behavior associated with fossil theft at Petrified Forest National Park, Arizona, and Fossil Butte National Monument, Wyoming (Williams et al., 1993; Widner and Roggenbuck, 2000, 2003; Hockett and Roggenbuck, 2002, 2003; Hockett, 2008). The results of these studies provided valuable data to the National Park Service, informing resource protection planning and demonstrating the need for further research on the human dimensions of paleontological resources.

HUMAN DIMENSIONS AND PALEONTOLOGICAL RESOURCES

The principle focus of this summary is to develop a conceptual framework for assessing the human dimensions of paleontological resources. The human dimensions of natural resources represent an expanding area of social science research that informs land and resource managers about the relationships and interactions of humans with natural resources (Ewert, 1996a, b). For example, studies focused on the human dimensions of wildlife attempt to understand human motivations and behaviors, which may lead to conflict or unsafe interactions with wild animals (e.g., grizzly bears or bison). This article proposes a framework for applying the principles of human dimensions research to non-renewable paleontological resources.

The application of the human dimensions concept to non-renewable paleontological resources has great potential for benefiting those individuals, organizations, institutions and agencies involved with fossils. Previous human dimensions research provides valuable



FIGURE 3. Triassic dinosaur tracks (*Atreipus milfordensis*) preserved in the building stones of a historic bridge at Gettysburg National Military Park (V. Santucci photo).

insights that are directly applicable to developing a framework for assessing human values associated with fossils (Manning and Moore, 2002; Harmon and Putney, 2003; Harmon, 2004). The application of social science research in paleontology may yield information and understandings that would benefit the management, protection, science, education, partnerships and stewardship of fossils.

HUMAN AND SOCIAL VALUES ASSOCIATED WITH FOSSILS

To begin to assess the human dimensions of paleontological resources, and to gain a greater understanding of the human attitudes, perspectives, motivations and behavior associated with fossils, we should first identify the range of human and social values applied to fossils. The identification of the range and differences in human values associated with fossils may reveal the basis for conflicting perspectives. A proposed list of human values associated with fossils, which are values often considered in other human dimensions of natural resource evaluations, include: aesthetic values, personal values, heritage values, historical values, scientific values, educational values, recreational values, commercial or economic values, and perhaps some spiritual values (Decker et al., 1996, 2001; Harmon and Putney, 2003; Harmon, 2004; Manfredo et al., 2004, 2008; Manfredo, 2008).

Aesthetic values: The tremendous diversity of life represented in the fossil record exhibits some exceptionally beautiful, morphologically diverse and uniquely preserved fossils. The symmetry of a fossil starfish, the intricate details displayed in a fossilized bird feather, or the colorful patterns of agatized petrified wood have aesthetic qualities that may evoke human emotions in relation to the sense or perception of beauty. The opal-like or iridescent organic preservation of the aragonite shells from two species of the ammonite genus *Placenticeras* is extremely popular and is mined for use as a gemstone called ammolite (<http://geology.com/stories/13/ammolite/> accessed July 2016). Fossil ammonites exhibiting this beautiful form of mineralization can yield tens of thousands of dollars for an individual specimen on the commercial fossil market.

Personal values: Individuals may have their own personal values they place on a fossil based on an infinite array of personal reasons. These scenarios exist when there is some meaningful personal connection between the individual and the fossil, although that personal value may not be recognized by other individuals. For example, an individual may have a sentimental value for a particular fossil if it was the first fossil that individual ever discovered. Another example would be when the individual has an attachment to a fossil that was passed down from a beloved family member or friend. Another scenario where there may be some personal value tied to a fossil specimen could be based upon the fact that the fossil was dug up on the family property. These personal values applied to fossils would be individual and varied.

Heritage values: Heritage values are directly linked to the values of humans and cultural groups. These values may be based upon some resource significance or how different populations perceive the significance of a resource, potentially contributing to resource conservation. The heritage values specifically applied to the conservation and preservation of fossils and fossil localities have been demonstrated widely with the establishment of many paleontological parks, monuments, landmarks, and other designations for the benefit of the public and to support science and education. Another example of heritage value is demonstrated with the designation of a fossil known from within a particular state as the "State Fossil" (<https://www.fossilera.com/pages/state-fossils#kansas> accessed July 2016).

Historical values: The science of paleontology has a rich and colorful history which dates back many centuries. Both Thomas Jefferson and Benjamin Franklin had a great fascination with mammoths, and today fossilized remains of mammoths are on display at Jefferson's home at Monticello, in Virginia. Often superlative characteristics, such as largest, most complete, earliest, etc., bring notoriety or fame to a particular fossil. One well known example is the 1858 discovery of a first nearly complete dinosaur skeleton (*Hadrosaurus foulkii*) in Haddonfield, New Jersey. This famous fossil specimen is one of the most revered in the science of vertebrate paleontology and is unquestionably valuable from a historic perspective (<http://www.levins.com/dinosaur.shtml> accessed July 2016).

Scientific values: Perhaps one of the most obvious values associated with fossils is tied to the scientific information that humans have gained through the excavation, preparation and study of fossils. Through the study of fossils worldwide the evolutionary relationships between extinct and modern biota have become better understood.

Fossils and the geologic context in which they are preserved provide evidence for past ecosystems and biotic communities, the environments of deposition and relative relationships of fossils over time. The temporal data derived from fossils has been used as the primary source of information to delineate the Phanerozoic portion of the global geologic time scale. The main subdivisions (Paleozoic Era [time of ancient animal life], Mesozoic Era [time of middle animal life] and Cenozoic Era [time of recent animal life]) have been adopted as the standard divisions for geologic time by geologists from around the world. Although the divisions and subdivisions of the geologic time scale are a human convention, they are based on globally consistent paleontological data. Finally, some of the strongest data supporting climate change over geologic time is derived from the evidence in the fossil record.

Educational values: Another obvious value that humans have demonstrated relative to fossils relate to education. Human interest in fossils, especially children's interest, is observable around the world by the popularity of fossil exhibits in museums, nature centers, fossil sites, and other venues. Children are naturally interested in fossils and dinosaurs. This fact, alone, is one of the strongest observations justifying the need for further research on the human dimensions of paleontology. Fossils and dinosaurs are routinely used by elementary school teachers to initiate children's interest in science (Gunckel, 1994). The establishment of National Fossil Day in 2010, as part of Earth Science Week, has been a catalyst to a nationwide partnership promoting the scientific and educational values of fossils. Nearly 350 partners nationwide, including museums, professional science organizations, professional teacher organizations, universities, public and private fossil sites, universities, libraries, amateur fossil groups and other groups interested in fossils, have joined to celebrate America's Fossil Heritage and the outreach to millions of children across the U.S. During the past six years, the National Park Service Junior Paleontologist Program has resulted in nearly 100,000 children taking the Junior Paleontologist pledge and inspiring an entire generation of future fossil stewards (Fig. 4).

Recreational values: The development of recreational paleontology and fossil tourism demonstrate another example of how some individuals value fossils. Large numbers of amateur fossil collectors and rock hounds participate in the search for fossils across the U.S. Some families plan weekend trips to local fossil localities where they are able to legally discover and collect fossils. Some serious avocational fossil collectors compile large and valuable collections and often share the rare discoveries with scientists and museums for study.

Some individuals and families plan vacations to participate in organized fossil excavations sponsored by museums or private organizations. Local chambers of commerce or state tourism bureaus promote fossil or dinosaur tourism in some of the western states. The Dinosaur Diamond Prehistoric Highway is a 480 mile route in western Colorado and Eastern Utah. This tour includes fossil sites such as Dinosaur National Monument, the Cleveland-Lloyd Dinosaur Quarry



FIGURE 4. Hundreds of children take the Junior Paleontologist pledge during the 2010 National Fossil Day celebration on the National Mall in Washington, D.C. (NPS Photo).

(National Natural Landmark), Fruita Paleontological Area, Mill Canyon Dinosaur Trail and the Eastern Prehistoric Museum in Price, Utah

(<http://travel.nationalgeographic.com/travel/road-trips/dinosaur-diamond-prehistoric-highway/> accessed July 2016).

Commercial/economic values: According to Mayor (2000), fossils have been collected, bartered, bought and sold by humans for thousands of years. The commercial sale of fossils and fossil replicas has become a well-established business in the U.S and internationally. In the United States, the fossil trade ranges from the small town “mom-and-pop” rock shop to the “Fossil and Mineral Galleries” in more upscale markets such as Jackson Hole, Wyoming, Sante Fe, New Mexico, or Sedona, Arizona. The sale of the nearly complete *Tyrannosaurus rex* specimen nicknamed “Sue” for over 8 million dollars demonstrates how valuable fossils can be in the commercial market. A more in-depth assessment of the economic considerations of paleontological resources is presented later in this article.

Spiritual values: The books and publications of Adrian Mayor (2000, 2005, 2007), especially “Fossil Legends of the First Americans,” have enhanced our understanding and appreciation of the relationships between fossils and pre-Columbian Native Americans and ancient Europeans. Fossils discovered in archeological sites demonstrate the utilization of fossils by early cultures, from projectile points fashioned from petrified wood to Native American burials, which include jewelry incorporating fossils such as ammonites, trilobites or crinoid columnals (Kenworthy et al., 2006). The spiritual values associated with fossils are often part of sacred or traditional cultural practices or ceremonies and are not disclosed beyond the members of a cultural group.

LEGAL FRAMEWORK FOR PALEONTOLOGICAL RESOURCES

Federal laws, regulations, and policies associated with paleontological resources are specifically developed to address issues that relate to human activities or to define the use, or limits to the use, by the public. This category represents the legal framework in the United States for the human dimensions of paleontological resources. The Paleontological Resources Preservation Act (PRPA; 16 US Code 470aaa) is the principal federal law that specifically focuses on paleontological resources. The PRPA was signed into law on March 30, 2009 and represents the most recent and comprehensive federal authority for the management and protection of fossils on lands administered by the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), Fish & Wildlife Service (FWS), National Park Service (NPS), and U.S. Forest Service (USFS). A number of law review journal articles address the Paleontological Resources Preservation Act and issues associated with the management and protection of fossils on federal and other public lands (Marshall, 1976; Lazerwitz, 1994; Sakurai, 1994; Dussias, 1996; Lundgren, 1998; Malmshemer and Hilfinger, 2003; Weimer, 2004; Chew, 2005; Rogers, 2011; Knowles, 2013).

Federal regulations and policies associated with the management of paleontological resources are also directly related to human activities on public lands. The National Park Service has developed strategies for monitoring the stability and condition of paleontological resources relative to both natural and human-caused impacts (Santucci and Koch, 2003; Santucci et al., 2009). Brunner et al. (2010) presents an example of policy evaluation by the National Park Service related to unauthorized fossil collecting on park beaches by park visitors.

Internationally, many foreign countries have specific laws that address paleontological resources. These fossil protection laws are often contained within cultural heritage legislation.

SCIENTIFIC PRINCIPLES AND PERSPECTIVES

The human dimensions of paleontological resources are clearly represented through the science of paleontology. The science of paleontology is an integrated field of study based upon biological and geological principles. Paleontology began to emerge during the 18th and 19th centuries through the observations and contributions of naturalists, including Carl Linnaeus (1707–1778) and Georges Cuvier (1769–1832), and geologists, such as James Hutton (1726–1797), William “Strata” Smith (1769–1839) and Charles Lyell (1797–1875). Over the past 250 years the science of paleontology has advanced and evolved based upon the integrity of the scientific method. In paleontology, our understanding of the fossil record is only as good as the discoveries made during the most recent field season.

Nearly three centuries of scientific inquiry involving fossils has advanced human understanding of important questions related to the

history of life on Earth. These questions include, but are not limited to, the evolutionary relationships between ancient and modern biota; interpretations of ancient environments, climates and paleoecosystems; patterns of evolution and extinction preserved in the fossil record; and, the biogeographic and temporal distribution of life on the planet.

PALEONTOLOGICAL RESOURCE MANAGEMENT— PRINCIPLES AND PRACTICES

The management of paleontological resources on public lands is often a responsibility defined by legal mandates or scientific principles. Paleontological resource management practices are based upon the recognition that fossils are non-renewable resources. One of the first components of managing fossils involves the completion of baseline field inventories or surveys of geologic strata to identify the scope, significance, distribution and condition of paleontological resources and localities. The availability of this information helps to better inform resource managers about potential or actual occurrences of fossils when involved in planning or decision-making.

Paleontological resource monitoring is a relatively new methodology used for assessing the stability and condition of fossils that are maintained in situ (Santucci and Koch, 2003; Santucci et al., 2009). In 2009, Glen Canyon National Recreation Area (GLCA), Arizona and Utah, was selected as the prototype paleontological resource monitoring park for the National Park Service. GLCA was considered an ideal location for assessing the paleontological resource monitoring strategies due to the impacts to fossils along the shoreline of Lake Powell given the dramatic changes in lake levels.

Paleontologists and resource managers employ a wide array of techniques to protect and stabilize fossil localities. In cases where the excavation and collection of fossils is warranted, either under a research permit or with permission from the land owner, the use of standardized field methods are essential to limit any damage to fossils during excavation. Paleontological resource management includes the active involvement of human decision-making.

PALEONTOLOGICAL RESOURCE CONSERVATION— PRESERVATION AND STEWARDSHIP

The conservation and preservation of paleontological resources and localities are intimately tied to human values and collaboration. America’s paleontological heritage includes remarkable historical accounts of individuals and organized groups advocating for the protection of fossil sites. During the early years of the twentieth century, John Muir’s journeys to the petrified forests of Arizona were influential in establishing Petrified Forest National Monument in 1906, a few months after the Antiquities Act was signed into law. Leopold and Meyer (2012) present a detailed account of paleoconservation in their book on the establishment of Florissant Fossil Beds National Monument, Colorado. In 2014, after nearly a decade of public outreach and education, the Protectors of Tule Springs, National Parks Conservation Association and other conservation organizations celebrated the creation of Tule Springs Fossil Beds National Monument, Nevada, with bipartisan support in the U.S. Congress.

In addition to the establishment of national parks and monuments to preserve paleontological resources and localities in the United States, the National Natural Landmarks Program encourages and supports the voluntary conservation of paleontological sites (<http://www.nature.nps.gov/nnl/> accessed July 2016). At least 37 National Natural Landmarks (Table 1) have been designated by the Secretary of Interior based primarily on the significant paleontological resources (personal communication, H. Eggleston, 2016).

On an international level, the World Heritage Program, administered by UNESCO since 1972, designates natural and cultural sites of “outstanding universal value” as World Heritage Sites (Lipps, 2009; Pages, 2009). A small number of paleontological sites are designated as World Heritage Sites, including the Messel Fossil Pit Site (Germany) and Joggins Fossil Cliffs (Canada) (<http://whc.unesco.org/en/list/> accessed July 2016).

The concepts of paleoconservation and paleoheritage have emerged in the scientific literature during the past decade. The global scientific community recognizes the importance of preserving fossil sites around the world, and is working at local, national, and international levels to support the protection and interpretation of fossil sites (Endere and Prado, 2015; Henriques and dos Reis, 2015). These efforts will collectively demonstrate the value in understanding the human dimensions of paleontological resources.

TABLE 1. List of 37 National Natural Landmarks established primarily based upon their paleontological resources.

National Natural Landmark Name	State / Territory
Unga Island	Alaska
Comb Ridge	Arizona
Rainbow Basin	California
Rancho La Brea	California
Sharktooth Hill	California
Garden Park Fossil Area	Colorado
Indian Springs Trace Fossil Site	Colorado
Morrison – Golden Fossil Areas	Colorado
Dinosaur Trackway	Connecticut
Hagerman Fauna Sites	Idaho
Hanging Rock and Wabash Reef	Indiana
Ohio Coral Reef / Falls of the Ohio	Indiana / Kentucky
Big Bone Lick	Kentucky
Mississippi Petrified Forest	Mississippi
Bridger Fossil Area	Montana
Bug Creek Fossil Area	Montana
Cloverly Formation Site	Montana
Hell Creek Fossil Area	Montana
Ashfall Fossil Beds	Nebraska
Riker Hill Fossil Site	New Jersey
Ghost Ranch	New Mexico
Ichthyosaur Site	Nevada
Fall Brook Gorge	New York
Fossil Coral Reef	New York
Petrified Gardens	New York
Chazy Fossil Reef	New York / Vermont
John Day Fossil Beds	Oregon
Mammoth Site of Hot Springs	South Dakota
Big Bone Cave	Tennessee
Dinosaur Valley	Texas
Greenwood Canyon	Texas
Cleveland-Lloyd Dinosaur Quarry	Utah
Coki Point Cliffs	Virgin Islands
Vagthus Point	Virgin Islands
Ginkgo Petrified Forest	Washington
Como Bluff	Wyoming
Crooked Creek Natural Area	Wyoming

ECONOMIC CONSIDERATIONS ASSOCIATED WITH FOSSILS

Human interest in fossils can frequently be measured by a wide range of economic considerations and influences. The use of fossils and especially dinosaurs have been effective for marketing fossil tourism, entertainment, merchandising and even the commercial sale of original and replica paleontological specimens. Fossils can also represent a source for employment and income for individuals, especially in fossil-rich areas around the world.

As non-renewable resources, fossils exhibit the influences of the principle of supply and demand relative to commercial values. Rare and more complete fossil specimens tend to demand higher commercial values (Browne, 1994; McClain, 1996; Hippensteel and Condliffe, 2013). The escalating commercial fossil market observed during the 1990s generated interest in fossils as financial investments, and Forbes Magazine published articles on the theme of fossils as investments (Ebeling, 2000; Rohleder, 2001). In 1997, an individual skeleton of a

nearly complete *Tyrannosaurus rex* specimen, nicknamed “Sue,” was auctioned by Sotheby’s for \$8.35 million dollars. This extreme example demonstrates how the economics of fossils can be a powerful factor influencing human values, attitudes, behaviors and motivations.

The commercial fossil market expanded from rock shops to catalog and internet sales offering a diverse range of fossils, including complete skeletons of fossil vertebrates. Large annual rock, mineral and fossil shows, such as the Tucson Gem, Mineral and Fossil Show, draw thousands of visitors from around the world. Sotheby’s, Heritage and other well-established auction houses feature high-priced fossil specimens during their natural history auctions.

Fossils are an important economic resource in several developing countries, providing jobs in the excavation and preparation of fossils (Krowitz, 2001). Fossils from Morocco, Madagascar and other locations around the world are legally collected and exported for sale to meet the demand for these fossils. According to Sincree (2009), the Moroccan fossil industry, including fossil mining operations for Paleozoic trilobites and Cretaceous marine invertebrates and vertebrates, may represent the country with the highest grossing fossil industry, with annual fossil sales estimated at \$40 million dollars and employing as many as 50,000 individuals.

Serious fossil-minded individuals are able to experience a real fossil dig offered by a number of museums, organizations and commercial fossil operations as volunteers or paying participants. These digs provide opportunities for novice fossil hunters to work side-by-side with professional paleontologists uncovering ancient remains. A few public (<http://mentalfloss.com/article/50997/10-states-fossil-hunting-sites-public>) and private fossil sites offer opportunities for fossil collecting. Commercial fossil quarries in the Eocene Green River Formation, near Kemmerer, Wyoming, offer opportunities for “pay to dig” to the public. The ancient lake sediments preserve millions of fossil fish and other lifeforms exhibiting an extraordinary degree of preservation, typically preserving complete or near complete skeletons. Green River fossil fish are found in rock shops and museums around the world. Similar “pay to dig” fossil localities enable the search, discovery and collection of a wide range of fossils including trilobites, dinosaurs, shark’s teeth and fossil remains of many other ancient plants and animals. Typically the “pay to dig” fossil sites allow the participants to keep the common fossils; however, the rarer types of fossils discovered are retained by the individuals or businesses managing the fossil site.

Dinosaurs and other prehistoric organisms have been the focus of motion pictures, television productions and other entertainment media (Tables 2-3). The *Jurassic Park* series of movies are among some of the highest grossing films in history. Preschoolers are able to enjoy their own age-appropriate dinosaur-themed television show called *Dinosaur Train*. Both Walt Disney World and Universal Studios theme parks have major dinosaur-focused attractions. In Downtown Disney in Orlando, Florida, a popular restaurant named *T-rex Café* is every “fossil-enthusiast’s” dream, with a menagerie of prehistoric animatronic lifeforms and fossil-themed menu selections.

“Fossil Tourism” is a pervasive concept in locations around the world enabling the public to experience the world of fossils. Federal, state and local fossil parks, museums, education centers, and a variety of other categories of paleontological sites draw tens of thousands of



FIGURE 5. Sinclair Oil advertising featuring their iconic dinosaur painted on the wall of a building (V. Santucci photo).

TABLE 2. List of dinosaur- and fossil-themed motion pictures, dates of release and production companies.

RELEASE DATE	FILM TITLE	PRODUCTION COMPANY
June 23, 2015	<i>Jurassic Prey</i>	Polonia Brothers Entertainment
June 12, 2015	<i>Jurassic World</i>	Universal Pictures & Amblin Entertainment
May 29, 2015	<i>Jurassic City</i>	Canal & Little Dragon Productions
May 19, 2015	<i>Cowboys and Dinosaurs</i>	Oracle Film Group
December 14, 2014	<i>Dinosaur Island</i>	Extinct Productions
October 31, 2013	<i>Raptor Ranch</i>	Nu Imagination
August 10, 2012	<i>The Dinosaur Project</i>	Moonlighting Films
April 20, 2012	<i>Attak of the Jurassic Shark</i>	Dudez Productions
January 26, 2012	<i>The Dino King</i>	C J Entertainment
February 28, 2011	<i>Azteca Rex</i>	Rigel Entertainment & Talkstory Productions
July 28, 2009	<i>The Land That Time Forgot</i>	Asylum
June 5, 2009	<i>Land of the Lost</i>	Universal Pictures
July 29, 2008	<i>100 Million B.C.</i>	Asylum
July 11, 2008	<i>Journey to the Center of the Earth</i>	New Line Cinema
December 14, 2005	<i>King Kong</i>	Universal Pictures
September 2, 2005	<i>A Sound of Thunder</i>	Franchise Pictures & Crusader Entertainment
July 14, 2005	<i>Attack of the Sabertooth</i>	Film Brokers International & Wood Canyon Ventures
April 20, 2004	<i>Dinocroc</i>	Concorde - New Horizons
March 23, 2004	<i>Sabertooth</i>	International Film Group & Sabertooth Productions
July 18, 2001	<i>Jurassic Park III</i>	Universal Pictures & Amblin Entertainment
April 28, 2000	<i>The Flintstones in Viva Las Vegas</i>	Universal Pictures, Amblin Entertainment & Hanna Barbera Productions
May 20, 1998	<i>Godzilla</i>	Centropolis Film Productions & Independent Pictures
May 23, 1997	<i>The Lost World: Jurassic Park II</i>	Universal Pictures & Amblin Entertainment
January 17, 1997	<i>Carnosaur 3: Primal Species</i>	Concorde - New Horizons
December 14, 1995	<i>Theodore Rex</i>	J&M Entertainment & New Line Cinema
February 23, 1995	<i>Carnosaur 2</i>	Concorde - New Horizons
May 27, 1994	<i>The Flintstones</i>	Universal Pictures, Amblin Entertainment & Hanna Barbera Productions
March 23, 1994	<i>Dinosaur Island</i>	Unknown
September 23, 1993	<i>Prehysteria!</i>	Full Moon Entertainment & Paramount Pictures
June 11, 1993	<i>Jurassic Park</i>	Universal Pictures & Amblin Entertainment

visitors each year to experience and learn about paleontology. Local chambers of commerce and offices of tourism recognize and utilize the power of paleontology in drawing tourist dollars to small towns such as Vernal, Utah, near Dinosaur National Monument, or Kemmerer, Wyoming, near Fossil Butte National Monument. Fossils are sometimes incorporated into advertising in order to draw tourists to discover the paleontological heritage of the American west.

For the ultimate fossil getaway, the Best Western Denver Southwest is another dinosaur-themed destination catering to the paleontologically inspired traveler. Located in Lakewood, Colorado, the hotel décor is dominated by a Mesozoic menagerie of skeletal remains to inspire the would-be paleontologist, young or old. The hotel is located near several fossil attractions including the Denver Museum of Nature and Science and the Morrison – Golden Fossil Areas National Natural Landmark featuring Dinosaur Ridge, Fossil Trace and the *Triceratops* Trail (<http://nature.nps.gov/nnl/site.cfm?Site=MOGO-CO>).

The use of fossils and dinosaurs in marketing, advertising and merchandising has been designed and constructed on the notion that people are attracted to these prehistoric icons. The Sinclair Oil dinosaur is perhaps one of the most familiar examples of dinosaur-focused marketing (Fig. 5). First introduced in 1930, the Sinclair “*Brontosaurus*” gained fame at the Chicago World Fair “Century of Progress” during 1933–1934. The dinosaur exhibit was displayed at

the 1936 Texas Centennial Exposition and the New York World’s Fairs during 1939–1940 and, again, in 1964–1965. During the most recent exhibition, the Sinclair dinosaurs made a dramatic appearance in New York City with a *Triceratops* sculpture being delivered by helicopter and several dinosaurs traveled by barge on the Hudson River. Today, Sinclair dinosaur merchandise and souvenirs are popular collectibles in antique shops and on Ebay.

There are many examples of prehistoric animal sculptures, sometimes life-size, which are used as popular roadside attractions for travelers. Along Interstate 90 in western South Dakota, the famous Wall Drug in Wall, South Dakota, has a life-size sauropod model on display. The attraction is one way that Wall Drug helps to draw in customers to purchase a meal and buy souvenirs in their world-renowned business. There are dozens of examples of businesses and community recreational parks featuring models or sculptures of prehistoric animals to attract users.

Fossil and dinosaur toys, games, figures and other merchandise have been popular sales items for children and adults. There are quite a few Ph.D. paleontologists in museums and universities that have these fossil toys on display in their offices. A number of competing companies have produced authentic plastic replicas of prehistoric creatures, especially the dinosaurs. Louis Marx and Company (MARX) began producing dinosaur toy sets in the 1950s, and has been followed

TABLE 2. (continued)

RELEASE DATE	FILM TITLE	PRODUCTION COMPANY
May 21, 1993	<i>Carnosaur</i>	New Horizons Picture
February 12, 1992	<i>Adventures in Dinosaur City</i>	Smart Egg Pictures
March 22, 1985	<i>Baby: Secret of the Lost Legend</i>	Silver Screen Productions & Touchstone Pictures
April 17, 1981	<i>Caveman</i>	Turner Foster Company
August 27, 1979	<i>Planet of Dinosaurs</i>	Deathbeast Productions
August 17, 1977	<i>The People that Time Forgot</i>	American International Pictures
March 1, 1977	<i>The Crater Lake Monster</i>	Crown International Pictures
February 11, 1977	<i>The Last Dinosaur</i>	Rankin Bass Productions
August 13, 1975	<i>The Land That Time Forgot</i>	Amicus Productions & Lion International
March 17, 1971	<i>When Dinosaurs Ruled the Earth</i>	Hammer Films
July 19, 1969	<i>Valley of the Gwangi</i>	Morningside Productions
February 21, 1967	<i>One Million Years B.C.</i>	Associated British Pathe & Hammer Films
May 19, 1965	<i>Journey to the Beginning of Time</i>	Ceskoslovensky Statni Film
March 21, 1961	<i>Gorgo</i>	King Brothers Productions
August 10, 1960	<i>Dinosaurs!</i>	Fairview Productions
July 13, 1960	<i>The Lost World</i>	20th Century Fox Film Corporation
January 14, 1960	<i>Journey to the Center of the Earth</i>	20th Century Fox Film Corporation
March 3, 1959	<i>The Giant Behemoth</i>	Artistes Alliance Limited. & Diamond Pictures Corporation
October 1, 1957	<i>The Animal World</i>	Irwin Allen Productions
August 1, 1957	<i>The Land Unknown</i>	Universal International Pictures
August 1, 1956	<i>The Beast of Hollow Mountain</i>	Nassour Studios
April 27, 1956	<i>Godzilla: King of the Monsters</i>	Toho Company & Jewell Enterprises Inc.
June 17, 1955	<i>King Dinosaur</i>	Zimgor Productions
June 13, 1953	<i>The Beast from 20,000 Fathoms</i>	Jack Dietz Productions
August 17, 1951	<i>Lost Continent</i>	Sigmund Neufeld Productions
April 5, 1940	<i>One Million B.C.</i>	Hal Roach Studios
April 7, 1933	<i>King Kong</i>	Radio Pictures
June 22, 1925	<i>The Lost World</i>	First National Pictures

in recent decades by Safari Ltd.'s "Carnegie Collection," Invicta Inc., Battat Inc., Papo Co., Schleich Co., and several other companies (<http://www.dinosaur-toys-collectors-guide.com/toy-companies.html>).

Many libraries and bookstores have shelves filled with children's books about dinosaurs. Some of the classic and vintage books such as the "How and Why Wonder Books on Dinosaurs & Prehistoric Mammals," "The Golden Book on Dinosaurs," "Danny and the Dinosaur," and the more recent "Magic School Bus: In the Time of the Dinosaur," have inspired millions of junior paleontologists. For adult readers, Edgar Rice Burroughs' "Land That Time Forgot" (1924) or Michael Crichton's "Jurassic Park" (1990), were best-selling books for the grown-up paleontology enthusiasts.

Whatever the motivation, passion or factor which links humans to fossils, there are clearly economic benefits and consequences associated with the sale of actual or replica fossils, prehistoric-themed merchandise and entertainment. Future social science research evaluating the human dimensions of paleontological resources may enable us to better understand the basis of the economy of paleontology and to better understand how to answer questions such as "How much is that dinosaur in the window?"

ETHICAL CONSIDERATIONS FOR PALEONTOLOGICAL RESOURCES

In the assessment of the human dimensions of paleontological resources, a consideration of any ethical or moral issues pertaining to fossils would be worth investigating (http://serc.carleton.edu/research_education/paleontology/ethics.html accessed July 2016). Ethics,

or more specifically moral philosophy, is the branch of knowledge pertaining to moral principles and the concepts of right or wrong pertaining to human behavior and decision-making. This review is not intended to specifically address those right or wrong opinions related to paleontological resources, but rather to provide a few examples of considerations which are ethical in nature.

The first and most fundamental consideration related to the fact that fossils are non-renewable resources which possess scientific and educational values. Although various fossils may be abundant or rare in the fossil record, they all are non-renewable. Therefore, should our behavior and decision-making relative to fossils include consideration that they are non-renewable resources? This topic is worthy of extensive scholarly and resource management discussion.

Directly tied to the non-renewable nature of paleontological resources is the fact that there are many genera and species of fossil taxon which are known from only a single specimen of that extinct group of organisms. It is widely acknowledged by taxonomists and paleontologists that most of the prehistoric life forms that once inhabited the Earth are not yet known from fossils or described in the scientific literature. Perhaps many of these forms will never be known to science due to a variety of factors. However, there is an ethical question involving those rare or one-of-a-kind fossil specimens pertaining to access and preservation of the specimen. Since a single specimen of an ancient group may provide the only available data for scientific research or public education, should there be any ethical considerations relative to scientific or public access to these rare specimens? Should rare or one-of-a-kind specimens be viewed in the

TABLE 3. List of dinosaur and fossil themed animation movies, release dates, and production company.

RELEASE DATE	ANIMATION FILM TITLE	PRODUCTION COMPANY
July 26, 2016	<i>Ice Age: Collision Course</i>	20th Century Fox Film Studios & Blue Sky Studios
November 25, 2015	<i>The Good Dinosaur</i>	Walt Disney Pictures
July 13, 2012	<i>Ice Age: Continental Drift</i>	20th Century Fox Film Studios & Blue Sky Studios
July 7, 2011	<i>March of the Dinosaurs</i>	Wide-Eyed Entertainment
July 1, 2009	<i>Ice Age: Dawn of the Dinosaurs</i>	20th Century Fox Film Studios & Blue Sky Studios
March 30, 2007	<i>Meet the Robinsons</i>	Walt Disney Pictures
March 23, 2006	<i>Ice Age: The Meltdown</i>	20th Century Fox Film Studios & Blue Sky Studios
March 15, 2002	<i>Ice Age</i>	20th Century Fox Film Studios & Blue Sky Studios
May 19, 2000	<i>Dinosaur!</i>	Walt Disney Pictures
November 24, 1993	<i>We're Back! A Dinosaur's Story</i>	Universal Pictures & Amblin Entertainment
November 18, 1988	<i>The Land Before Time</i>	Universal Pictures & Sullivan Bluth Studios
November 5, 1985	<i>Prehistoric Beast</i>	Tippett Studio
November 17, 1918	<i>The Ghost of Slumber Mountain</i>	Herbert M. Dawley Productions
1915	<i>The Dinosaur & the Missing Link: A Prehistoric Tragedy</i>	Conquest Pictures & Herman Wobber
September 15, 1914	<i>Gertie the Dinosaur</i>	Windsor McCay & Vitagraph Company of America

same context as an endangered species of modern biota? Should there be safeguards or provisions in place to ensure that one-of-a-kind fossils are not lost to science? Is there a human desire to ensure that we strive to preserve the most complete understanding for the fossil record of life available to science and education? Do we have a responsibility to all of those fossil-loving school children to ensure the highest level of integrity and completeness of the fossil record? Additional ethical questions involving rare fossil specimens should be evaluated through future research.

Shimada et al. (2014) consider the commercialization of fossils as the greatest challenge to 21st century paleontology and that it threatens the science. The hotly debated topic of commercial versus scientific fossil collecting dates back at least four decades (Padian, 2000; Shimada, et al., 2014). Attempts to address some of the ethical issues related to commercial and scientific fossil collecting have been incorporated into Codes of Ethics adopted by both the Society of Vertebrate Paleontology (<http://vertpaleo.org/Membership/Member-Ethics/Member-Bylaw-on-Ethics-Statement.aspx> accessed July 2016) and the Association of Applied Paleontological Sciences (previously known as the American Association of Paleontological Suppliers <http://www.aaps.net/ethics.htm> accessed July 2016). The online auction website Ebay has developed a webpage addressing the ethics associated with buying and selling fossils online (<http://www.ebay.com/gds/Buying-Fossils-Law-Ethics-Forgeries-/10000000001926697/g.html> accessed July 2016).

Another important ethical consideration related to paleontology involves the legality and permission for the physical collection of fossils from geologic strata. Authorized fossil collection should only be undertaken with the informed permission/consent from the landowner (if private lands) or from the appropriate government agency authorized to administer the lands and resources. Illegal fossil collecting has been widespread in the United States and includes documented cases of fossil theft incidents from public lands and even a few cases of fossil theft from museums. Illegal fossil collecting is an ethical breach worth assessing both in the United States and internationally (Kim and Weiler, 2013).

A related ethical consideration in paleontology involves the intentional falsification of the locality information from which the fossil was collected. In some instances, the actual locality information for a fossil may not be disclosed in order to conceal the fact the specimen was collected in an area where the removal of the fossil was not permitted or prohibited. Clearly, the falsification of fossil locality information is unethical and unscientific and compromises the integrity of the scientific information associated with the paleontological specimen.

There are a number of other potential ethical issues associated with paleontological resources, including: the creation and sale of fossil

forges; poor collecting techniques which lead to damage or loss of scientifically important fossil specimens; and the illegal international trade in fossil specimens involving countries which prohibit the collection or export of fossils as defined in that country's laws. Some of these ethical considerations may be influenced by the rapid escalation of fossils on the commercial fossil market, where the financial rewards may outweigh the risks or influences related to laws and ethics.

PALEONTOLOGICAL RESOURCE CRIMES AND DEPRECIATIVE BEHAVIORS

Paleontological resource theft and vandalism is documented in countries around the world (Mamalis, 2012; Roof, 2012). The U.S. National Park Service maintains data extending back to 1991 documenting incidents of paleontological resource crimes, including fossil theft and vandalism. Hundreds of individual case incidents related to fossil crimes in national parks illustrate the need for social science research to better understand those variables that may contribute to inappropriate behaviors by park visitors to the fossil parks. The unfortunate story of Fossil Cycad National Monument exemplifies the extent of resource degradation that can occur to non-renewable paleontological resources (Santucci and Hughes, 1998; Santucci and Ghist, 2014). In this case, a unit of the National Park Service was abolished due to the complete removal of rare plant fossils at the surface through unauthorized collecting.

The pioneering social science research assessing human behaviors linked to paleontological resources was undertaken by the faculty at Virginia Tech during the 1990s. The National Park Service documented several decades of unauthorized collecting of petrified wood by visitors to Petrified Forest National Park, Arizona. Funding was obtained by the National Park Service to support a three-year study to assess visitor attitudes, perceptions and behaviors associated with the petrified wood during visits to Petrified Forest National Park (Widner and Roggenbuck, 2000, 2003). This research provided the National Park Service with social science data that park managers could use for public education, interpretive media, and effective messaging to deter the unauthorized "souvenir" collecting of petrified wood by park visitors.

The seminal work of the VA Tech team was adapted to assist the National Park Service at Fossil Butte National Monument, Wyoming, by assessing visitor attitudes, perceptions, and behaviors associated with the fossils present at Fossil Butte National Monument (Roggenbuck and Hockett, 2002, 2003; Hockett, 2008). The area surrounding Fossil Butte National Monument represents the largest commercial operations for the collection of fossil vertebrates in the United States. The commercial fossil industry in southwestern Wyoming is an important revenue-generating enterprise and enhances tourism in an economically

depressed area. Hockett (2008) evaluated how the commercial interests and economic values associated with fossils in southwestern Wyoming may have influenced visitor attitudes and behaviors during their visit to Fossil Butte National Monument.

FUTURE WORK

This initial attempt to understand the scope of human values, attitudes, motivations and behaviors associated with paleontological resources demonstrates a rich and interesting relationship between people and fossils. Future research which measures human attitudes and behaviors pertaining to fossils will enable the correlation of these variables to the values people identify with and assign to our paleontological heritage resources.

A fundamental first step for future social science research would be to acquire demographic information in conjunction with any surveys assessing human values, perspectives and motivations related to fossils, along with their enjoyment, use, and management. Once baseline human dimension data for fossils are available, there will be the ability to evaluate and monitor how human values, motivations and other factors change over time or among different social groups. Further, these data can potentially serve as indicators to assess how social variables influence thinking and behavior. Additionally, these data will be valuable for determining strategies to address conflict relative to legal, ethical and other considerations involving the enjoyment, use, and management of paleontological resources.

Further information can be gained by targeted research on the traits of people who have already taken an active role in support of paleontology outreach and fossil resource conservation. The National Fossil Day partnership includes more than 335 partners across the U.S. According to the American Geosciences Institute, National Fossil Day and Earth Science Week reach tens of millions of people annually. The National Fossil Day partnership includes a wide range of stakeholders from professional to amateur paleontologists celebrating America's Paleontological Heritage. Future research should include social science surveys of the National Fossil Day participants and partners in order to further illuminate our understanding of the human dimensions that lead to advocacy, stewardship and volunteer participation.

The rich story regarding the history and evolution of life on Earth is worth preserving and sharing. This story has inspired and continues to inspire generations of children living in every corner of the Earth. Some of these children never lose their childhood fascination about dinosaur and other prehistoric creatures and carry this enthusiasm forward throughout life. In life's journey from a junior paleontologist to a senior paleontologist, there are some yet undiscovered human dimensions associated with fossils that wait to be uncovered through future research.

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