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BEST PRACTICES IN MITIGATION PALEONTOLOGY

By

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Abstract

Mitigation paleontology focuses on the recovery and preservation of paleontological resources (fossils) that are threatened by ground disturbance associated with land and energy development projects. Mitigation includes the assessment of potential impacts and the development of measures to reduce or eliminate adverse impacts to scientifically important fossils, as well as the implementation of those measures. After several decades of steady progress with the development of standard procedures and regulatory guidelines for the assessment and mitigation of impacts, we present what we hope will become industry-wide standard operating procedures. These practices are methods and techniques that we believe have shown results superior to those achieved by other means and are used as a benchmark for judging the adequacy of mitigation work. These standards present a consistent way of doing things that multiple organizations can adhere to, and they are intended to evolve and improve over time. In this paper, we offer comprehensive and detailed best practices for the mitigation paleontology community that fall into 10 categories: 1) qualifications 2) land ownership and permitting, 3) analysis of existing data, 4) field data collection, 5) field surveys, 6) construction monitoring, 7) fossil specimen recovery, 8) data management and reporting, 9) curation facilities, and 10) business ethics and scientific rigor. Our purpose, based on our own experiences and with input from the wider mitigation community, is to establish standard procedures that are successful in maintaining a rigorous scientific standard while promoting integrity in the industry in order to accomplish the common goal of paleontological resource preservation via impact mitigation.

INTRODUCTION

Since the 1970s, regulatory protections for scientifically important paleontological resources, or fossils, have resulted in the recovery of vast numbers of these nonrenewable resources in the western United States—and many of these fossils were literally plucked from the path of bulldozers. From city and county regulations designed to protect paleontological resources from earth-moving operations at residential and commercial construction sites in southern California, to state and federal policies developed largely in response to the increasing use of public lands by large-scale energy development projects for oil, gas, wind, and solar energy, the trend is clearly toward resource management policies that promote resource preservation. The efforts of those who have been involved with policy development and implementation are laudable. After all, the recognition that paleontological resources are worthy of preservation and protection is an acknowledgement of their scientific value as finite and irreplaceable evidence of the history of life. The many benefits to science are illustrated by the vast amount of research that has been based on fossils collected as the result of impact mitigation projects.

Not surprisingly, paleontological resource regulatory requirements have created a new niche for paleontologists. The growing demand for mitigation paleontologists has to date resulted in at least two generations of paleontologists who, in addition to their academic and field training in paleontology, have expertise in working with fossils and associated rock strata exposed under the incredibly challenging field conditions that exist at construction sites, some of which are vast and in remote locations.

The last 20 years have seen an increase in employment opportunities for mitigation paleontologists—this at a time when funding to higher education and public funding for natural history museums has been sharply declining. In light of this, it is useful to consider the value, purpose, and goals of the emerging profession of mitigation paleontology. As applied scientists, mitigation paleontologists are typically hired by private companies or, less frequently, by government agencies. Under contract to such a client, a specific service, or set of services (scope of work), is provided. These services are often required in order to achieve regulatory compliance for the client's project. Common deliverables often include a final project report, which is often necessary for the project proponent to obtain an environmental clearance for their project in the form of a license or permit, and/or to prepare other supporting environmental documents. A paleontological technical report may include recommendations for additional work that is needed in order to adequately mitigate potential impacts to fossils that would be exposed, damaged, destroyed, or displaced as the result of project construction. An additional common work product is a collection of fossils typically made either prior to or during construction, or both. The prepared and identified fossils, along with associated data, are ultimately transferred to an approved curation facility. Such facilities are typically museums that are approved by the government agency that issues the paleontological resource use permit and/or construction permit.

Mitigation paleontologists, as applied scientists, have the contractual responsibility to help their clients achieve their objectives in a manner that complies with agency regulations and meets accepted scientific standards as well as the expectations of the institutions with which they hold curation agreements. It is the added, although regrettably more nebulous, responsibility of mitigation paleontologists to ensure that all paleontological work is done to an acceptable standard of scientific rigor so that detailed, reliable data accompanies every fossil. Unless specifically requested by a client, it is typically not the purview of the mitigation paleontologist to conduct research on the fossils they collect under contract, but rather to ensure that the fossils and associated data are in a condition that is suitable for research upon arrival at the curation facility.

Despite legislative achievements such as the Paleontological Resources Preservation Act (PRPA) of 2009 (OPLA-PRP 2009), and the many benefits to science resulting from paleontological resource impact mitigation, significant challenges related to scientific integrity and ethical business practices exist and must be addressed. Some examples of ethical issues include construction contractors instructing paleontological subcontractors at a project site to sit in their vehicles so they do not find any fossils in order to avoid incurring additional costs, reporting that adequate field surveys have been completed via so-called "windshield surveys" or "drive-by surveys," staffing projects with "cross-trained" archaeological monitors who do not possess sufficient paleontological knowledge to properly document and collect fossils, or failing to curate fossils collected from mitigation projects in appropriate curation facilities—there are far more examples than can be listed here.

If left unchecked, these and many other unethical practices will continue to undermine regulatory intent and do a disservice to the very resources that these laws were designed to protect. What's more, such practices are not consistent with preserving paleontological resources using scientific principles and expertise, which should be the goal of all paleontologists and involved agencies regardless of the jurisdictional applicability of federal and state laws and local ordinances. The root of the problem is a compounding of three primary factors: 1) market forces that reward the lowest bidder with the most consulting contracts because of a lack of incentive to pay for quality; 2) an unwillingness or inability on the part of managing agencies due to lack of resources, knowledge, or authority to provide consistent and meaningful oversight and ensure compliance with appropriate laws and policy, leading to a situation where permittees are not held accountable for the quality and quantity of their work; and 3) a lack of proper training and/or ethical standards.

With recent industry growth and more paleontologists (and non-paleontologists) striving to work in the field of impact mitigation, it is our belief that a critical juncture has been reached. Paleontologists working in this field need to develop and implement industry-wide standard operating procedures based on rigorous and scientifically defensible principles. The purpose and goal of this paper is therefore, with a degree of urgency, to articulate the problems and challenges that currently exist in the field of mitigation paleontology and to offer an effective path toward a solution. We present a set of detailed, comprehensive best practices in mitigation paleontology that are intended to be complimentary to other existing standards and procedural guidelines such as those of the Society of Vertebrate Paleontology (SVP) and those federal, state, and local agencies that have already developed such standards and guidelines. This paper does not represent agency policy, which is a topic worthy of a separate paper. Nor is it our purpose to convey paleontological and geological knowledge or field skills, which are also required prerequisites for practicing mitigation paleontology. Rather, with a combined perspective gained from working on well over a thousand mitigation projects over a period of decades, our focus is on fostering quality and consistency among the day-to-day tasks of background research, data management, field surveys, construction monitoring, fossil recovery and preparation, reporting, "museum" curation, business practices, and scientific rigor. Of course, not all best practices apply to every mitigation project, and the order and manner in which best practices should be most effectively applied may vary from project to project. This paper provides a comprehensive and detailed presentation on best practices in mitigation paleontology with input from the community of mitigation paleontologists. It proposes a high scientific standard and challenges those who work as mitigation paleontologists to work to accomplish our shared objective—to achieve the goals of our clients while preserving nonrenewable paleontological resources and associated data so that they can be stored in perpetuity to advance scientific understanding of the history of life.

History and Scientific Contributions

Given the stereotypical image of paleontologists collecting fossils in remote, picturesque badlands, many people are surprised to learn just how many fossils have been discovered in mining and construction excavations, and how many of these discoveries have been made in areas with few or no opportunities for fossils to be found in natural outcrops due to lack of exposed sedimentary bedrock. Classic examples of such discoveries include remains of the first formally named nonavian dinosaur, *Megalosaurus bucklandii* (recovered from the Stonesfield limestone quarry near Oxford, England); the first recognized fossil remains of the ornithopod dinosaur, *Iguanodon* (recovered from the Whitemans Green quarry, near Cuckfield, England); famous fossils of *Archaeopteryx lithographica* (recovered from the lithographic limestone quarries near Solnhofen, Germany); the spectacularly preserved Messel plant and vertebrate fossils (recovered from the Messel Pit bituminous shale quarry in Messel, Germany); and the renowned Rancho La Brea Pleistocene fossil assemblages (initially recovered from commercial asphalt quarry excavations in Los Angeles, California, U.S.A.), to name just a few. Today, excavations for development—natural gas and oil well pads, pipelines, electrical transmission lines, renewable energy generation facilities, coal mines, gravel pits, landfills, new and existing highways, railway alignments, above- and belowground public transportation systems, housing developments, commercial developments, urban developments, and underground parking structures—provide excellent and often unique opportunities for paleontologists to access fossils and the strata in which they are preserved in settings that may not have been made available via natural processes of weathering and erosion. Most major natural history museums in the western United States house substantial collections of fossils recovered as a result of fossil recovery projects at construction sites.

Following the first formal gathering of mitigation paleontologists at an annual meeting of the SVP in 2013, a subset of the authors of this paper (Knauss, Fisk, and Murphey) posted an online survey, the purpose of which was to prepare a report on the demographics of mitigation paleontology (Knauss et al. 2014). In conjunction with the survey, an effort was launched to compile a comprehensive database of peer-reviewed scientific publications, theses, and dissertations that involve fossils collected as the result of mitigation paleontology. The total number of such publications is in the hundreds. Furthermore, based on the preliminary data from the published literature, combined with data obtained from museums and other curation facilities, we estimate the total number of curated fossil specimens from mitigation projects to be in the millions. Included in this is an ever-increasing number of holotype specimens representing species new to science.

History of Mitigation Paleontology in the United States

For more than a century, the importance of preserving the cultural and natural heritage of the United States has been recognized and addressed by legislation, including the Antiquities Act of 1906, the National Environmental Policy Act (NEPA) of 1969, the Federal Land Policy and Management Act of 1976, and the California Environmental Quality Act (CEQA) of 1970. A primary goal of these legislative actions was to require agencies to address concerns about development and other land uses that might impact significant and nonrenewable natural resources, including paleontological resources. CEQA specifically requires California state and local agencies "to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible." Local agencies such as county and city planning departments are tasked with maintaining compliance with CEQA and NEPA, thereby reducing impacts on resources.

Following the passage of CEQA in 1970, Orange County was the first county in California to require mitigation of impacts to paleontological resources. The urban development of Orange County accelerated rapidly in the early 1970s and concerned citizens and scientists, including John Cooper, Carol Stadum, Larry Barnes, Mark Roeder, and Rod Raschke, lobbied for regulations to protect paleontological resources in the county as development increased and more land was disturbed (Babilonia et al. 2013). In response to these lobbying efforts, in 1972 the Mission Viejo Company hired one of the first paleontological monitors, Paul Kirkland. In 1976, as part of the conditions of approval for development, the Orange County passed the first paleontological mitigation guidelines, Resolution No. 1977-866 (Orange County Resolutions 1977), requiring monitoring and salvage of fossils as part of the development process. This was followed a decade later by passage of Resolution No. 1987-516 (Orange County Resolutions 1987), requiring donation of paleontological finds from sites in unincorporated parts of Orange County to a central county facility "for the purpose of promoting scientific study and for display for the education and enjoyment of the people of Orange County" (Eisentraut and Cooper, unpubl. report).

These municipal resolutions required preconstruction surveys, impact assessments, and construction mitigation measures to prevent the destruction of fossils. However, although thousands of fossils were collected and housed at an Orange County facility, there were no provisions for these fossils to be accompanied by adequate field data or to be prepared, stabilized, and professionally housed in perpetuity in a repository where they could be retrieved for study. Even today, Orange County does not require that developers provide funds for preparation and curation of collected specimens. In 2009, Orange County Parks and California State University (CSU) at Fullerton entered into a 5-year agreement to provide funding for staffing and managing a curation facility that meets the modern standards of professional collection care. However, in 2018 the County of Orange took back management of the facility from CSU Fullerton, and although it is unknown how this change in management will eventually play out, the John D. Cooper Archaeological and Paleontological Center ("Cooper Center") in Santa Ana remains Orange County's authorized curatorial facility, with a large and growing collection of paleobotanical, invertebrate, and vertebrate fossils that document the paleontological record preserved in the sedimentary rocks of Orange County. Although still largely unstudied, this collection is beginning to attract the attention of numerous research paleontologists, students, and citizen scientists.

When adjacent California counties—Los Angeles, Riverside, San Bernardino, and San Diego—began to rely on mitigation paleontologists from Orange County to mitigate impacts, established museums in those four counties began to feel the burden of receiving large volumes of unprepared specimens without compensation for preparation and cabinet/storage space. Starting in the late 1970s, Robert (Bob) Reynolds, Earth Science curator at the San Bernardino County Museum and member of the San Bernardino County Environmental Review Committee, arranged meetings with museum curators and paleontological contractors to discuss differing standards, methods of recovery, and the unsustainable practice of "dumping" collected specimens at museums or in warehouses. Participants in these discussions sought to create standard guidelines that would make assessment and collection programs, methods of recovery, preparation and stabilization, and curation of specimens and associated field data "conformable."

Discussions focused on the necessity for advanced scoping of potential impacts using sensitivity maps; the need for adequate preconstruction assessment (including record and literature searches and field surveys); the importance of adequate full-time monitoring and criteria for reducing monitoring effort to half-time or spot-checking; the scientific value of salvaging not only skulls, but also postcranial remains, small and microscopic vertebrate fossils, and associated environmental and habitat indicators; the necessity of preparation of specimens to a point of identification (thereby concurrently reducing storage volume and costs); and the need for funding for the curation of specimens, field data, and reports into an established repository.

In 1980, the City of Chula Vista in San Diego County began requiring residential developers to implement paleontological resource mitigation programs during mass grading operations. Soon other cities in the county (i.e., San Diego, Vista, Carlsbad, Oceanside, National City, and La Mesa) followed suit. The result was that a wealth of fossils ranging from Cretaceous ammonites, mosasaurs, and dinosaurs to Pliocene scallops, walruses, and baleen whales began to be collected from the upper Cretaceous through Pleistocene stratigraphic sequences along the coastal plain of San Diego County. By the early 1990s, even the California Department of Transportation (Caltrans) began to realize the significance and benefits of paleontological mitigation in the District 11 region (San Diego and Imperial counties) and issued the first on-call paleontological resource mitigation contract in state history. Fossils collected from District 11 roadway projects, together with fossils from the rampant growth of residential and commercial development in San Diego County during the 1980s and 1990s, were deposited at the San Diego Natural History Museum (SDNHM). From the very beginning, the staff of this regional education, research, and curation facility realized the importance of avoiding the problems faced by Orange County in terms of the impact on institutions of receiving large amounts of unprepared, unidentified, and uncurated fossils. Fortunately, city and state environmental planners based in San Diego County also realized these potential problems and required paleontological mitigation contracts in the region to include provisions for preparation, curation, and long-term storage of collected fossils. The result was that fossils reposited, prepared, and curated at SDNHM are immediately accessible for research and educational purposes.

However, other regions of southern California were not faring as well during this period and seeing what was happening, Michael Woodburne, then president of SVP and a member of its Government Liaison Committee, appointed Bob Reynolds to chair the SVP committee for Conformable Impact Mitigation in 1990. The existing southern California guidelines, already tested in the states of California, Nevada, and Arizona on utility projects crossing federally (Bureau of Land Management [BLM]) administered lands as well as lands managed by counties and municipalities, were used as a template for guidelines that could be applied to agency-managed lands elsewhere in the western states. A draft of the SVP "Standard Measures" was distributed for review in 1991 (SVP 1991). The revised SVP "Standard Guidelines" were published in 1995 (SVP 1995), and to strengthen the position of museums receiving mitigation collections, in 1996 the SVP "Impact Committee" issued "Conditions of Receivership" (SVP 1996). During 2009 and 2010, the SVP Standard Guidelines were reviewed, revised, and expanded by the Conformable Impact Mitigation Committee, cochaired by Lanny Fisk and Bob Reynolds. The revised Standard Procedures are available online (SVP 2010).

In 2009, the Paleontological Resources Preservation Act (PRPA) was signed into law by President Barack Obama as part of the Omnibus Public Land Management Act (OPLA-PRP 2009). PRPA requires that coordinated policies and standards be developed that apply to fossils on federal public lands. Section 6302 of the PRPA mandates that federal agencies "manage and protect paleontological resources on Federal land using scientific principles and expertise." Thus, federal agencies began looking to the professional paleontological community to implement these PRPA-mandated policies and regulations. It was partially in anticipation of new regulations that in 2009 the SVP reactivated the Conformable Impact Mitigation Committee as the Impact Mitigation Guidelines Revision Committee and invited input from federal and state land management agencies.

With the presentation of impact mitigation measures/guidelines/procedures by the SVP in 1991, 1995, 1996, and 2010, western states, federal agencies, counties, and other municipalities were able to adopt guidelines that would support the preservation of paleontological resources and associated data. In California, southern counties and several in the Bay Area (thanks largely to the efforts of Bruce Hanson) adopted guidelines. Examples were developed for the BLM's California Desert Conservation Area (BLM 1986), Riverside County (2015), and San Diego County (2007; updated 2009). Updated versions of these mitigation guidelines were prepared for the Needles (USFS 2005) and Barstow BLM (BLM 2008) field offices. With agency-specific modifications, Caltrans (2012) adopted similar guidelines.

As use of public lands increased from the late 1980s into the 2000s, largely tied to a surge in energy development projects (especially oil and gas), there was an increase in demand for mitigation paleontologists in the Intermountain West, particularly in parts of Colorado, Wyoming, and Utah. Initially, the demand was met by paleontologists who were employees or associates of museums, including the Utah Field House of Natural History Museum, the University of Colorado Museum, the Museum of Western Colorado, the Idaho Museum of Natural History, and the University of Wyoming Geological Museum. Small firms and independent consultants were soon established, agency positions were added (including state paleontologists in Utah and North Dakota, highway department paleontologists in Colorado and Nebraska, and BLM and United States Forest Service [USFS] paleontologists in Colorado, Utah, Wyoming, Montana, New Mexico, and Nebraska), other museums became involved, and at least 2 larger environmental firms established dedicated paleontological resource programs. The BLM developed procedural guidance for paleontological resource management (BLM 1998), which included assessment and mitigation procedures, permitting and reporting requirements, and a resource management classification system (Conditions 1–3). The USFS revised its Fossil Yield Potential Classification (FYPC) system (USFS 2005), and the BLM adopted its own version of the FYPC, the Potential Fossil Yield Classification system (PFYC) in 2007 and updated it in 2016 (BLM 2007, 2016). In 2013, the USFS developed the Paleontological Resources Rapid Assessment System to replace their FYPC system. In 2008, the BLM released revised procedural guidelines for the assessment and mitigation of potential impacts to paleontological resources. Regulations under the PRPA were published by the USFS in 2015 (USFS 2015) and are presently undergoing development at the Department of the Interior (DOI 2016).

METHODS

Much of the information in this paper was gathered and synthesized by the authors based on their own experiences in mitigation paleontology. Additional information and input was obtained from colleagues working as consultants, in museums, and for government agencies. Fact-checking with regard to the standard archaeological procedures discussed in this paper was done in collaboration with cultural resource management (CRM) professionals. Agency paleontologists were consulted for the purpose of fact-checking paleontological resource laws, regulations, and policies.

An earlier version of this paper was published in *Dakoterra*, the Proceedings of the 10th Conference on Fossil Resources, held at the South Dakota School of Mines and Technology (Murphey et al. 2014). The intent of the earlier version was to generate interest and discussion concerning the proposed 10 best practices among the community of mitigation paleontologists, including our agency and museum partners. Following the conference, an online survey was circulated as a means of providing feedback on the best practices and details thereof. Twenty individuals responded with individual comments on the best practices and their specific subparts. The survey results were carefully reviewed and analyzed, and the vast majority of suggestions were incorporated into this greatly modified and improved second edition. It is expected that the best practices described herein will evolve over time. However, thanks to the valuable input of the survey participants and users of this document, it will serve as a critical road map for professionalizing the practice of mitigation paleontology, thus increasing the potential of achieving scientific rigor with professional integrity for the shared goal of the preservation of paleontological resources.

Each of the 10 revised best practices detailed in this paper include subparts. The best practices and subparts are summarized in Appendix I, and for quick reference, the text of the paper includes reference numbers that correspond to numbered best practices and subparts in the appendix.

Best Practice Categories

The following sections of this paper detail the 10 categories of best practices, each of which include subparts which are summarized in Appendix I.

1. QUALIFICATIONS

Any consideration of minimal qualifications to work in mitigation paleontology must include justifications for why such qualifications are necessary, as well as consideration of the problems resulting from nonqualified practitioners engaging in impact mitigation work. Our intention here is not to judge the adequacy of current agency criteria for vetting paleontologists (where they exist), but rather to establish a baseline set of minimal qualifications for field paleontologists (technicians/surveyors/monitors), field supervisors, principal investigators, and laboratory paleontologists that can serve as industry best practices (Appendix I, 1.1). The obvious answer to why qualifications are necessary is that these qualifications ensure that work is completed according to established professional standards (see SVP 1991, 1995, 1996, 2010), including the best practices described herein, and in compliance with procedural guidelines, if any, of the overseeing lead agency (e.g., see BLM 2008). To any paleontologist, the problems with nonqualified practitioners doing paleontology are patently obvious. With no disrespect intended for the vast majority of highly knowledgeable and ethical archaeologists, the fact is that many archaeologists, and to a lesser extent geologists without paleontological training, have taken on mitigation paleontology projects falsely presuming that their education and field experience renders them competent in mitigation paleontology.

We recognize that few paleontologists have degrees in paleontology because few institutions offer degrees in paleontology. Typically, paleontologists earn degrees in geology or biology with an emphasis in paleontology. Academic training and field experience in sedimentary geology is an important prerequisite to work in mitigation paleontology. The aforementioned four categories of paleontological mitigation personnel are not intended to correspond to paleontological mitigation personnel categories developed by agencies, but rather to clearly represent the roles and responsibilities that have proven to achieve the best results across the spectrum of mitigation paleontological projects over several decades. Henceforth, we refer to principal investigators and field supervisors as “professional mitigation paleontologists.”

Confusion between Resource Disciplines

Although there are archaeologists and biologists who have sufficient expertise to work in more than one discipline, and registered professional geologists who have sufficient expertise in paleontology, it should never be assumed that any archaeologist, biologist, or geologist is qualified to do mitigation paleontology. Likewise, it should not be assumed that all paleontologists have sufficient training and expertise to be considered professional mitigation paleontologists. Paleontologists who specialize in morphology, taxonomy, or phylogeny of specific taxonomic groups may not have the knowledge needed in stratigraphy, taphonomy, or with other taxonomic groups, let alone the training needed to mitigate construction-related adverse impacts on paleontological resources. Thoroughly vetting all individuals in order to ensure their professional competency to work as mitigation paleontologists is critical. The proof is that this practice, when it has been well implemented, has been directly responsible for the successful recovery of countless scientifically important fossils and associated data from construction sites over the last 30+ years, resulting in the preservation of large numbers of important fossil collections and the production of a vast body of published scientific research. Ultimately, a universally effective solution to the problem of ensuring professional competency may be a professional registration process similar to that of the “Registered Professional Archaeologist,” a process that was developed to ensure that only properly trained archaeologists conduct archaeological work.

Unfortunately, the seed for the confusion between paleontological and archaeological resources was unknowingly planted by land managers and municipal planners who, several decades ago, programmatically included paleontological resource management within cultural resources (and archaeology). This confusion still permeates many agencies, municipal planning departments, and private firms in the environmental consulting industry. The two disciplines are also inextricably linked in our popular culture, much to the frustration of archaeologists who often get questioned about dinosaurs, and paleontologists who often get questioned about projectile points. The fact is that in the Western Hemisphere, there is a clear distinction with relatively little temporal overlap between archaeological and paleontological sciences. This distinction is fuzzier in the Old World due to the significantly more ancient record of pre-Holocene humans and associated cultural remains. In North America, virtually all of the research questions, field methods, and analytical techniques traditionally employed in each discipline are unique. Archaeological testing methods are essentially useless for paleontology for reasons that are discussed in Section 5.

Another manifestation of the confusion between paleontology and archaeology is the notion that practitioners of either discipline are capable of doing the other or can become capable with minimal training. “Cross-trained” is a term that applies to individuals who purportedly have sufficient expertise to work in both their own discipline and another or even two or three others. You would not hire a cardiologist to perform oral surgery, nor would you ask a vascular surgeon to replace a knee joint, but nonqualified “cross-trained” individuals continue to solicit contracts to perform paleontological mitigation. This practice comes at the expense of the very resources that the laws and regulations are intended to preserve and demonstrates a lack of understanding of the complexity of paleontology and the complexity of other resource disciplines. In the many years the authors have been involved with mitigation paleontology while working in universities, in museums, and as consultants, we have known few individuals who were legitimately trained and sufficiently experienced to work as both archaeologist and paleontologist. In fact, it is rare to come across an individual who is legitimately qualified to work as a cross-trained scientist in any combination of disciplines. It is also a fact that there are few paleontologists (by training) who claim to have the expertise (or desire) to work as an archaeologist, whereas many archaeologists continue to profess expertise in both disciplines.

Professional Geologists as Mitigation Paleontologists

An example of a well-intentioned but largely ineffective effort to ensure that only qualified paleontologists work in mitigation paleontology is the currently unenforced attempt by the State of California’s Board of Professional Engineers, Land Surveyors, and Geologists to equate paleontological mitigation work with professional geological work and in turn to imply that paleontological mitigation work should be supervised by a California Professional Geologist (including California Certified Engineering Geologist, California Certified Hydrogeologist, or California Professional Geophysicist). However, the qualifications for being a professional geologist or other licensed geoscientist do not include an extensive knowledge of paleontology and paleontological methods and procedures and thus do not translate into qualifications for conducting paleontological mitigation work. While there are California paleontologists who are also licensed geoscientists, most are not, and a large percentage of those that are not licensed do not have the breadth of geological and engineering training that is required to pass the professional geologist exam, which largely focuses on engineering geology, hydrogeology, and geophysics and not on sedimentary geology, stratigraphy, paleontology, and taphonomy.

Mitigation Paleontologist Categories

Paleontological mitigation work is generally conducted by four categories of personnel with different levels of expertise and responsibility (see Appendix I, 1.1, for a summarized list of responsibilities): 1) paleontological principal investigator, 2) paleontological field supervisor, 3) field paleontologist, and 4) laboratory paleontologist. Individuals lacking the nonacademic, field-based, construction-related, or safety skills described below should receive training provided by the organizations or companies that hire them. Paleontological principal investigators and field supervisors are both considered to be qualified professional mitigation paleontologists. The field paleontologist is an introductory-level position, needing further training and/or experience to achieve the level of professional mitigation paleontologist.

Paleontological Principal Investigator

A paleontological principal investigator is someone with an advanced academic degree (M.A., M.S. or Ph.D.) with an emphasis in paleontology or demonstrated equivalent professional experience (e.g., minimum of 3 years [or 75 projects] of project experience with paleontological mitigation is considered equivalent to a graduate degree), in combination with 2 years (or 50 projects) of demonstrated professional experience and competency with paleontological resource mitigation projects at the level of field supervisor. The paleontological principal investigator should also have a working knowledge of how paleontological resources and their associated data are used in conducting and publishing professional paleontological research (such as is demonstrated by having a record of peer-reviewed paleontological publications) and should participate in professional scientific organizations. The paleontological principal investigator is responsible for evaluating the significance of unearthed fossils, for obtaining all necessary federal and state agency permits, for preparing and submitting any and all required progress and final mitigation reports, and for ensuring compliance with all scientific and operational requirements of the project. It is critical that the principal investigator have knowledge of federal, state, and local laws, regulations, and procedures that apply to all aspects of mitigation paleontology. The paleontological principal investigator is also responsible for evaluating the qualifications of field supervisors and field paleontologists and making project staffing decisions.

Paleontological Field Supervisor

A paleontological field supervisor is someone with an advanced academic degree (M.S., M.A., or Ph.D.) with an emphasis in paleontology or demonstrated equivalent professional experience (as defined in the following section), in combination with 1 year (or 25 projects) of experience with paleontological mitigation from project initiation to fossil discovery to fossil collection, laboratory preparation, fossil inventory, specimen identification, and curation. Equivalent experience to a graduate degree is defined herein as a minimum of 3 years (or 75 projects) of project experience with paleontological mitigation from project initiation to fossil discovery to fossil collection, laboratory preparation, fossil inventory, specimen identification, and curation under the supervision of a principal investigator. Additional recommended experience includes knowledge of impact mitigation procedures and strategies; junior or senior authorship of mitigation reports; an understanding of the regulatory environment including knowledge of federal, state, and local laws and procedures that apply to mitigation paleontology; an

Table 1. Minimum recommended academic coursework for field paleontologists in paleontological resource impact mitigation.

Any Two	Stratigraphy Plus Any Two	Any Three	Both
Paleobiology	Sedimentology[a]	Mammalogy	Field geology[a]
Vertebrate paleontology	Geomorphology	Ornithology	Field paleontology[a]
Invertebrate paleontology	Structural geology	Herpetology	
Paleobotany	Physical geology	Ichthyology	
Historical geology	Mineralogy and petrology	Ecology	
Taphonomy	Oceanography	Osteology	
Paleoecology		Botany	
		Comparative anatomy	

[a]Can be combined into a single course if taught as such.

understanding of project management; and an understanding of the business of mitigation paleontology. The field supervisor typically manages the field paleontologists (on field survey and/or mitigation projects), supervises fossil recovery operations, and communicates with construction foremen and superintendents. This role includes the evaluation of scientific importance and decisions regarding impact mitigation of paleontological resources. An important responsibility of a field supervisor is to ensure that field notes and observations are routinely completed, that the stratigraphy of project areas is accurately and completely recorded, and that fossil localities are positioned on stratigraphic sections as appropriate to the project.

Field Paleontologist

A field paleontologist (aka paleontological technician, surveyor, and/or monitor) is someone with academic training (B.S., B.A., M.A., or M.S.) with an emphasis in paleontology or demonstrated equivalent experience. Academic training as defined herein should include completed basic coursework in paleontology (preferably vertebrate and invertebrate paleontology, paleobotany, and taphonomy), geology (preferably sedimentology, stratigraphy, and field camp), and biology (preferably comparative anatomy, osteology, and ecology). A list of recommended courses is provided as Table 1. Equivalent experience is defined as a minimum of 2 years of cumulative professional or nonprofessional work in laboratory preparation, curation, or field work related to paleontology, as well as documented self-taught knowledge of the discipline of paleontology. The field paleontologist should be able to safely find, recover (hand quarrying, systematic excavation, bulk matrix collection, etc.), and identify to a basic level (higher-level taxon and element) paleontological resources discovered in undisturbed settings as well as in active excavations at construction sites. The field paleontologist should also be able to identify and describe sedimentary rocks and stratigraphic relationships and be able to effectively communicate information about the discovery, whether using photographs or descriptions, to the paleontological principal investigator and/or field supervisor. Other requirements include the ability to record the basic taphonomy of fossil assemblages and recognize and describe unusual depositional or preservational conditions and associations; the ability to interpret basic depositional environments based on site geology and paleontology; the ability to properly complete field forms, operate a global positioning system (GPS) receiver, apply basic mapping and navigational skills, photograph fossils and localities, and plot localities on grading plans when applicable; and the ability to comply with safety requirements and use proper personal protective equipment. Experience with similar rock units and/or with similar fossils is more important to the successful outcome of a given mitigation project than experience in the same state or human-defined region. Individuals who lack sufficient experience to be qualified as a field paleontologist can work alongside qualified field paleontologists, field supervisors, or principal investigators in order to gain the necessary experience.

Laboratory Paleontologist

The laboratory paleontologist is someone with demonstrated experience in fossil preparation. This includes past professional experience in a laboratory that prepares fossil vertebrates, invertebrates, and/or plants for curation and/or exhibition; knowledge of laboratory techniques applicable to a diversity of fossil types (e.g., sorting of microfossils or repairing/reconstructing large bones); familiarity with the use of archival chemicals and fossil preparation tools; and a basic understanding of paleontological resource conservation. Those preparing vertebrate fossils should have experience as summarized in "Defining the professional vertebrate fossil preparator: essential competencies" (Brown et al. 2011). In addition, laboratory paleontologists should also have experience with basic curation and collections management practices (e.g., see Leiggi and May 1994; Simmons 2006; NPS 2016). It is common for field paleontologists and field supervisors, and occasionally the principal investigators, to assist with laboratory-related tasks depending upon their abilities and experience level.

2. LAND OWNERSHIP AND PERMITTING

Knowledge of land ownership in a project area as well as the regulatory environment that applies to that area is essential before undertaking any subsequent analyses or mitigation actions. The major land ownership distinctions are federal, state, tribal, county, city, and private. Differences between certain types of federal, state, and tribal land may also affect the scope of mitigation paleontological work. For example, mitigation requirements may vary between different classifications of state land in some states, and also commonly vary between federally managed lands, even at the level of field and district offices. Land ownership data are available in a number of formats including hard copy maps and geographic information systems (GIS) data coverages. Because land ownership changes frequently, it is important to obtain the most recent and most accurate data available (Appendix I, 2.1). This is often available from and provided by the project proponent and should be requested at the initiation of any project.

Permits and Access Permission

The primary issue related to land ownership for both field surveys and construction monitoring concerns whether a permit(s) is required to conduct fieldwork and collect fossils. Several federal and state agencies require persons proposing to conduct paleontological mitigation work on public lands to apply for a paleontological resource use permit. When working on projects on federal land or with federally mandated requirements under such a permit, it is necessary to coordinate with agency personnel, typically in field or district offices, before initiating fieldwork. For example, when working under BLM paleontological resource use permits it is often mandatory to check in with the local field or district office paleontology coordinator. Additionally, it may be necessary to coordinate with the paleontology coordinator or regional paleontologist with regard to extensive fossil discoveries (see Section 5 for definition). Fieldwork on tribal lands typically requires an access permit and daily check-ins, and may require individual employee work permits. It is highly recommended that an email or other written authorization that contains details about the survey methodology be obtained from the applicable agency prior to beginning any fieldwork on a project. On privately owned land it is essential to obtain written right of entry from the landowner, even if crossing through private property is only needed to access federal or state land. Be sure to understand the trespass laws of the state you are working in (Appendix I, 2.2). Copies of all written authorizations should be carried by each member of the field crew when in the field. If there is a need for additional land access after a project initiation (e.g., a fossil locality extends outside of originally approved access), the agency, landowner, and client should be consulted, and a new or modified authorization should be obtained (Appendix I, 2.3).

Authorized Fossil Collection

Land ownership is an important consideration pertaining to fossil collection. Regardless of their scientific value, fossils should never be collected without written permission from the landowner or without an approved paleontological permit that covers fossil collection. In some southern California counties, all scientifically important fossils recovered from privately owned lands during construction monitoring projects are required to be housed at a regional curation facility. However, in other states, landowners own all fossils on their lands and are not required to reposit them in a curation facility.

After right of entry is granted, the ideal practice for field surveys is to evaluate and document all fossils and notify landowners in writing of any that have scientific importance. Landowners are then provided with the option to have the fossil(s) collected, to have them left in place in the path of construction (waiving the project proponent of any liability in the event of damage), or to have them collected, prepared, and transferred to a curation facility (Appendix I, 2.4). A donation of fossils by a private landowner may be tax-deductible. A similar procedure is followed for construction monitoring projects, the primary difference being that the fossil likely has already been unearthed and may have already been damaged by construction at the time it is discovered, so the decision to collect has to be made by the field paleontologist, usually without the possibility of immediate landowner input (Appendix I, 2.5). This removes the option of having the fossil left in the path of construction unless the landowner provided their preference for fossil collection prior to construction.

Excavations to collect any fossil(s) discovered during field surveys or prior to construction may require a special permit. On BLM-managed land, an excavation permit is required for any ground disturbance that exceeds 1 m^2 in size, and an environmental assessment of the excavation site must often be performed as part of the permitting process (in some cases the NEPA evaluation done for the larger project may accommodate these discoveries making subsequent analysis unnecessary) (Appendix I, 2.6).

Permitting Paleontological Resource Work—Agency Review

Agency review of permit applications is designed to ensure that only qualified paleontologists are issued such permits. In the absence of a permit application process, some city and county jurisdictions in southern California have a vetting process in which resumes are reviewed and approved individuals are placed on lists of “qualified” or “certified” paleontologists. However, there are agencies and jurisdictions in California where, despite regulations including CEQA (see Scott and Springer 2003), there is no mechanism for permitting or vetting potential mitigation paleontologists. For this reason, it is fair to view California as the state with the strongest paleontological regulations on one hand, and the least oversight on the other. The result of this odd combination is unfortunate. The participation of nonpaleontologists in mitigation paleontology has led to the preventable destruction and permanent loss of scientifically important fossils and associated data. Any agency with regulatory oversight for the protection for paleontological resources that has not developed minimal qualifications and a vetting process for prospective mitigation paleontologists will undoubtedly experience a similar result. This problem is most widespread in certain jurisdictions and with certain agencies in California. But the problem is not unique to California. Over the last several decades many nonqualified practitioners have obtained paleontological resource use permits (or worked without them), resulting in the loss of scientifically important specimens (personal observation, authors). This unfortunate practice has contributed to the strict minimal qualifications for obtaining paleontological resource use permits that are now required by many federal and state agencies across the western United States. For example, the BLM and the USFS have established processes that include a review of consultant qualifications to obtain or work under a paleontological resource use permit. BLM procedural guidelines (BLM 1998, 2008), including minimal qualifications for permitting, are often consulted by other federal and even some tribal and state agencies that lack their own guidelines. The practice of standardizing permitting qualifications should be encouraged to the maximum extent possible.

3. ANALYSIS OF EXISTING DATA

The purpose of an analysis of existing data is to evaluate the potential of geologic units in a geographic area to produce fossils of scientific importance. This potential is commonly determined from an analysis of existing paleontological and geological data. There are six elements of an analysis of existing paleontological data: 1) geologic map review, 2) literature search, 3) paleontological records search, 4) aerial image review, 5) consultation with local technical experts, and 6) project theoretical framework. The analysis of existing data is typically a prerequisite to any mitigation action such as a field survey or construction monitoring and may also provide the background information for a paleontological resource evaluation. Like all aspects of mitigation paleontology covered in this paper, analyses of existing paleontological and geological data should be completed under the oversight of a professional mitigation paleontologist in possession of a valid paleontological resource use permit or certification/qualification when applicable (See Section 1).

For the purpose of conducting geologic map reviews and quantifying the size of a project and its disturbance area, the area of analysis is conceptually three-dimensional—it is a two-dimensional geographic area with a third dimension consisting of a stratigraphic interval that underlies or is laterally equivalent to the area of proposed ground disturbance. The geographic area or areal extent of disturbance is most commonly expressed in acres or linear miles. The stratigraphic interval or thickness/depth of the proposed disturbance is most commonly expressed as the volume of rock or sediment in cubic yards or cubic meters. The geographic and stratigraphic limits of the disturbance area are important considerations in evaluating the potential impacts on paleontological resources associated with ground-disturbing projects. However, information regarding disturbance depth is often not available to the mitigation paleontologist at the time of preliminary data analysis (or even prior to construction if disturbance depth is not pre-engineered), at least not with any meaningful level of precision.

Geologic Map Review

The geologic map review is the first component of the analysis of existing paleontological data. The purpose of the geologic map review is to determine which geologic units occur within a project area (especially fossiliferous units), and to determine their areal and likely subsurface distribution. Geologic map reviews should utilize published and, if necessary, unpublished but reputable data sources. Maps with the highest precision (i.e., largest scale) available should be used. The U.S. Geological Survey National Geologic Map Database (https://ngmdb.usgs.gov/Geolex/search) is an incredibly useful tool for geologic map reviews. Because electronic geologic map data are often not available at the same scale as hard copy maps, it may be necessary to scan, georeference, and digitize portions of hard copy maps in order to utilize them in a GIS. A geologic map review is especially important for stratigraphically and/or structurally complex project areas containing multiple geologic units. Depending upon the scale of the available maps, geologic units shown on a given map may consist of groups, formations, members, submembers, or combinations thereof, and may consist of bedrock units and/or surficial deposits (Appendix I, 3.1). Soils maps may also assist in a determination of areas of potential fossiliferous bedrock or surficial deposits. However, soils data are often inaccurate and should be used with caution, and only in combination with field verification.

While discussing geologic map reviews, it is useful to consider paleontological resource-sensitivity classification systems because the most widely used systems, namely SVP's "rock unit potential" classification system, the BLM's Potential Fossil Yield Classification system (PFYC) and the USFS's Fossil Yield Potential Classification System (FYPC) are geospatially defined on the basis of geologic map units (USFS 2005; SVP 2010; BLM 2016). It is important to distinguish between a project-specific analysis of existing data completed by a professional mitigation paleontologist and the assignment of PFYC (or similar) class values. The latter is not the purview of the mitigation paleontologist but is a resource management process undertaken by the agency (or its qualified consultants) to assess the general paleontological potential of a geologic unit (usually an entire formation) and inform agency personnel about recommended management approaches. The former, which is typically performed by a mitigation paleontologist on behalf of a client for a localized area, is based on a more detailed data set that is synthesized to inform the client and the lead agency about the need, or lack thereof, for the development of paleontological impact mitigation measures. While a critique of the aforementioned predictive classification systems is beyond the scope of this paper, it should be pointed out that paleontological resource-sensitivity class rankings are often assigned based on 1:500,000 scale (state scale) geologic mapping, and in such cases the highest class ranking is assigned to combined map units. This is both a practical function of the available geologic maps, since more precise geologic mapping generally is not available for entire states, but also because the PFYC (or similar) systems were designed to function as a resource management step completed by the agency that triggers further analysis by a professional mitigation paleontologist. Higher-precision geologic mapping is available in many states and should be used to refine the analysis to the greatest extent feasible. The BLM in many states, including New Mexico, Arizona, Utah, and Montana, is currently working to incorporate higher-precision (better than state scale) geologic map data in its digital PFYC data sets. Additionally, the scale of the map used to assign the PFYC (or similar) classes may not account for rare or isolated occurrences of important fossils that may necessitate further consideration.

As mentioned above, PFYC (or similar) assignments should be completed by the applicable lead agency prior to the start of a specific project. Exceptions occur if, for example, an agency has not yet completed the classification of the geologic unit(s) in question. In such cases, the mitigation paleontologist, using the results of the analysis of existing data, may assign preliminary values pending agency concurrence. Ideally, the predetermined paleontological sensitivity values of geologic units are provided by agencies prior to the mitigation paleontologist beginning work on a given project and have been used by the lead agency in determining paleontological resource requirements for the project. Because the paleontological potential of geologic units varies geographically, sensitivity classification system assignments may also vary geographically. It is important to check with agency paleontologists or paleontology coordinators at local offices to obtain the most up-to-date assignments.

It is a best practice to apply the appropriate paleontological resource classification system to the project area being worked on, whether it be on BLM or USFS land, a city or county project, in other municipalities or for agencies that have developed their own resource-sensitivity classification systems (e.g., Caltrans), or a project for which the lead agency has recommended using SVP guidelines (Appendix I, 3.2). For projects in which there are no recommended or mandated classification systems to apply, we have developed a simplified classification system (Table 2) that is essentially a fusion of the BLM's PFYC, the USFS's FYPC, and SVP's classification system. It is purely informal, and its use is at the discretion of the principal investigator.

Literature Search

The literature search is the second component of the analysis of existing paleontological data. The purpose of the literature search is to obtain published paleontological locality information and relevant geological and stratigraphic information, as well as qualitative information regarding the scientific importance of paleontological resources in a project area and in the same geologic units elsewhere in the region. There is no standard literature search area size—in many cases, the most appropriate search area might be the geologic unit's entire distribution, the depositional basin in which the unit is located, or the entire distribution of the geologic unit within the state in which the project is located for more widely distributed geologic units. In other cases, it might be most appropriate to limit the search to a member or facies of a geologic unit that is known to be distinct from the other portions of the unit in terms of its fossil content.

The reviewed literature can include published scientific papers and unpublished literature such as graduate student theses and dissertations and technical reports written by government agencies and

Table 2. Simplified paleontological resource classification system based on combination of the Potential Fossil Yield Classification system, the Fossil Yield Potential Classification system, and the Society of Vertebrate Paleontology classification system (2010) for use on projects in which no recommended or mandated classification systems applies.

Designation	Assignment Criteria Guidelines and Management Summary
No or very low potential	Geologic units are not likely to contain recognizable fossil remains.
	Units are igneous or high-grade metamorphic, excluding reworked volcanic ash units and/or units are Precambrian in age.
	Impact mitigation is typically unnecessary except in rare circumstances.
Low potential	Sedimentary geologic units that are not likely to contain vertebrate fossils or scientifically significant nonvertebrate fossils.
	Field surveys have verified that significant paleontological resources are not present or are very rare.
	Units are generally younger than 10,000 years before present and/or sediments exhibit significant physical and chemical changes making fossil preservation unlikely (i.e., diagenetic alteration).
	Impact mitigation is typically only necessary where significant paleontological resources are known or are found to exist.
Moderate potential	Sedimentary geologic units in which fossil content varies in significance, abundance, and predictable occurrence.
	Includes fossiliferous geologic units that are marine in origin but with sporadic occurrences of significant paleontological resources and/or significant paleontological resources occur but are widely scattered.
	The potential for impacts to significant paleontological resources by ground disturbing activities is low to moderate.
	Surface-disturbing activities may require sufficient assessment to determine whether significant paleontological resources occur in the area of a proposed ground-disturbing action and whether the action could affect the paleontological resources. Mitigation strategies should be based on the nature of the proposed surface-disturbing activity, and options could include record searches, predisturbance surveys, monitoring, fossil recovery, or avoidance.
High potential	Highly fossiliferous geologic units that consistently and predictably produce significant paleontological resources.
	Significant paleontological resources have been documented and occur consistently and/or rare or uncommon fossils, including nonvertebrates, may be present.
	Paleontological resources are susceptible to ground-disturbing activities and may also be the focus of illegal collecting activities.
	Management concern is high. A predisturbance field survey by a qualified paleontologist is usually recommended and monitoring during ground disturbance may also be recommended. Avoidance or resource preservation through controlled access, designation of avoidance areas, or special management designations should be considered.
Unknown potential	Geologic units that have been poorly studied or understudied.
	Geologic units may exhibit features or preservational conditions that suggest significant paleontological resources could be present, but little information about the actual paleontological resources contained within the geologic unit is known.
	Reports of paleontological resources have not been verified.
	Geologic map units are defined on lithologic characteristics or depositional environment and have not been studied in detail.
	Scientific literature does not exist or does not reveal the nature of the paleontological resources.
	Field surveys are typically necessary prior to ground-disturbing activity. Literature searches or consultation with professional paleontologists may allow an unknown unit to be assigned to another class, but formal class assignment should take place after adequate survey and research is performed to make an informed determination.

mitigation paleontologists. The latter can include the results of prior field surveys, which may be useful in delimiting the location and nature of previous fossil discoveries, as well as in determining the amount of time that has elapsed since the last survey and whether additional, new, or updated surveys are warranted (see Section 8 for recommendations regarding resurvey timeline). Detailed fossil locality data are typically not provided in recently published scientific papers. However, other information relevant to the analysis can consist of general information regarding fossil localities including the types and abundance of fossils collected, physical characteristics of the fossil-producing strata, the depositional environments in which fossils were preserved, and the scientific importance of the fossils. In many cases, project-specific geotechnical reports are also very useful and provide critical information about the thickness of surficial deposits and the depths at which potentially fossil-bearing rock units are likely to occur. Popular websites including Wikipedia entries are not a reliable source of scientific knowledge and should not be a substitute for literature searches—even for the preparation of typically more abbreviated paleontological resource sections of NEPA documents (see Section 8) (Appendix I, 3.3).

Paleontological Records Search

The third component of the analysis of existing data is a paleontological records search, the purpose of which is to obtain fossil locality data from within a project area in order to determine the extent of previous paleontological work and fossil discoveries, in particular geologic units and the types, modes of preservation, and relative abundance of known fossil assemblages from these units. Record searches for areas outside the project area can also be useful for establishing paleontological potential of the same geologic unit based on findings from another, adjacent geographic area. These data in turn provide a means for establishing the potential of a given rock unit to produce fossils within the project area. Record searches also provide information that can ensure that recorded localities in the project area are reevaluated and mitigated or avoided by the project if needed. Quantitative and qualitative information about fossil localities is used to determine the need for a field survey or construction monitoring of a project area. Ideally, the following types of data should be requested, although the amount of data available will vary by institution:

- map plot of the locality, legal location (Public Lands Survey System [PLSS]), and precise geographic coordinates (this information should be kept confidential);
- stratigraphic data (e.g., formation, member, and/or horizon);
- stratigraphic context of recorded localities (i.e., a description of strata exposed at a locality, the nature of contacts, lithologic descriptions, stratigraphic thicknesses, geometry of deposit, etc.);
- sedimentological data (e.g., lithology, sedimentary structures, and facies);
- nature of the exposure (i.e., natural outcrop, temporary artificial exposure, road cut, etc.);
- depth below original ground surface (if applicable);
- conditions of discovery (i.e., surface prospecting, construction monitoring, etc.);
- types of recovered fossils (a list of catalogued fossils);
- method of recovery (i.e., recovered as float, excavated as single element, bulk matrix sampling followed by screen-washing, quarry excavation, etc.); and
- taphonomic description of the locality (i.e., how the fossils were preserved in the original stratum including mode of preservation, taxonomic composition, specimen orientation, specimen packing and sorting, degree of fragmentation, etc.).

The reason precise geographic locality data are necessary is because project footprints shift frequently and unpredictably. If precise data are not provided initially, localities may be unintentionally impacted.

The size of the area for paleontological records searches is more confined and precise than that for literature searches. Depending on the lead agency, the search area may either be specified or left to the discretion of the mitigation paleontologist. The format that the data are in at the source institution/agency may also play into the determination of the boundaries of the search area. For small, block-area projects, it is common to search for fossil localities within the same geologic unit within 1 mile of the project area. For larger block-area projects or linear projects such as interstate pipelines, transmission lines, and highways, a good minimum search area is a 1-mile buffer of the project area (1 mile from the external boundaries of a project, or 1 mile on either side of the centerline of a linear project), although it may be more expedient to search the same township or county, depending upon the format of the data.

Paleontological locality data on public lands are confidential (see Section 8) and are maintained by both government agencies and institutions including museums and universities. In many jurisdictions, fossil locality data are only provided to paleontologists in the possession of a valid paleontological resource use permit. Institutions are not under any obligation to provide locality data, and many charge for this service. Regardless of whether a locality search request is answered, it is critical to document that the request was made in whatever type of paleontological report is required for the project. Paleontological localities have been destroyed simply because they were not identified due to either inadequate analyses of existing data or because institutions holding such data were unwilling to provide them. Importantly, the PRPA prohibits public disclosure of paleontological locality data from Department of Interior– and USFS-managed lands without permission. Once received, paleontological locality data must be kept confidential by the recipient of those data.

Paleontological locality data, including both institutional/agency records and locality records obtained from literature searches (and/or local experts), are vital to the development of paleontological resource-impact mitigation plans, and they play a critical role in the decision-making process for field survey and construction monitoring requirements. A reasonable fee is frequently assessed for paleontological records searches because it is necessary to support the data management infrastructure of the curation facility. These costs should be paid by the project proponent.

It is extremely useful to digitize fossil locality data originally contained on hard copy maps and documents upon receipt. These data are utilized for the data analysis, for continued use in future projects, and to supplement the data set with the results of subsequent searches conducted as they are completed. The results of records searches are also an important component of paleontological reports (see Section 8), although detailed locality data should only be included in copies of the report provided to the applicable agencies. The inclusion of records search requests (i.e., date, person contacted, response if any, etc.) and results obtained document that the analysis of existing data was conducted as required by the regulatory agency, and it provides the justification for the mitigation recommendations included in the report (or mitigation plan) both for the agency and the project proponent. It is important to bear in mind that an absence of fossil locality records is more likely to reflect the lack of prior paleontological fieldwork in a particular area rather than the actual absence of fossils in that area. However, this may not be the case for areas that have been the subject of intensive and long-term paleontological fieldwork (Appendix I, 3.4).

Aerial Image Review

The fourth component of the existing data analysis, aerial image review, is extremely easy to accomplish using widely available technology such as Google Earth. The purpose of this step is to virtually examine the terrain within the boundaries of the project area from above (or using "street view") in order to estimate the amount and locations of exposed potentially paleontologically sensitive bedrock or surficial deposits. The aerial image review provides information that is useful for the evaluation of paleontological resource potential as well as the logistical planning for fieldwork (Appendix I, 3.5). The results of an aerial image review should be verified during fieldwork, as should geologic mapping.

Consultation with Local Technical Experts

The fifth component of an analysis of existing data is consultation with local technical experts. Such experts are researchers who are currently active in the area of interest, have worked there previously, or otherwise possess specialized knowledge of its paleontology and geology. These experts may include agency personnel and avocational paleontologists. The types of contributions a technical expert can make to the analysis are important, and include information on undocumented or unpublished fossil localities, particularly productive (or unproductive) stratigraphic or geographic locations, detailed stratigraphic information, and information about any paleontological concerns, including specialized data recording procedures in support of ongoing research. If recent fossil collection activities are not taken into consideration, it could cause the paleontological potential of an area to appear lower than it actually is and skew recommendations based on the results of analyses of existing data or field surveys. In addition to supplementing the data obtained from literature and record searches, the information provided by technical experts can provide invaluable information when planning field surveys or other future mitigation actions. Contacting a technical expert is the responsibility of the mitigation paleontologist (Appendix I, 3.6).

Project Theoretical Framework

The sixth and final component of the analysis of existing data is the development of a project theoretical framework. There is currently a considerable diversity of opinion about research in mitigation paleontology. In part this stems from the anticipated negative reaction of clients in response to the use of the word "research," implying added project costs. However, mitigation paleontologists are in general agreement that, as emphasized elsewhere in this paper, impact mitigation should be an endeavor that is separate from, although indirectly connected to, scientific research. The technical approach to every mitigation project should include an awareness of the existing scientific knowledge, or theoretical framework, pertaining to a project area. This is because when properly implemented for a project with scientifically important paleontological resources, the impact mitigation process can result in the discovery, recovery, and curation of well-documented fossil collections permanently housed in curation facilities, where the fossils are then accessible for research and educational purposes. While the mitigation process does not involve conducting hypothesis-driven scientific research per se, as a best practice, every impact mitigation program should be designed around a theoretical framework so that the results of the program (i.e., fossil collections and associated data) will be able to support ongoing and subsequent research activities.

The information needed to develop a theoretical framework is generated as part of the existing data analysis, which informs the mitigation paleontologist about the geology of a project area, the types and numbers of fossils that have been collected previously from the project area and surrounding region, and previous paleontological research that has taken place in the geologic units of concern. A theoretical framework is paleontological knowledge—it does not necessarily take the form of a stand-alone document or even a section of a report. Rather, it consists of information that serves as a road map to guide the implementation of the impact mitigation process including the development of the threshold criteria for scientific importance, which fossils are collected, how they are collected, and the types of data that are collected.

For example, a principal investigator should be aware that the majority of previously recorded fossil localities in a given area were discovered on western red harvester ant mounds, in paleosols, or in lacustrine limestone beds. This information could be obtained from fossil locality records and published scientific literature and would inform the mitigation field crew about the most likely settings in which to find fossils. Knowing that even small ceratopsian frill fragments are important for an ongoing research on bone histology in a given area is vital knowledge that could be obtained both from published literature and consultation with researchers working in the area. This information would then be incorporated into the fossil collection criteria developed for a mitigation project. Fossil turtle carapace fragments are known to be ubiquitous in certain geologic units, but there are some units in which they are conspicuously rare, and this rarity increases their scientific importance. Even one identifiable carapace fragment would likely be an important fossil discovery in such a scenario, whereas in another geologic unit, an "exploded" turtle carapace of a common taxon could justifiably be considered scientifically nonimportant. The abundance or lack thereof of certain types of fossils in a given rock unit in a geographic area is information that could be obtained from the published scientific literature, fossil locality records, and consultation with researchers working in the area and would influence the fossil collection criteria of a mitigation project. As a final example, stratigraphic data are always important, but critically so in project areas containing significant stratigraphic relief and which span faunal or floral transitions, especially those that are poorly understood. Consultation with researchers and a familiarity with the published literature about the existing stratigraphic framework for an area are necessary in order to ensure the scientific usefulness of fossils collected during a mitigation project, and the effort to stratigraphically document fossil localities should be built into project scopes and budgets as appropriate. Stratigraphic documentation of fossil localities is part of the impact mitigation process and contributes to the advancement of the theoretical framework pertaining to a project area.

The theoretical framework developed for impact mitigation projects should be taken into account when developing scopes of work for field surveys and construction monitoring projects, during consultations with agency personnel, and during the preparation of monitoring and mitigation plans, and should be disseminated to field paleontologists prior to commencing fieldwork. Discussions with the designated curation facility should also be carried out to ensure that fossils are documented, prepared, and delivered according to the expectations of the facility. It is recommended that the theoretical framework developed for each project be discussed in final reports for field surveys and monitoring projects, and, when applicable, impact evaluation reports (see Section 8) (Appendix I, 3.7).

Data Synthesis

The components of the analysis of existing data can be efficiently examined and analyzed together using geospatial technology. The output of the analysis of existing data can be presented in a variety of formats but should always include a discussion of the methods used, as well as the results obtained. If the analysis is a preliminary step to additional work, it may only involve synthesis of the data into a format that is useable in a later project report (e.g., field survey report), or it may form the subject of a report unto itself. A report based on an analysis of existing data is appropriate for many types of projects, and we recommend that it be called a paleontological resource-impact evaluation report in order to avoid confusion with other types of reports (see Section 8). The purpose of these types of reports is typically to synthesize information necessary to evaluate the paleontological sensitivity of a project area. This information, in turn, can be used by a project proponent and the lead agency to make a determination of the need for paleontological impact mitigation measures such as field surveys, construction monitoring, or more project-specific mitigation recommendations. It is also common for the product of an analysis of existing data to provide the basis for paleontological resource analyses for NEPA studies such as environmental assessments (EAs) and environmental impact statements (EISs). If a report based on the analysis of existing data is not required, then consultation with the lead agency (if applicable) should take place in order to determine the need for impact mitigation measures, and the consultation may include the development of project-specific mitigation recommendations (Appendix I, 3.8).

4. FIELD DATA COLLECTION

The collection of accurate field data is one of the most complex aspects of mitigation paleontology. The challenge is to design and implement a data recording protocol that promotes accuracy and is efficient, adaptable, and intuitive. The protocol also should be easy for field crew members to learn, readily comparable between field crew members, and designed for use on all sizes and types of projects. Ideally, the protocol should be designed so that it can be quality-checked by the principal investigator and/or field supervisor, and so that data corrections and methodological changes can be introduced if necessary. Field data often need to be collected quickly, especially on certain types of mitigation projects. Typically, there is only one opportunity and a brief window of time in which to record data. For example, when monitoring a mass grading project, the topography is modified rapidly and often drastically, and entire fossil localities (and enclosing strata) are graded away almost immediately after fossils have been collected. In such cases, a working version of the project stratigraphy should be under constant development even if fossils are not being found, so that when fossils are eventually found the portions of the "lost" stratigraphic section will already have been documented.

Data Capture

In many cases, agency guidelines (where they exist) are vague about what data are required to be collected for mitigation paleontology projects. This decision is typically left up to the discretion of the principal investigator or field supervisor based on his or her training and field experience. Even agencies with robust procedural guidelines such as the BLM require little more than standard fossil locality data for project and permit reporting purposes. In reality, in order to properly implement a mitigation project having any degree of complexity, much data must be recorded. A well-designed theoretical framework can go a long way toward establishing the data recording protocol to be followed in the field. It is often not just important to know what data to collect and how to collect it, but perhaps equally as important to know what data not to collect. It is well beyond the scope of this paper to recommend and describe detailed data capture procedures or provide a comprehensive list of data that should be collected. Most paleontologists prefer to do things in their own way, and projects may require variations in data collection and management. Rather, in this section we provide recommended minimal data capture guidelines that constitute best practices for typical mitigation projects. Additional data should be collected on specific projects depending upon scientific or reporting aspects of projects as determined by the principal investigator, field supervisor, or agency representative.

As a preface to the following section, it is understood that given the rapid evolution and application of digital forms of geographic data capture, it is likely that the techniques described below may eventually become obsolete. Field data are traditionally recorded in field notebooks and on hard copy topographic maps, aerial images, and/or hard copies of grading plans or plan and profile sheets. Customized hard copy or digital field forms (e.g., locality forms, photographic logs, etc.) may be more effective than traditional field notebooks, especially when more than one person is involved (Appendix I, 4.1). Supplemental information can be recorded in a traditional field notebook even if field forms are used. Other readily available data recording devices include GPS receivers, tablet computers, and digital cameras. In addition to recording position with a GPS receiver, it has traditionally been important to plot positional data (e.g., localities, stratigraphic sections, photographic locations, etc.) directly on paper maps. For GPS receivers, sub–meter-level precision may be needed in certain field applications. However, a position error of no more than 6 m is probably sufficient for most applications (Appendix I, 4.2). Use of a standard geographic coordinate system is recommended unless a project-specific coordinate system is required. All crew members should understand the system they are working in and verify that their GPS receivers are set to the same system (Appendix I, 4.3). At this time most government agencies in the United States prefer paleontological data to be recorded in Universal Transverse Mercator (UTM) NAD 83 datum. Increasingly, digital data and integrated data recording systems are being utilized in the environmental consulting industry, and undoubtedly will replace hard copy field notes and field forms in the near future. The ability to enter data directly into relational database management systems on tablets or advanced GPS units saves significant amounts of data entry time. On the other hand, these data continue to require careful quality-checking in the office because of the inherent difficulty of entering data accurately in the field, which requires extra attention to detail and can be a drain on precious field time (a constant challenge in itself).

Using GPS receivers, fossil localities should be geographically documented appropriately for their size. Single, isolated fossils should be recorded as locality points, larger localities should be documented as lines for localities exposed along beds, and polygons for nonlinear localities (Figure 1). If the GPS receiver lacks the capability to record lines and polygons, a series of points should be recorded (again taking into account GPS position error) (Appendix I, 4.4).

Prior to the commencement of any mitigation project, it is important to provide information about the project to crew members, typically in the form of an orientation and training session (see Section 5). An important component of such a prefield orientation session is a review of the types, preservation, and data needs of anticipated paleontological resources, as well as a review of field data collection procedures and associated data management responsibilities. This includes a review of field data forms and/or digital custom form applications, recording procedures and protocols, and

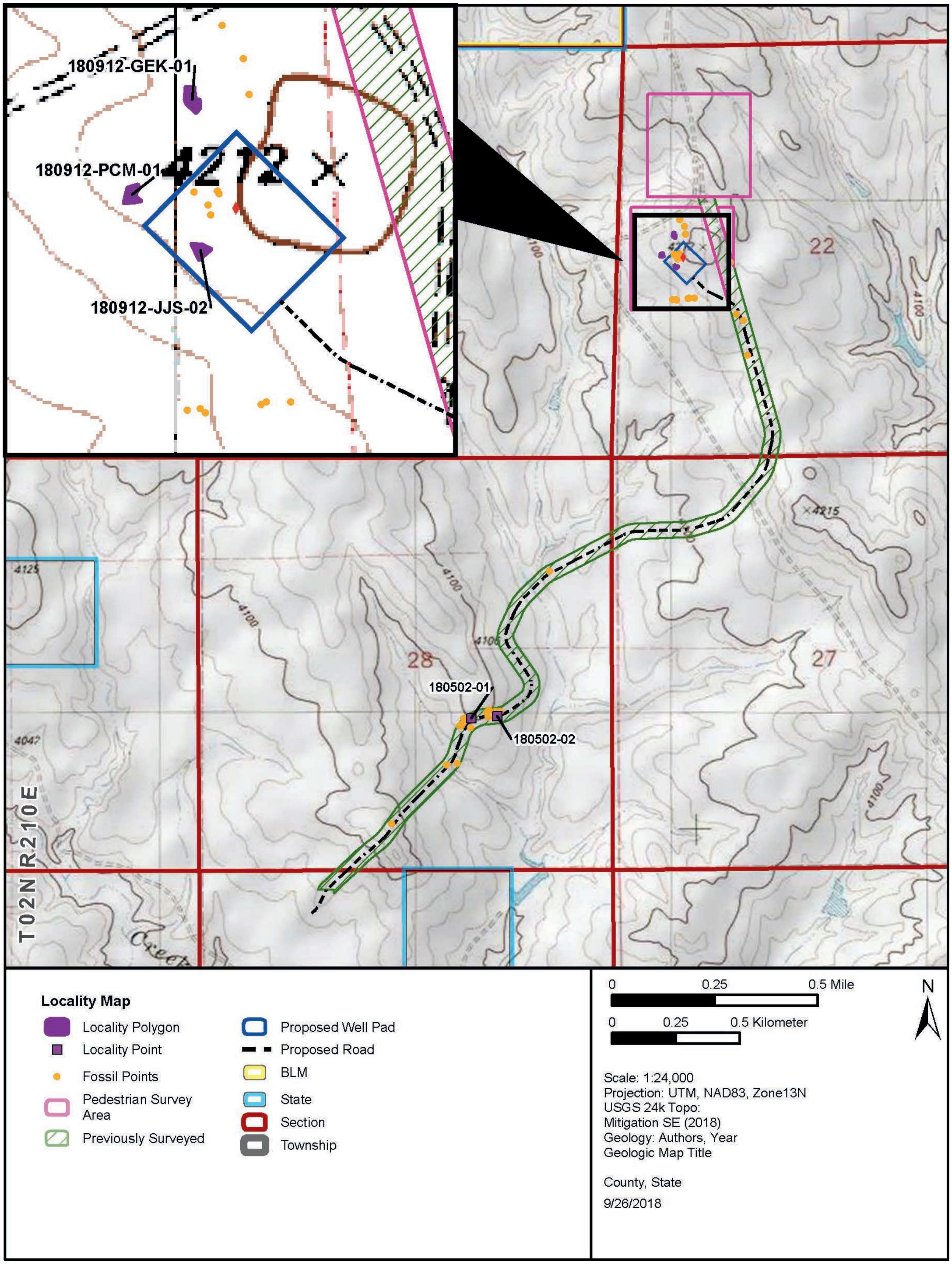

Figure 1. Fictional example of a fossil locality map showing fossil localities as points and polygons within a project area overlaid on a 1:24,000 scale topographic base.

data management procedures. In particular, it is critical to discuss thresholds for paleontological importance for the purpose of providing guidance about what constitutes a paleontological locality, because this may vary by project as discussed below (Appendix I, 4.5). In addition to data recording procedures, field paleontologists should be instructed on what is and is not appropriate to record on field forms or in field notebooks.

The Importance of Negative Data

All data recording protocols should include capture of "negative data," because such data can be important for resource management. There are two aspects to negative data in mitigation paleontology projects. The first is documentation of all areas that were surveyed or monitored regardless of whether fossils were found. This serves the dual purpose of providing data on where fossils were not present during surveys or monitoring and also, as a best practice, providing a record that the fieldwork was completed according to the scope of work and agency requirements. If possible, a GPS track log file and/or polygons depicting locations of field crew activities along with GIS locality data should accompany the agency copy of the mitigation report (Appendix I, 4.6). The second aspect of negative data involves non–scientifically important fossil localities. Although these localities are often omitted from final reports, all fossil locality data are useful for resource management and should be reported (see Section 8). The primary distinction between scientifically important and nonimportant localities is that important fossil localities (those with fossils of scientific value, and as defined using agency provided significance criteria when applicable) are subject to mitigation whereas nonimportant fossil localities are not. Most land managers want negative data including nonimportant fossil localities because it provides information on the overall abundance and quality of preservation of fossils and the distribution of fossil-bearing strata in a project area (Appendix I, 4.7). In addition, these data are critical during the analysis phase of subsequent projects. Finally, paleontological localities deemed nonimportant may be reevaluated for scientific importance at a later time.

Scientific Importance Criteria for Paleontological Resources

The scientific importance threshold for fossil localities varies by geologic unit, geographic area, agency criteria, and ongoing research related to the fossils within a project area. Therefore, the significance criteria should be reviewed by all parties involved, including the permitting agency, the permittee, and the curation facility. For example, in the Middle Eocene Uinta Formation in northeastern Utah, fossil turtles consisting of both complete carapaces and fragments thereof are prolific. A survey of 17,000 acres yielded 3,910 localities with turtles, for a density of 1 locality per 4.35 acres. Of these, approximately 110 localities were recorded as scientifically important because they yielded relatively complete carapaces, some of which were associated with crania and postcrania. The other 3,800 localities were recorded as nonimportant because they consisted of exploded scatters of turtle carapace fragments with no associated cranial or postcranial remains that either represented common taxa or were poorly preserved and unidentifiable (Imhof et al. 2008; Murphey et al. unpubl. report). Indeed, fossil turtles are so abundant in certain Uinta Formation strata that it is impractical to report isolated carapace fragments even as nonimportant fossil localities. Consequently, in this case a minimum nonsignificance threshold needs to be established and adhered to during fieldwork. In stark contrast, in the stratigraphically overlying upper Middle Eocene Duchesne River Formation, fossil reptiles, including turtles, are exceedingly rare. Even an isolated turtle carapace fragment found in this unit should be recorded as an important fossil locality because of the rarity of turtles and the associated potential scientific contribution from the discovery of additional specimens.

We have reviewed all paleontological importance criteria of which we are aware. Unless required to use other criteria, we recommend the use of the following criteria developed by Scott and Springer 2003, wherein fossils are considered scientifically important if one or more of these criteria are met:

- The fossils provide data on the evolutionary relationships and developmental trends among organisms, both living and extinct.
- The fossils provide data useful in determining the age(s) of the rock unit or sedimentary stratum, including data important in determining the depositional history of the region and the timing of geologic events therein.
- The fossils provide data regarding the development of biological communities or interaction between paleobotanical and paleozoological biotas.
- The fossils demonstrate unusual or spectacular circumstances in the history of life.
- The fossils are in short supply and/or in danger of being depleted or destroyed by the elements, vandalism, or commercial exploitation, and are not found in other geographic locations.

It may also be useful to evaluate scientific importance by considering the converse. For example: Paleontological resources that may be considered to not be scientifically important include those that lack provenience or context, lack physical integrity because of decay or natural erosion, or that are overly redundant or are otherwise not useful for research.

Data Confidentiality

Before discussing field data specifically, a final consideration involves data confidentiality, which is another aspect of data collection and management that varies between projects. It is a best practice to err on the side of discretion whenever working on a mitigation project, and this should be strongly emphasized to field crews. For example, it is important that field crew members refrain from posting any information about a project, including fossils that were found, on their websites or social media sites. This includes not posting images that may identify geological context or are geographically referenced. It is also important that field crew members refrain from discussing any aspect of projects, especially paleontological data, with nonproject personnel. Such discretion is expected by clients who are paying for this work (Appendix I, 4.8). Under PRPA it is unlawful for federal fossil locality data to be disclosed to the public unless the bureau has determined that doing so would not result in harm to the resource (see Section 8).

Types of Field Data

There are two general categories of field data: paleontological data and project data (Table 3). Paleontological data document the locations and types of fossils and their geologic context. These data provide the contextual information necessary to make the associated collected fossils scientifically valuable. Without adequate information concerning stratigraphic provenience and taphonomic fabric, most fossils become just interesting objects that immediately lose their scientific value. Project data, on the other hand, include

Table 3. Recommended types of field forms and minimal data fields. Bold text represents repeated subparts of a form for recording successive stratigraphic units and photographs.

Fossil Locality Log	Monitoring Area Log	Survey Area Log	Stratigraphic Log	Photographic Log
Locality no.	Monitor name	Surveyor name	Recorder name	Photographer
Date	Date	Date	Project no.	Date
Project no.	Project no.	Project no.	Project name	Project name
Project Name	Project name	Project name	Infrastructure name	**Photograph no.**
PLSS location[a]	Arrival and departure times	Survey area name	**Unit**	**Location reference**
UTM or lat/long (NAD 83 datum)	Infrastructure name	Survey area type	**Thickness**	**Direction/bearing**
Found by	Infrastructure type	Infrastructure name	**Rock type**	**Photograph description**
Survey area name	Landowner	Infrastructure type	**Color fresh**	
Survey area type	PLSS location	Landowner	**Color weathered**	
Landowner	County	PLSS location	**Texture**	
Location description	State	County	**Grain size**	
Topography	Weather conditions	State	**Sorting**	
Formation	Safety concerns	Survey type (pedestrian, visual, aerial)	**Rounding**	
Member	Equipment	Survey start and stop	**Carbonate minerals**	
Age	Excavation activities	Topography	**Cementation**	
Stratigraphic position	Project start and stop	Amount and approximate locations of bedrock exposures	**Bottom contact**	
Lithology	Continuous or spot-check	Formation	**Sedimentary structures**	
Fossil type(s)	Formation	Member	**Fossils**	
Field taxonomic ID	Member	Age	**Points recorded**	
Field element ID	Age	Stratigraphic observations	**Start and Stop Points**	
In Situ or float	Stratigraphic observations	Lithologies	**Dip/strike**	
Preservation quality	Lithologies	Site sketch		
Taphonomic observations	Site sketch	Associated fossil localities		
Depositional environment	Associated fossil localities	Associated photographic points		
Locality dimensions	Associated photographic points	Associated stratigraphic points		
Collected?	Associated stratigraphic points	Matrix collected		
Significant?	Matrix collected	Field recommendations		
Field recommendations				
Photograph nos.				

[a]Abbreviations: PLSS indicates Public Lands Survey System; UTM, Universal Transverse Mercator.

details of the work performed on a daily basis and other project-related information and are discussed in greater detail below. Some clients also require project-specific daily logs that typically serve the purpose of reporting what work was done, where it was done, how many hours were spent at the field site, and localities found (if any). It is a best practice to fully and properly complete all client- or company- required project paperwork (Appendix I, 4.9). This may include vehicle inspection forms, job hazard analyses or other safety related forms, and project daily logs. These requirements are supplemental to scientific and project data recorded by field crews and will not be discussed further. Much of the information listed on fossil locality forms, such as geographic coordinates, legal location (PLSS), stratigraphic and lithologic data, and fossil identifications, is standard for paleontological fieldwork. The primary difference for mitigation projects is that the locality is associated with a project name and tied to a survey or monitoring area. A survey or monitoring area, in turn, is a subdivision of a project area depending on the project type, whether it be an alignment segment between highway mileposts, pipeline station numbers, geophysical source points, a transmission tower, a wind turbine, a well pad, or a quarter-quarter section. Another important component is whether the locality is scientifically important or not, whether fossils were collected (nonimportant fossil localities typically are not), and preliminary mitigation recommendations depending upon the nature of the fossil locality and the type of anticipated impact. As discussed in Section 8 there is no single formula that can be used for designing mitigation recommendations. Best practices related to impact mitigation are those that accomplish the objectives of the project while preserving the value of paleontological resources. Finally, it should be noted that the information on field locality forms is not identical to fossil locality forms that are produced for mitigation reports—the former have some different data fields and they report only preliminary information.

Monitoring and survey-area logs accomplish the same thing for monitoring and survey projects, respectively, and can be utilized in place of or in addition to standard field notes. Such logs document what work was done in which part of a project area, whether the project has a linear (e.g., pipeline, transmission line, or roadway alignment) or a nonlinear (e.g., solar energy generation facility, residential development, or landfill) footprint. The purpose of these log forms is to capture information about subareas within a project area to provide details about what was done and when, and observations about each area, regardless of whether fossils were found. It is not possible to accurately characterize any but the smallest of project areas unless the project area is subdivided into more meaningful subareas such as a quarter-quarter section, a pipeline divided into station number segments, or a range of distance between highway mileposts. Finally, both monitoring and survey area logs should also include a listing of other associated data such as scientifically important and nonimportant paleontological localities, stratigraphic logs and photographic points recorded within them, and bulk matrix or other samples collected.

Lithologic information is applicable to fossil locality logs, monitoring logs, and survey logs (see gray shaded fields under stratigraphic log in Table 3). The fossil-bearing stratum is typically recorded on a fossil locality log, while the complete exposed stratigraphic section within a survey or monitoring area along with positioned fossil localities is recorded on monitoring and survey area logs. The purpose of a stratigraphic log is to record thicker sequences and can either be used to record a traditional stratigraphic section or a trench log (log of strata exposed in a linear exposure such as a pipeline trench). Photographic logs simply provide a way to track digital photographs taken of localities, fossils, and other visual project aspects so that they can be used in mitigation reports and locality forms (Appendix I, 4.10).

5. FIELD SURVEYS

The purpose of a field survey is to locate and document exposed fossils and potentially fossil-bearing surface strata within a project area, to relocate previously recorded fossil localities, and to document areas that have high potential to produce subsurface fossils. The word "survey" may or may not include fossil collection (see Section 7), whereas a paleontological resource inventory connotes resource documentation with no collection. It is assumed that basic scientific skills, such as finding and identifying fossils and documenting their geologic and stratigraphic context, are prerequisites to undertaking a mitigation project and thus have been mastered by professional mitigation paleontologists during the course of their academic training and/or premitigation professional and nonprofessional experience. As such, these subjects are not covered in this paper, but applicable topics including paleontological field surveying, field geology, and macrovertebrate collection are covered in numerous other publications (e.g., Compton 1985; Leiggi et al. 1994; Clites and Santucci 2012; Moses et al. 2014).

Terminology

Some important and often confusing issues associated with project-area terminology are worthy of discussion. These include the following terms: disturbance area, project area, buffer, survey area, corridor, right-of-way (ROW), and area of potential effect (APE). Every project for which a mitigation paleontologist is contracted has a disturbance area that is never larger than the project-area boundary. The disturbance area may include a buffer, and the disturbance area plus the buffer constitute the survey area. Linear survey areas are often referred to as survey corridors. The size and magnitude of planned disturbance varies greatly from minor for such activities as laying seismic cables across the landscape, to major for such activities as mass grading and open pit mining. The size of the buffer is also variable, and is determined by the agency or the client, depending on regulations and project objectives. The buffer provides flexibility for the project so that if resource surveys identify environmental concerns within the buffer such as fossil localities, archaeological sites, or threatened species, the disturbance area can be shifted within the area surveyed to avoid them without having to perform additional resource surveys. However, the buffer also serves the practical purpose of reducing the possibility that project personnel or equipment that stray from the disturbance area will adversely impact sensitive resources nearby. There is no one appropriate buffer size since project needs and requirements are variable. In our experience, survey areas, whether linear or not, may include buffers that vary from 10 feet from the disturbance-area boundary or centerline, to 200 feet from the disturbance-area boundary or centerline. For mitigation paleontology, a buffer of 50 to 100 feet from the disturbance-area boundary or centerline is adequate in most circumstances. In the case of linear projects (e.g., pipeline, transmission line, road) the term corridor may be utilized. The project corridor is typically twice the buffer width. It may or may not be centered on the proposed linear infrastructure. ROW is a term that refers to a linear easement for which a legal right has been granted to pass through property owned by another. For most projects the ROW represents an area within which all project activities must occur. The size of an APE is resource dependent and may be larger than the project area. The term APE is usually used in connection with NEPA-related studies, and because the meaning and size are variable between local agency offices and resources, we recommend avoiding the use of APE in mitigation paleontology. To reduce confusion and misunderstandings it is crucial that each term is clearly defined in all project documents.

Prefield Preparation

It is important to prepare for all fieldwork in advance, and such preparations are generally similar whether the proposed work involves a field survey, construction monitoring, or other types of mitigation field activity. Prefield preparation should also be included in scopes of work and budgets and is focused on assembling information and providing training to those who will be doing the work. Field crew members should be provided with the following (Appendix I, 5.1):

- the results of the existing data analysis completed for the project (or similar information if a formal analysis was not completed),
- key publications and technical reports relating to the geology and paleontology of the general geographic area and geologic units involved,
- maps (hard copies and/or digital versions) and/or construction design or grading plans of the project area,
- a list of the necessary field equipment (see Compton 1985; Leiggi et al. 1994 for examples),
- an overview of safety requirements and concerns,
- a schedule,
- area priorities, and
- notification procedures for discoveries.

Ideally, for larger field projects an orientation to the project area should be provided by a technical expert (e.g., a researcher who does fieldwork in the area), and such an expert, if available, should be kept informed of the results of the project as it proceeds as permitted according to project confidentiality requirements. Field personnel should also be provided copies of project-area entry authorization as well as copies of required permits (Appendix I, 5.2; see Section 2 for details on obtaining these documents). Importantly, prefield training should also include discussions of data recording and management procedures, fossil evaluation criteria, and fossil collection procedures (see Section 4). Field paleontologists should be instructed not to collect any objects for personal use from a project area, regardless of land ownership or legal status. These include modern bones and antlers, cultural artifacts (projectile and spear points, etc.), plants, rocks, and nonimportant (poorly preserved and unidentifiable) fossils. Collecting for personal use on a mitigation project is unprofessional and may invite unanticipated problems for a project (Appendix I, 5.3).

Safety

Considering the diverse range of environments that mitigation paleontologists work in—from wilderness to urban construction sites and everything in between, safety is of critical importance. Increasingly, safety training programs and equipment are not only being employed by mitigation paleontologists but are routinely being required by their clients. Mitigation paleontologists should utilize safety equipment and procedures that are appropriate to the conditions they are working in. This includes the use of appropriate personal protective equipment (PPE), and safety training courses such as first aid, wilderness survival, drivers' safety, railroad safety, Hazardous Waste Operations and Emergency Response, and Mine Safety and Health Administration courses. Specific safety training courses and PPE are also increasingly required on a project-specific basis by contractors and project owners. Safety procedures are increasingly integrated into each workday through the use of daily safety briefings, and safety violations may even result in project-wide safety stand-downs. Many of these safety practices are also applicable to monitoring (see Section 6).

Figure 2. Paleontologist Betsy Kruk and GIS Specialist Barbara Webster surveying for fossils in Bears Ears National Monument, Utah.

Field Survey Methods

The small size of many scientifically important fossil specimens, and the presence of small bone fragments on the ground surface that could indicate more extensive subsurface fossil remains, makes it impossible to determine whether fossils are present in areas where the ground surface is not fully visible. For these reasons, the ground should be completely free of snow and not saturated with water (e.g., flooded or too muddy) before a paleontological field survey commences (Appendix I, 5.4). In contrast, archaeological field surveys can typically be conducted with 75% or greater ground visibility. This percentage is variable and is usually at the discretion of the principal investigator or local agency office. The differences between these resources and the fundamentally different ways in which they are preserved and discovered make archaeological standards inappropriate for paleontology.

Typically, field survey activities should be confined to the project area. However, in some circumstances exposures of the same units outside of the project area may provide important information and they should be inspected if access has been approved (Appendix I, 5.5). When surveying in geologic units that have a high potential to contain scientifically important paleontological resources, every exposure should be examined. However, in rocks with moderate or unknown potential, spot-checking of exposures of rocks and surficial deposits is typically an acceptable level of effort (Appendix I, 5.6). Because exposures of sedimentary rocks are not continuous over the landscape in most areas, often being restricted to ridges, canyon walls, stream cuts, badland knobs, and so forth, field surveys should be focused in such areas (Figure 2). While walking evenly spaced transects is a standard procedure for archaeological surveys, it is not a best practice in paleontology. Rather, a field survey crew should spread out to cover as much ground in as little time as possible, as opposed to hiking closely together. Field surveyors should be cautioned to avoid the traditional research-oriented approach, focusing on the most promising outcrops. For mitigation projects, all outcrops need to be thoroughly prospected. Many important fossil discoveries have occurred in unlikely settings, including small exposures that are often ignored by researchers. For example, certain highly fossiliferous rock units are known to yield scientifically important fossils even in areas with weathered and entirely vegetated exposures, including flat prairie, so this should be taken into account during the scoping and planning process. The use of emerging technologies such as aerial drones can greatly increase the efficiency of locating outcrops, mapping geology, and planning the overall survey (Figure 3). For archaeological surveys, a slope exclusion is sometimes imposed in order to eliminate steeper areas with a low likelihood of containing archaeological sites. Slope exclusions should not be imposed on paleontological field surveys because of the high likelihood of finding fossils in steeper and more rugged terrain where bedrock is more likely to be exposed. Field crews should be advised to exclude exposure faces that are too steep to survey safely (Appendix I, 5.7). Because fossils are not identifiable from a vehicle, windshield surveys are never acceptable and are not an acceptable practice for fossil prospecting and are only useful for determining the physical locations of rock outcrops from a road. For these reasons, field survey reports should clearly differentiate between areas that were subject to pedestrian survey versus any other form of nonpedestrian visual inspection (Appendix I, 5.8).

There are two general types of field surveys with various permutations and exceptions: block surveys and infrastructure-specific surveys. Block surveys are often employed at the programmatic level and provide a resource clearance for a larger project with unknown infrastructure locations by surveying the entire project area. Infrastructure-specific surveys are targeted to planned locations of specific project elements with anticipated ground disturbance within a larger project area (e.g., well pads or seismic source points), and may include a survey buffer. The results of the field survey generate the data used in reporting and in making mitigation recommendations. Impact mitigation in the form of fossil collection may occur at the time of initial fossil discovery during a field survey, or be deferred until input from the principal investigator, agency, client, and/or landowner has been obtained. Although resource avoidance has traditionally been the agency-preferred approach to impact mitigation, the fact is that most surface fossils have a very limited lifespan due to environmental factors such as weathering and erosion, not to mention theft. Therefore, fossil collection and curation is the best practice for paleontological resource preservation of exposed surface fossils. This deviates considerably from CRM, where most resources are recorded, but not collected. Clients are frequently concerned that collecting surface fossils identified during a field survey and placing them in a curation facility will be costlier than avoiding the resources and believe that it is less costly to reengineer the project in order to relocate it away from fossil localities. In the case of block surveys, if a project has not yet been designed, it may be possible to avoid scientifically important fossil localities. However, for projects that have been designed, it is often less costly to collect, prepare, identify, report, and curate isolated surface fossils than to reroute or move project infrastructure, and as a best practice, this should be explained to clients. Exceptions certainly exist, such as bone beds or large fossils, and fossiliferous ant hills that may be time consuming to prospect and collect, since they may contain hundreds of small fossils (see “extensive” fossil discoveries below). Of course, the client typically retains the option to pay for mitigation of extensive fossil discoveries if it is not feasible to move the project to avoid a fossil locality. A client is under no obligation to mitigate impacts to paleontological resources that will not be affected by the project. Fossil collection is not permitted on some tribal lands, and in these cases, for scientifically important fossils documented during field surveys, resource avoidance is the only mitigation alternative, necessitating project relocation. However, in the case of fossil discoveries of high scientific importance it is worth contacting the appropriate tribal authorities to make them aware of their options (Appendix I, 5.9).

Figure 3. Aerial drone operated by Lance Murphey being used during a paleontological survey of the Upper Jurassic Morrison Formation on Bureau of Land Management lands in San Juan County, Utah.

During routine field surveys and monitoring in paleontologically sensitive rock units and surficial deposits, one expects to find fossils, and typical fossil discoveries can be anticipated and included in the budget. However, extensive fossil discoveries are not anticipated, and are outside of the scope of work of normal impact mitigation projects. Typically, these include bone beds or other exceptionally rich accumulations of vertebrate fossils, or large fossils such as complete or nearly complete skeletons of large mammals or reptiles. In the case of such discoveries, the client and agency (when applicable) should be notified immediately, and the locality should be avoided until a decision on a mitigation approach has been reached. Generally, the locality will be avoided by the project, and the mitigation paleontologist or agency should contact an institution or researcher(s) who may have an interest in the discovery. However, the client may choose to have the site excavated, and in such cases, the preparation of a locality-specific mitigation plan may be required. There are cases in which it has been necessary for a client to provide security for fossil discoveries, even nonextensive localities (Appendix I, 5.10).

“Unanticipated discovery” is a CRM term that is sometimes misapplied to mitigation paleontology. In CRM its meaning varies on a project-by-project basis and may mean something completely different from one project to another. It is problematic when the term is applied to mitigation paleontology because many paleontological discoveries are anticipated depending on the specific project area. Furthermore, “unanticipated discovery” is a term that is sometimes used in mitigation measures or scopes of work developed by nonpaleontologists to refer to fossil discoveries that are inadvertently made by construction personnel in the absence of a paleontological monitor. In mitigation paleontology, it would be preferable to avoid confusion with CRM by using the term “predicted fossil discovery” for fossils that are expected and “unpredicted fossil discovery” for fossils that are not expected within a project area—for example, an area with low sensitivity that unexpectedly produces fossils. An additional and related term that should be applied to paleontological localities is “extensive fossil discovery” (as defined above). It is a best practice to avoid the use of CRM terminology in mitigation paleontology, thereby minimizing continued confusion between the two disciplines (Appendix I, 5.11).

Various forms of exploratory "shovel testing" are employed by archaeologists in order to determine the presence of cultural resources in areas where the ground surface is obscured by vegetation, or where there is a known feature of unknown extent and eligibility. A key assumption in shovel testing is that human habitation is tied to certain features of the landscape, such as areas with low topographic relief and close proximity to water, and it is also assumed that despite climatically induced environmental change, the overall geomorphology of the area has not changed significantly between the time of earlier human occupation and the present day. With the arguable exception of the Late Pleistocene, fossil occurrences are tied to depositional environments on the basis of lithofacies and taphofacies rather than the topographic features of the modern landscape. Therefore, the use of archaeological testing techniques such as exploratory shovel testing to infer the presence or absence of paleontological resources is meaningless. This practice is typically imposed by uninformed agency personnel who lack paleontological training and should be advised against by mitigation paleontologists. It is possible that future techniques or technologies will be developed that will be useful tests for the presence of subsurface paleontological resources. However, at the current time no such tests exist (Appendix I, 5.12).

Figure 4. Pat Sena monitoring excavations into Middle Pleistocene deposits of the Bay Point Formation at the Thomas Jefferson School of Law project site, downtown San Diego, California.

6. CONSTRUCTION MONITORING

Unlike field surveys, there is no academic training available for the basic skills specific to paleontological resource construction monitoring. On-the-job training is the only option. In this section the word monitor refers to a field paleontologist, field supervisor, or principal investigator (see Section 1) who is performing the construction monitoring. The purpose of monitoring is to discover and reduce damage or destruction (i.e., minimize adverse impacts) to scientifically important fossils that are unearthed during construction. The job of a paleontological monitor is largely visual, but it is, nevertheless, also mentally and physically demanding. Monitoring entails conducting inspections of excavation sidewalls, graded surfaces, trenches, and spoils piles for evidence of fossils exposed by excavations, often on surfaces that are obscured by debris and clouds of dust (or snow). The inspections must be conducted at a safe distance from the excavation equipment in the controlled chaos of a construction site (Figure 4). Time is of the essence because if equipment is running, the freshly exposed fossil can be destroyed with the next scoop of a track-hoe bucket or the next pass of a scraper or bulldozer. For this reason, equipment operators must be alerted before the fossil is irreparably damaged.

Monitoring stands apart from other aspects of mitigation paleontology in that it requires not only a specialized skill set, but also a particular temperament. For example, most mitigation paleontologists would agree that being skilled at finding surface fossils in traditional paleontological field surveys does not necessarily translate into the ability to find fossils in an active construction site. Also, it is imperative to stay alert at all times both for safety reasons, and because depending upon the density of subsurface fossil occurrences, weeks can go by without a fossil discovery and then a fossil is exposed with no warning. For this reason, a monitor does not have the luxury of letting his or her guard down. Many paleontologists find monitoring to be excruciatingly tedious, so though it is important, it is not for everyone.

Monitoring Methods

For the purpose of avoiding confusion, it is worth pointing out that some agencies do not consider paleontological monitoring to be mitigation. The distinction made by some agencies is that monitoring refers to the process of discovering fossils during ground disturbance, whereas mitigation is the process of reducing impacts by removing fossils from the path of construction. This is a distinction that these agencies have made for monitoring other types of natural resources. However, as a practical matter, monitoring and mitigation go hand in hand during excavation activities and for the field paleontologist, fossil recovery is a logical extension of the monitoring process.

Prefield project preparation procedures for monitoring are similar to those recommended for field surveys (see Section 5). Monitoring should be a mitigation requirement when construction will disturb bedrock units or surficial deposits with a high potential to contain fossils of scientific importance. Continuous monitoring, also called on-site monitoring (i.e., BLM 2016), refers to a full-time level of effort, and is typically required for project areas (or portions thereof) underlain by geologic units that have a high potential to contain scientifically important paleontological resources. Spot-checking refers to a part-time level of effort and is typically required for project areas with moderate or unknown potential (also applied to low-potential areas when using SVP guidelines in California). Operationally, spot-checking can be a challenge in cases in which the project area is a great distance away from the nearest other project, and there are no other mitigation activities available for the monitor. As the name indicates, spot-checking means performing limited inspections at monitor-selected locations within a project area. Obviously though, scientifically important fossils may be missed by the monitor in such situations since he or she is not always present while ground disturbance is occurring (Appendix I, 6.1). Regardless of the stipulated monitoring level of effort, the principal investigator should have the ability to increase (or decrease) the monitoring effort if the monitoring results indicate that a change is warranted. SVP (2010) recommends that monitoring should be downgraded or suspended if no fossils are found after 50% of a given project has been completed. We find this threshold problematic and recommend that changes to the monitoring level of effort be decided on a project-by-project basis with input from both the principal investigator and the applicable lead agency. For example, a 200-mile long pipeline could very well cross 50 geologic units with different levels of paleontological potential. Downgrading the monitoring program after 100 miles of construction would be nonsensical because many of the geologic units within the project area may not have been monitored at all. Regardless, any changes in monitoring intensity should be approved in writing by the appropriate agencies and project owner (Appendix I, 6.2).

Figure 5. Georgia Knauss operates a Trimble GPS receiver while Dale Hanson examines rocks of the Sentinel Butte Formation (Fort Union Group) exposed in a natural gas pipeline trench in North Dakota.

In some instances, monitors have the opportunity to do a brief, final surface inspection prior to ground disturbance to ensure that no scientifically important fossils were missed during or exposed after the preceding field survey (Appendix I, 6.3). If fossils are found prior to ground disturbance, they should be documented and mitigated as if found during a field survey (see Sections 4 and 5). However, in most cases monitors only watch active construction excavations, which can vary from relatively small disturbance areas such as access roads, oil and gas well pads, drilling for footings, and trenching for pipelines to relatively large disturbance areas such as mass grading for residential or commercial development, new roadway construction projects, solar energy generation facilities, and open pit mining operations. Monitors should be aware of the effects of certain types of construction equipment on bedrock and contained fossils (Appendix I, 6.4). In most sedimentary rock units and surficial deposits, drilling with an auger with a tool diameter of 2 feet or less typically pulverizes the sedimentary matrix, including any contained fossils. Therefore, monitoring of drilling activities when a small auger is used is typically not recommended. However, if a monitor is already on site inspecting project-related excavation activities, the drilling spoils should be periodically checked for the presence of fossils and the breakage characteristics of the matrix should be checked to see if the drilling is yielding rock fragments large enough to contain identifiable fossils. Some types of ditching equipment are known to turn rock to a fine powder, obliterating any evidence of fossils in the spoils piles. If such equipment is in use, the only option for monitoring is to inspect the trench sidewalls for exposed fossils (Figure 5). This procedure has been shown to be effective in identifying fossils in cross section depending on the lithology of the rock unit and types and sizes of fossils the rock unit is known to contain. Track-hoe excavations have been found to be more conducive to the discovery and recovery of unearthed fossil remains than ditching machines, because they produce larger blocks of rock which can contain more complete fossils. Finally, when equipment is not running due to lunch breaks, end of shift periods, and/or equipment breakdown, there is an extra opportunity to safely examine the cut, document the stratigraphy, and investigate spoils piles (Appendix I, 6.5).

Monitoring inspections should be performed as close to the active cut or other type of excavation as is safe in order to see fossils as they are unearthed, whether in spoils piles or exposed in excavation sidewalls or horizontal graded surfaces. Monitoring cannot succeed if monitors are not within visual range of the excavation where they have access to freshly disturbed rock, ideally 5 to 20 feet but no greater than 30 feet, and even at that distance fossils may not be visible (Appendix I, 6.6). When equipment activity (multiple machines in a small area), terrain instability (uneven/ripped/slippery bedrock), and/or other circumstances make the excavation area an unsafe environment, it is also acceptable to monitor the spoils pile for fossils. This includes spoils piles in the immediate vicinity of the excavation, or at an alternate location on site to where spoils are being relocated.

There are specific Occupational Safety and Health Administration (OSHA) safety requirements (or Cal-OSHA in California) for the types and depths of excavations that can be entered by project personnel, and it is critical that these safety requirements be strictly followed. For example, monitors should not enter trenches that are greater than 5 feet deep; and should not approach the edge of a trench that is more than 6 feet deep without a guard rail. Also, monitors should never walk underneath any construction equipment, and should stand at a distance greater than the length of the extended arm of equipment that can rotate, such as track hoes. Be sure to consult with project safety personnel prior to entering the construction area for site-specific safety requirements. However, as a rule of thumb, monitors should never do anything that feels unsafe. It is important for their safety that monitors understand the movement patterns of construction equipment around the project area (e.g., haul road) and use standard hand signals to communicate with equipment operators. If the monitor cannot see the operator, chances are that the reverse is also true and the operator cannot see the monitor. Verbal communication with all project personnel, including the foreman, environmental inspector(s), grade checker, other environmental monitors, and project geologist, is also very important. Although there is a safety benefit to communication, it is also very helpful for the success of monitoring to develop a good working relationship with all project personnel. Developing an attitude that the field paleontologist is just another member of the project team has been proven to help minimize the perception that paleontologists are "elitist academics" out to shut down construction. Overall, this team approach will greatly increase the likelihood that in the event fossils are unearthed and unseen by the monitor, the equipment operator will alert the monitor to their presence (Appendix I, 6.7).

Documentation

Monitors should pay close attention to the stratigraphy of the project area as it is sequentially revealed in exposed strata and document their observations on a field form or in a field notebook. A minimum of one stratigraphic section should be measured as the project progresses, even if no fossils are found, and the monitor should consult with the project geologist if practical for geologic information about the project site and surrounding area. In the case of larger projects, it may be necessary to measure multiple stratigraphic sections in order to document facies changes and refine the stratigraphic position of local channel features and surfaces of erosion. Measuring stratigraphic sections on an active construction site is challenging because of discontinuous exposures, here-today–gone-tomorrow parts of the section, compaction which tends to obscure the stratigraphic profile, and ubiquitous dust and/or snow. However, stratigraphy can be documented in the current monitoring area and added to and revised as the excavation moves and progresses up- or down-section. Having a working stratigraphic framework of the emerging section makes it possible to more accurately plot the stratigraphic position of discovered fossils. Fossils collected without stratigraphic control lose a considerable degree of their scientific integrity. On projects with more than one monitor, all monitors should work cooperatively to ensure that the stratigraphic framework for the entire project area is documented consistently. For linear projects that follow the approximate contours of the landscape, such as a pipeline trench, unless the bedding planes are dipping noticeably (in which case standard stratigraphic sections are preferable), a trench log may be the best option for documenting the lithologic changes along the project alignment and their relationships to discovered fossil localities. All stratigraphic and structural geologic observations should be for the purpose of interpreting the context of the fossil assemblages within the project area and should never be construed as providing data for project geotechnical or engineering design purposes. For projects involving drilling operations, vertical stratigraphic position (i.e., depth below ground surface) can be roughly estimated by measuring the distance from the ground surface to the level of the bit on the auger. All fossil localities must be tied to the stratigraphic sections measured for the project when geologically possible, and all stratigraphic documentation should be included in the final monitoring report. A stratigraphically well-documented project will make it possible to interpret facies relations and depositional environments, as well as the relative age relationships of the recovered fossil assemblages (Appendix I, 6.8).

Fossil Discoveries

An unfortunate practice, but one which some project managers and equipment operators prefer, is for monitors to make themselves scarce on the job and spend the majority of their time sitting (or sleeping) in their vehicles. The rationale is that by not actively monitoring, fossils will not be found, and this will decrease project costs. Requiring monitors to stand too far from the equipment to visually observe the excavation under the guise of safety concerns is another way of preventing monitors from making fossil discoveries and thereby reducing perceived financial risks. Monitors are on site to help crews meet their deadlines. Professional paleontologists and the firms and organizations they represent should educate clients and construction personnel about monitoring best practices, particularly with regard to safety, but also with regard to the need to be within view of the active excavation in order to keep the project in compliance with agency-approved environmental requirements. Clients should also be notified that unless the land is owned by the project proponent, without adequate monitoring there is a financial risk to projects, particularly if fossils with scientific importance (which may translate to economic value on privately owned lands) are destroyed by construction equipment. Additionally, impeding the monitoring effort could be in violation of project conditions of approval or construction permits (Appendix I, 6.9).

The discovery of a fossil (or fossils) during monitoring initiates the recovery process with fossil evaluation and collection (see Section 7). After a brief evaluation to determine whether the fossil discovery has the potential to be scientifically important, the monitor should immediately alert the equipment operator and make any other necessary project-specific notifications depending upon the nature of the fossil(s) and the requirements of any approved project monitoring and mitigation plan. The fossil discovery (plus a 20-foot buffer depending upon locality dimensions) should be cordoned off with high-visibility flagging, and additional personnel immediately mobilized, as needed, to provide monitoring or fossil collection support while the discovery is explored and evaluated. Construction activity should not be discontinued but should be directed away from the discovery locality in consultation with the construction foreman. Equipment should operate no less than 20 feet from the fossil discovery locality, although this buffer should be increased if the monitor believes that the extent of the fossil locality may be larger than what is currently exposed or for safety reasons. All monitors should have expertise in fossil evaluation and collection techniques (Appendix I, 6.10).

7. FOSSIL SPECIMEN RECOVERY: FROM COLLECTION TO PRECURATION

Broadly speaking, fossil recovery activities for mitigation paleontology projects can be separated into two categories: fossils that are collected during field surveys and fossils that are collected during construction monitoring projects. For the purpose of this paper, fossil recovery also includes laboratory fossil preparation, fossil identification, and precuration. Although both recovery categories have many similarities in field procedures, they also have some important differences primarily having to do with impact mitigation. One of the most critical differences between the two is the amount of time available to complete recovery operations. For example, decisions regarding fossils discovered during monitoring have to be made quickly because the paleontological resource has already been impacted, whereas typically there are more options for fossils discovered during field surveys, and time is less of a factor. The fossil recovery process generally has five phases, as discussed below and summarized in Table 4.

Phase 1: Preliminary Mitigation Evaluation. Is the Locality Worth Exploring?

Phase 1 of the recovery process involves a preliminary evaluation of the fossil(s) found on the ground surface or exposed by construction equipment. The evaluation should follow predetermined threshold criteria for scientific importance (see criteria in Section 4 or agency-specific criteria) and should determine whether or not the fossil(s) discovered warrant collection. If the decision is not to collect, the locality should be recorded (see Section 4) as nonimportant and no further action taken. Note that locality avoidance is typically not an option for localities discovered while monitoring because the locality has likely already been impacted (Appendix I, 7.1).

Phase 2: Locality Exploration. Is the Fossil Worth Collecting?

If the discovered locality contains one or more fossils that have scientific importance or have the potential to have scientific importance based on what is exposed (i.e., visible), then Phase 2 of the recovery process, locality exploration, should begin. Evaluation continues during this phase because sometimes the full scientific importance of fossils cannot be determined until they have been more completely exposed. Locality exploration involves surface prospecting to determine the boundaries (lateral extent and depth) of the locality and the distribution and concentration of fossils. Exploration is typically done using hand tools (e.g., small shovels, trowels, hammers, chisels, etc.). Because time is of the essence on active construction projects, heavy equipment can be useful to expedite the locality exploration process and can also facilitate access to the locality (e.g., by digging an access ramp), as long as the equipment does not come into direct contact with the fossil(s). If during the exploration phase, the locality is determined to lack scientific importance, it should be recorded as nonimportant, and no further action is needed (Appendix I, 7.2). However, if during exploration the locality is determined to have scientific importance, the fossils can be collected immediately; fossil collection can be deferred until the principal investigator, agency and/or client have evaluated the scientific importance and/or mitigation options; or the entire locality can be avoided. Avoidance is an option during preconstruction fieldwork if the proposed activity is easily moved (e.g., a seismic project source point), or if the locality is extensive and would be prohibitively costly to mitigate. In such cases, it is important to survey an alternative project infrastructure location or corridor that avoids other scientifically important fossil localities (Appendix I, 7.3). Unlike field surveys, mitigation by fossil col-

Table 4. Phases of the fossil recovery process (collection to curation) during field surveys versus construction monitoring.

Phase	**Field Survey**	**Construction Monitoring**
1. Preliminary mitigation evaluation—is the locality worth exploring?	Initial examination indicates that fossil(s) are either possibly identifiable and meet predetermined threshold criteria for scientific importance, or unidentifiable, in which case locality should be recorded as nonsignificant and no further action is required (skip to Phase 3). Time is not usually a critical factor for all phases.	Initial examination indicates that fossil(s) are either possibly identifiable and meet predetermined threshold criteria for scientific importance, or unidentifiable, in which case locality should be recorded as non-ignificant and no further action is required (skip to Phase 3). Locality avoidance is not typically an option, even in the case of extensive fossil discoveries as defined in Section 5. Time is usually a critical factor for all phases.
2. Locality exploration—is the fossil worth collecting?	Determine areal extent of locality by surface prospecting and probing surface sediments with hand tools. Ant hills should also be explored. Unless necessary, avoid the use of adhesives or consolidants and focus on exploration rather than stabilization or excavation. In cases in which partially exposed fossils are determined to be nonsignificant following exploration, or can be avoided or collected later, skip to Phase 3. Locality avoidance is typically an option for scientifically important fossil localities and is likely preferable for extensive fossil localities as defined in Appendix I, 5.10, depending upon client priorities.	Determine lateral and vertical extent of locality using hand tools, and if possible in the case of larger localities, with heavy equipment. Unless necessary, avoid the use of adhesives or consolidants and focus on exploration rather than excavation. If the fully explored fossils are then determined to be nonsignificant, skip to Phase 3, and no further action is needed.
3. Locality excavation, collection, and documentation (See Section 4 and Table 3 for greater detail on documentation.)	Collect fossil(s) from ground surface by hand quarrying or if necessary by larger, but permit-conformable, sized quarry. Use adhesives and consolidants as necessary. Collect fossiliferous anthills if scoped for. Collect bulk matrix samples if scientifically important small fossils are present. If the budget and schedule permit, collect and wash test samples to determine whether the density of small fossils warrants bulk sampling.	Collect unearthed fossil(s) by hand quarrying and/or with the assistance of heavy equipment if needed, appropriate, and applicable, from the ground surface or spoils piles. Use adhesives and consolidants as necessary. Collect bulk matrix if scientifically important small fossils are present. Heavy equipment can be used to stockpile matrix away from construction activity. If the budget and schedule permit, collect and wash test samples to determine whether the density of small fossils warrants bulk sampling.
	Record locality as nonsignificant if fossils discovered were found to lack scientific importance. For scientifically important fossil(s), complete locality data recording during surface collection and/or excavation phases, but prior to jacketing or packing and removal of fossil(s) from locality. Additional mitigation recommendations could include collection if avoidance is not feasible, or deferred collection pending client and/or agency approval. If client-preferred mitigation is avoidance, survey and record an alternative corridor or project infrastructure location that avoids scientifically important fossil localities.	Record locality as nonsignificant if fossils discovered were found to lack scientific importance. For scientifically important fossil(s), complete locality data recording during surface collection and/or excavation phases, but prior to jacketing or packing and removal of fossil(s) from locality. Additional mitigation recommendations are usually not relevant to localities discovered during monitoring because such localities are typically graded away.
4. From the field to the curation facility	Transport fossils from the field to the laboratory and from the laboratory to the curation facility. Ensure that fossils are properly packed and protected from damage and theft during transportation and storage.	Same as field surveys.
5. Laboratory work	Fossil preparation, identification, and precuration work.	Same as field surveys.

Figure 6. Betsy Kruk prepares to jacket a mammoth vertebra in Larimer County, Colorado.

Figure 8. Katherine Card and Paul Murphey excavate a maxilla of the fossil horse *Mesohippus* found during a field survey in the White River Formation in Pawnee National Grasslands, Colorado. Note that the fossil was found prior to the snowstorm but was left in place until it could be evaluated by the principal investigator.

Figure 7. Paleo Solutions' paleontologists excavating Columbian mammoth remains unearthed by an excavator at the site of a new reservoir dam in Larimer County, Colorado.

Figure 9. Betsy Kruk explores a small fossil crocodilian partially weathered onto the surface in the Paleocene Coalmont Formation, North Park, Colorado.

lection is typically the only option for scientifically important fossils discovered during construction monitoring (Appendix I, 7.4). However, it is rarely necessary to shut down the project due to the discovery of a fossil unless the fossils requiring collection extend throughout the area remaining to be excavated. Furthermore, the stipulation sometimes applied to CRM projects that construction work be suspended project wide pending agency review and approval of a site-specific mitigation plan should not be applied to paleontological discoveries.

Phase 3: Fossil Recovery

Fossil collection and documentation constitutes impact mitigation because fossils are removed from the proposed or active construction disturbance area. Fossil excavation and fossil collection for mitigation paleontology projects is a complex topic due to the many considerations involved. Standard types of fossil recovery techniques for construction monitoring projects include preconstruction surface collection, collection of isolated fossils exposed during construction, small quarries, large excavations, and bulk matrix collection (Figures 6–9). Standard types of fossil recovery recommended for deferred collection (collected later pending client or agency consultation) following field surveys include surface collection, small quarries, large excavations, and bulk matrix collection (including sampling of western red harvester ant hills). Fossiliferous concretions may be collected or excavated during surveys or monitoring and should be documented and then removed from the project area in bulk form for later preparation in a laboratory setting.

Recovery techniques appropriate to the size and preservation of the discovered fossils should always be used. All field paleontologists should be knowledgeable of fossil recovery and sampling techniques and be properly equipped with field tools and supplies, including archival-quality reversible adhesives and consolidants. Speed and efficiency are crucial for salvaging fossils found during construction monitoring. Medium- to large-sized fossils or groups of fossils may be excavated as blocks, still encased in matrix to provide additional stability and to expedite their removal and minimize construction delays. Removing enclosing matrix to fully expose a fossil adds substantial time and increases the possibility of breakage during transport. As during the exploration phase, construction equipment can be used during Phase 3 to expedite fossil excavation as long as the equipment does not come into direct contact with the fossil(s). Construction equipment can also be useful in lifting heavy plaster jackets into vehicles for transport off-site. Equipment operators are usually willing to provide assistance to expedite the recovery process and reduce construction delays. Prior to moving or jacketing any fossil specimens, ensure that all data are recorded including the original orientation and concentration of the fossils (see Section 4 and Table 3 for additional information). If applicable, a scaled quarry map should be produced to accurately record critical taphonomic data. This could be done manually using a grid system, with high resolution GPS receiver, or with survey equipment such as a total station, depending on the size and complexity of the quarry. Properly label all bags, containers, and plaster jackets with field locality numbers. If needed and within scope, rock or sediment samples for future analysis (e.g., radiometric or biochronological dating) should be collected at the time fossils are recovered (Appendix I, 7.5).

Screen-washing for small fossils (vertebrate, invertebrate, and plant) is a critical procedure that has been demonstrated to yield results unobtainable via any other means and has greatly increased the taxonomic diversity and number of specimens available for study in geologic units wherein it has been employed (Figure 10) (Hibbard 1949; Waters 1978; McKenna et al. 1994). The presence of small fossils can be ascertained by collecting "test" samples (20 to 30 pounds) of sedimentary matrix. For fossil accumulations including bone beds (whether considered to be "extensive" fossil localities as defined in Section 5 or not), it may be necessary to collect bulk matrix samples, or excavate and jacket blocks of more indurated fossil-bearing sedimentary rock, depending on fossil size, durability, quality of preservation, and other factors evaluated by the field supervisor and/or principal investigator. SVP (2010, p. 7) provides guidance for bulk matrix sampling, recommending the collection of 600-pound test samples and if warranted, screen-washing of 6,000 pounds or more of matrix from each "site, horizon, or paleosol," depending on the "uniqueness" of the fossil content. However, because of variation in fossil density within and between geologic units, smaller samples are often sufficient based on the results of rarefaction analysis, or in cases in which the locality contains exceptionally high concentrations of fossils or has less matrix available for sampling. Rarefaction is a statistical procedure that estimates the point at which the taxonomic diversity of a fossil assemblage has been fully sampled. But due to the nature of mitigation paleontology, including the short period of time during which fossiliferous exposures are available for sampling, it is usually not possible to apply rarefaction analyses to a fossil locality found during construction. Collecting a large sample of matrix permits future decisions, such as ascertaining when diversity has been adequately sampled. During Phase 3 work, construction equipment can be used to collect bulk matrix and/or stockpile matrix away from the disturbance area for later processing by paleontologists (Appendix I, 7.6).

If a locality contains at least one scientifically important fossil, then it should be considered scientifically important and recorded as such. However, other than generalized significance criteria, there is little agency guidance provided about what to actually collect at a locality. Using the significance criteria alone, the implication is that only "scientifically significant" fossils should be collected. However, partial collection of fossil localities is generally not considered good scientific practice in vertebrate paleontology. For example, leaving some unidentifiable bone fragments at an outcrop after collecting the bulk of a given specimen could prevent a broken skeletal element from being repaired. The best approach is to incorporate guidance from technical experts and/or regional museums during the development of threshold criteria for paleontological importance so that field paleontologists are as well informed as possible about the criteria for scientific importance and fossil collection.

Figure 10. Paul Murphey operates a portable screen-washing workstation in a parking lot in Vernal, Utah.

Based on knowledge of the research context and paleontology of the area (see Section 3), collect all identifiable specimens that have scientific value using BLM or other federal significance criteria, if applicable. If nonimportant but identifiable specimens representing other taxa are present, it is a best practice to make a census collection that reflects the taxonomic diversity of the locality for paleoecological analysis. Assuming locality avoidance is not the chosen mitigation option, it is the responsibility of the mitigation paleontologist to document and fully collect or otherwise mitigate impacts to all scientifically important localities from within a project area (Appendix I, 7.7).

Fossil collection policies for mitigation projects on Native American tribal lands are variable and can be challenging. Of foremost importance is to respect all tribal policies and work within them to reduce impacts. Some tribes do not permit fossil collection even by professional paleontologists, and yet they still have the resource management objective of reducing impacts to paleontological resources associated with energy development. The mitigation strategy in this scenario is avoidance, which works well for fossils discovered during field surveys but can be problematic for fossils discovered during construction monitoring because it is too late to avoid them once their presence is known. Unless it is for the purpose of permanent preservation in a curation facility, a fossil should never be physically moved from its original locality, thereby removing it from its stratigraphic context. While it may be worthwhile to recommend fossil collection to the on-site tribal monitor or other tribal representative if a scientifically important fossil is discovered during monitoring, there may be no option provided by the tribe other than to document the fossil and leave it in place. In-situ molding of scientifically important fossils found on tribal lands during field surveys has been shown to be an effective means of collecting scientifically useful information in cases where fossil collection is not permitted (Imhof et al. 2008), and this approach could also be employed for scientifically important fossils found while monitoring. Molding protocols must have the express advance approval of the applicable agency or tribe in writing. Photogrammetry and three-dimensional scanning are increasingly affordable replication processes suitable for recording scientific information (see Matthews 2008; Matthews et al. 2016 and references within for appropriate methodologies) (Appendix I, 7.8).

Phase 4: From the Field to the Curation Facility

Transportation and storage of paleontological resources after they have been recovered but before they have been delivered to the curation facility is an important but rarely discussed topic about which there is little agency guidance. Once removed from the ground, recovered fossils are the responsibility of the permittee until they are formally transferred to the approved repository. Fossils are especially vulnerable to loss, theft, damage, or misuse during this time and negligence on the part of the permittee can lead to both criminal and civil charges. Failure to produce proper documentation (i.e., a copy of the permit or museum agreement) could result in a charge of larceny, interstate transport of stolen federal property, or similar unnecessary accusations. Mitigation paleontologists can avoid these issues by exercising due diligence and common sense.

After they have been collected in the field, fossils should be transported in a manner that protects them from both physical damage and theft. Protection from physical damage can be accomplished by properly packing, padding, and jacketing fossils as appropriate. Fossils should only be placed in a vehicle for as little time as is needed to move them to their destination. Boxes or jackets containing fossils should be covered with tarpaulins or other means to obscure their identity, and vehicles with fossils should be locked and not left unattended. In order to minimize the time in which the fossils are vulnerable, the most direct and quickest route possible should be selected. If stopped by law enforcement, it may be necessary produce a copy of a permit or other documentation that confirms the nature of your work. At a minimum, know the name and contact information of the office that issued the authorization or permit. This is especially important when transporting fossils through checkpoints or airports, or across international boundaries, but also applies to public lands and highways.

It is usually necessary for mitigation paleontologists to temporarily store fossils collected during the course of a mitigation project. Fossils need to be stored while a mitigation project is ongoing or until extended field work has been finished and storage may be extended while laboratory preparation and fossil identification work is completed. Sometimes temporary storage must continue until the final report has been accepted by the agency or the approved repository is ready to receive the collection. The permittee is responsible for these collections during this time, so the place and manner of temporary storage is of utmost importance. While there is little guidance available for mitigation paleontologists working under a paleontological permit, Department of Interior departmental manual 411 provides helpful standards (DOI 2012). It may not be possible to replicate museum standards for all collections, especially fossils that are still in large field jackets, but smaller fossils should be stored in a locked cabinet (archival quality preferred) in a locked room (or building). A common-sense standard is to maintain an environment that is equal to or better than the environment that the fossils would have been subject to if they had been left in the field. If the fossils survived millions of years preserved in the Earth, the actions of a mitigation paleontologist should bring them into a context of preservation, not destruction or loss. Once a project has been completed, no fossils from that project should remain in temporary storage. Rather, they should be transferred to the approved curation facility or their disposition (i.e., disposal, donation to a school, etc.) should be documented and reported to the overseeing agency (Appendix I, 7.9).

Phase 5: Laboratory Work

The final phase of fossil recovery includes laboratory work. This phase includes fossil preparation and identification, completion of any necessary associated analyses, and precuration. Preparation includes removal of surplus and concealing sedimentary matrix, repair and conservation using archival adhesives and consolidants, and limited infilling (with archival products) of voids that compromise the structural integrity of the fossils. All laboratory work should be supervised by a laboratory paleontologist with the qualifications defined in Section 1. In consultation with the curation facility, fossils should be prepared to the point of curation—operationally the point at which the bulk of enclosing matrix has been removed and the curation facility does not need to do additional preparation work prior to curation (see Section 9). Bulk matrix samples should be screen-washed, floated with heavy liquids if appropriate, and sorted (picked) for small fossils. All fossils should be identified to the lowest taxonomic level possible by a paleontologist with technical specialization in that taxonomic group. As a practical matter, recovered fossil specimens are not typically identified to the level of species because the level of detailed study needed to determine species crosses into the realm of research. It is assumed that the curation facility will verify the fossil identifications if there is a staff member with the necessary technical expertise. If included in the scope of work, additional analyses relating to the paleontological resources mitigated should be completed for inclusion in the monitoring or field survey report (e.g., palynological, radioisotopic, magnetostratigraphic, petrographic analyses, etc.). Precuration entails entry of field (e.g., geographic, topographic, and stratigraphic position) and laboratory (e.g., taxonomic, taphonomic, and preparation details) data into a computerized database, as well as proper labeling (e.g., temporary inventory or permanent catalogue numbers) and packaging fossils (e.g., placement in vials and/or specimen trays and construction of reinforced support cradles) for transport to the curation facility according to the terms of the curation agreement. Laboratory fossil preparation procedures for individual specimens should be recorded on a fossil preparation log form, which should be provided to the curation facility along with the fossil collection (Appendix I, 7.10). Data management is discussed in greater detail below in Section 8.

8. DATA MANAGEMENT AND REPORTING

In this section, we propose best practices in data management and reporting. Purely business data-related functions such as accounts payable/receivable, contracts, and human resources are not discussed because these have minimal overlap with best practices in mitigation paleontology. As with field data collection, data management and reporting require the establishment of a system that works for the individual mitigation paleontologist or larger mitigation program—currently there is no universally applicable system for data management and reporting.

Data Management

Data management strategies should emphasize efficient data entry, accuracy, regular backup, and efficient retrieval of information. Networked databases permit data entry, storage, and manipulation by multiple users working remotely. In mitigation paleontology, various types of data are generated prior to and during fieldwork (see Section 4) and subsequent analyses such as fossil preparation, specimen inventory, and specimen identification. There are numerous interrelated data sets that must be computerized, analyzed, and synthesized for inclusion in project reports, annual permit reports, and associated data that accompany fossil collections reposited at curation facilities (Table 5). Effective management of these data represents a logistical challenge, especially for large projects such as those that include multiple agencies, multiple states, multiple land ownership types, multiple curation facilities, complex geology, or large numbers of fossils. Often, the data consist of a combination of purely electronic information such as geographic coordinates and digital images, and nonelectronic information in the form of hard copy field forms, scientific publications, and paleontological resource use permits. Information in hard copy format is frequently

Table 5. Typical data types, formats, and uses in mitigation paleontology ("Final Project Report" refers to any report type listed in Table 6).

Data Type	Typical Data Source Format	Uses and Considerations
Fossil locality (newly recorded)	GIS[a] data, hard and electronic copies of field data forms	Agency-confidential appendix in project report; non-georeferenced summarized data for client final project reports; end-of-year permit reports
Fossil locality (previously recorded)	GIS data, hard and electronic copies of field data forms	Analyses of existing data; non-georeferenced summarized data for client final project reports
Survey areas	GIS data, hard and electronic copies of field data forms	Final project reports, end-of-year permit reports; surveyed areas need to be compared to changes in infrastructure locations throughout preconstruction phase of project
Monitoring areas	GIS data, hard and electronic copies of field data forms	Final project reports, end-of-year permit reports
Field photographs	Images and photographic logs	Locality forms in agency-confidential appendix in final project reports; project reports
Aerial images	Digital orthophotograph quadrangle maps (U.S. Department of Agriculture National Aerial Imagery Project, Google Earth, etc.)	Cost proposals; analyses of existing data (prefieldwork review)
Geologic maps	Digital or hard-copy USGS and state geological survey maps, published scientific literature	Analysis of existing data; final project reports
Topographic maps	Digital or hard copy USGS topographic quadrangle maps	Analysis of existing data; final project reports
Digital elevation models	GIS data	Analysis of existing data; final project reports
Literature	Digital or hard-copy scientific publications and gray literature	Analyses of existing data; final project reports
Site geology and stratigraphy	Digital or hard-copy scientific publications and gray literature; hard and electronic copies of field data forms	Final project reports, information for curation facility
Land ownership	Client or agency provided data usually as GIS or AutoCAD files	Agency-confidential appendix in project reports; non-georeferenced summarized data for client final project report; end-of-year permit reports
Fossil identifications	Principal investigator and technical expert(s): hard or electronic copy	Agency-confidential appendix in project reports; project reports for client; identifications to lowest possible taxonomic level, and detailed descriptions of elements
Literature	Digital or hard copies of scientific publications and gray literature	Analyses of existing data; project reports (a copy of each cited reference is required for NEPA document administrative records)
Project reports	GIS data, hard and/or electronic copy	End-of-year permit reports
Fossil preparation	Hard and/or electronic copies of lab preparation forms	Project files, curation facilities
Paleontological resource use permits and authorizations	Hard and/or electronic copy	Project reports, paleontological resource use permit files
Annual permit reports	GIS data, hard and/or electronic copy	Paleontological resource use permit files
Curation agreements	Hard and/or electronic copy	Paleontological resource use permit files
Project and staff schedules	Hard and/or electronic copy	Project implementation
Client, agency and curation facility communications	Hard and/or electronic copy	Permit files, project files (including administrative record if applicable)

[a]Abbreviations: GIS indicates geographic information system; USGS, U.S. Geological Survey.

scanned or entered into databases for more efficient organization and rapid retrieval. Furthermore, it is increasingly common for all project data to be digital from collection through reporting. As discussed below, the product ("deliverable") in mitigation paleontology is the final project report that documents the work performed. Therefore, all data types are related to the completion of the project and the content of the final project report (Appendix 1, 8.1).

Reporting

Final project report requirements vary by agency and should be prepared to meet or exceed agency standards. If there is no agency involvement or the agency involved does not have standards, then the best practices as presented here should be followed (Appendix 1, 8.2). There are five general types of reports in mitigation paleontology: paleontological resource impact evaluation report, paleontological field survey report, paleontological monitoring report, paleontological resource impact mitigation plan, and environmental compliance analyses required under NEPA, CEQA, or other statues (Table 6). However, not all of the listed reports are required for each project. For example, a paleontological impact evaluation report is a preliminary assessment of the potential for impacts on paleontological resources within a project area based on an analysis of existing data with no field survey (see Section 3). The term "assessment" is often applied to such reports, which is confusing because it may or may not include a field survey. For example, SVP (2010) proposes the term paleontological resource impact assessment report for a level of effort equivalent to an analysis of existing data with a field survey. We prefer the terms "paleontological impact evaluation report" and "paleontological field survey report" to clearly differentiate between these two types of projects.

This distinction would also avoid confusion with EAs under NEPA, which may or may not include field surveys. A report based on the analysis of existing data with no field survey is sometimes referred to by clients and agencies as a "desktop" review or analysis. However, this term is problematic because it is vague. A field survey report may or may not have been preceded by a stand-alone impact evaluation report. If not, a survey report should contain the results of the analysis of existing data as well as the results of the field survey. Likewise, a monitoring report may or may not have been preceded by a stand-alone impact evaluation report and a field survey report. If not, a monitoring report should contain the results of the analysis of existing data and field survey if one was completed. A field survey is not always a prerequisite to monitoring based on agency requirements and/or sensitivity (Appendix 1, 8.3).

Monitoring and mitigation plans are most commonly an agency requirement for large projects. Agencies use the results of an analysis of existing data and/or field survey to make detailed recommendations on monitoring locations and procedures, and fossil recovery procedures. For smaller projects, this information, in a less detailed format, may be included in either the paleontological evaluation report or the field survey report (Appendix 1, 8.4).

In reference to mitigation paleontology, NEPA documents are based on paleontological resource analyses completed under NEPA (1969) and include sections of EISs, EAs, and categorical exclusions (CXs). CEQA documents are parallel in their overall scope and approach to NEPA documents but are triggered by the CEQA (1970) and consist of environmental impact reports (EIRs). It is common for CEQA EIRs and NEPA CXs to include field surveys, whereas they may or may not be required in NEPA EISs and EAs (however, they may be a mitigation measure that requires subsequent field surveys). Paleontological resource sections completed for NEPA/CEQA studies generally consist of three sections (analysis of existing data, impacts analysis, and recommended mitigation measures; Table 6). An analysis of existing data generally provides the information needed to prepare the existing conditions (also known as affected environment) section. The impacts analysis (also known as environmental consequences) analyzes the anticipated impacts of the project or project alternatives on paleontological resources. Mitigation measures (as needed) are developed based on the results of the impacts analysis. The administrative record is an important part of the NEPA process because it contains all references and other sources used in the analysis. All paleontological reports, including NEPA/CEQA sections, should be written by or at a minimum, reviewed by, a professional mitigation paleontologist or agency paleontologist (Appendix 1, 8.5).

The BLM has requirements for the content of project and annual permit reports for work conducted under paleontological resource use permits (BLM 1998, 2008). These requirements are also generally useful for preparing reports for other federal agencies that lack their own resource management and reporting procedures. BLM end-of-year project reporting requirements fall entirely within the recommended content of field survey and monitoring reports listed in Table 6. BLM end-of-year permit reporting requirements are different than those for project reports (see BLM 1998). Annual permit reports are due on December 31 of each year. Some state agencies (e.g., Colorado and Utah) also have annual permit reporting requirements, but these vary by state.

There are various other issues related to paleontological reports, and paleontological locality confidentiality is one of the most important. It is unlawful to disclose to the public the locations of fossil localities on federal land and state lands in some states, either previously recorded or newly recorded during field surveys or monitoring. Some paleontologists find the policy of fossil locality confidentiality objectionable and the issue continues to be the subject of debate, especially with regard to implementing the PRPA (OPLA-PRP 2009; USFS 2015; DOI 2016). However, mitigation paleontologists should always treat paleontological locality data as confidential. This can be a difficult task when working with clients and sharing GIS data. All final project reports should omit legal locations, coordinates, and photographs of fossil localities in client copies and include this information as a confidential appendix of locality data for agency copies as required by local, state, and/or federal law (Appendix 1, 8.6). However, all paleontological resources, both scientifically important and nonimportant, should be reported (Appendix 1, 8.7). Because avoidance is a legitimate mitigation approach (although not the preferred approach for paleontological resource preservation), it is necessary to disclose the avoidance areas to clients so they can avoid known paleontological localities. This is typically done by providing a map and/or GPS data with the avoidance area as a polygon that encompasses the fossil locality without displaying the location of the actual fossils. Similar polygons can be used to identify areas that are recommended for monitoring based on field survey results without disclosing locality coordinates.

All field survey and monitoring reports should include documentation of areas that were surveyed or monitored, regardless of whether fossils were found (see Section 4) (Appendix 1, 8.8). All reports should include stratigraphic documentation of the project area with stratigraphically positioned fossil localities as appropriate to the project. Examples of graphically portrayed stratigraphic data are provided in Figures 11 and 12. As discussed and described in Section 3, paleontological resource impact evaluation reports and monitoring and mitigation plans should contain a theoretical framework, and final survey and monitoring reports should reference this framework and include a discussion of how the mitigation results preliminarily support or otherwise modify it.

Using local paleontological knowledge and experience, mitigation paleontologists should provide recommendations

Table 6. General types and typical minimum content of mitigation paleontology reports.

Paleontological Resource Impact Evaluation Report	**Paleontological Field Survey Report**	**Paleontological Monitoring Report**	**Paleontological Resource Impact Mitigation Plan**	**NEPA/CEQA[a] documents**
Summary and/or Introduction	Summary and/or Introduction	Summary and/or Introduction	Introduction	Existing conditions/affected environment
Methods	Methods	Methods	Methods	Environmental consequences/impact analysis
Laws, ordinances, regulations, and standards	Laws, ordinances, regulations, and standards	Laws, ordinances, regulations, and standards	Laws, ordinances, regulations, and standards	Mitigation measures
Project requirements (including agency-provided sensitivity classification if applicable)	Project requirements (including agency-provided sensitivity classification if applicable)	Project requirements (including agency-provided sensitivity classification if applicable)	Project requirements (including agency-provided sensitivity classification if applicable)	Cumulative Effects
Institution/agency record search results (without locality coordinates)	Institution/agency record search results (without locality coordinates)[b]	Institution/agency record search results (without locality coordinates)[b]	Institution/agency record search results (without locality coordinates)[b]	References
Geologic map review and literature search results	Geologic map review and literature search results[a]	Geologic map review and literature search results[a]	Geologic map review and literature search results[b]	Administrative record
Project theoretical framework	Project theoretical framework[b]	Project theoretical framework[b]	Project theoretical framework	
			Monitoring methods and procedures	
			Mitigation methods and procedures	
	Field survey results	Field survey results[b]	Field survey results[b]	
		Monitoring and mitigation results (stratigraphy and fossils recovered, if any)		
Mitigation recommendations	Mitigation recommendations	Mitigation recommendations	Recommended monitoring locations and level of effort (may need full version in an appendix)	
			Additional preconstruction tasks	
References	References	References	References	
	Appendix: documentation of areas surveyed	Appendix: documentation of areas monitored		
	Confidential appendix: fossil locality data	Confidential appendix: fossil locality data	Confidential appendix: fossil localities discovered during preconstruction field surveys	
	Appendix: receipt of fossil(s) from curation facility	Appendix: receipt of fossil(s) from curation facility		
	Appendix: permit(s)	Appendix: permit(s)		

[a]Abbreviations: NEPA indicates National Environmental Policy Act of 1969; CEQA, California Environmental Quality Act of 1970.
[b]If already completed for an earlier report for the same project or project area, cite earlier reports.

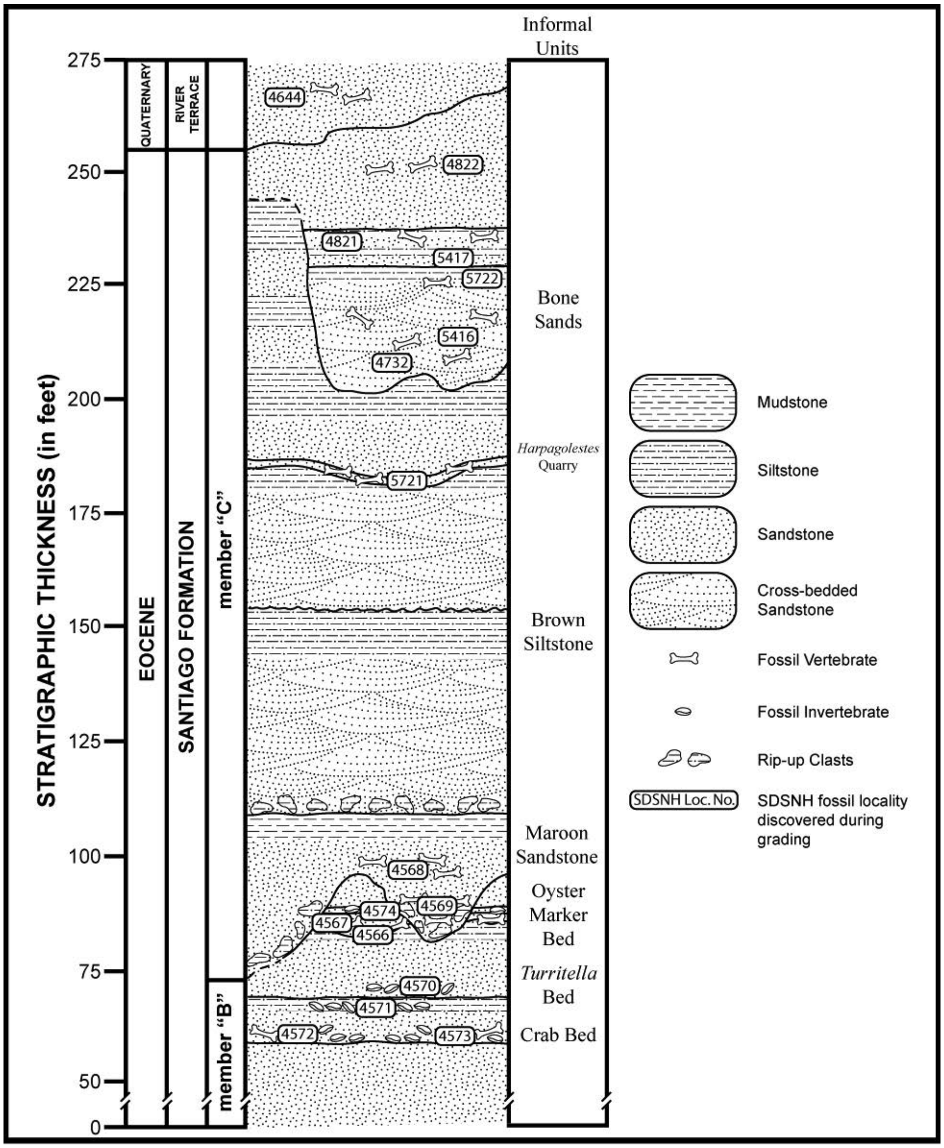

Figure 11. Composite stratigraphic column for the Ocean Ranch Project, Oceanside, California. Diagram depicts the lithologies, stratigraphic contacts, and stratigraphic positions of some of the fossil localities discovered within exposures of the Middle to Upper Eocene Santiago Formation and Quaternary stream terrace deposits. Diagram courtesy of the Department of PaleoServices, San Diego Natural History Museum.

regarding the frequency of repeated field surveys and provide justification to land managers in field survey reports and end-of-year permit reports (Appendix 1, 8.9). Professional mitigation paleontologists know that fossils, especially small specimens, will erode and weather when exposed at the surface, and will quickly be transported away from the locations of their initial exposure as the result of natural forces such as wind and rain. Therefore, the idea of a standard expiration date for an agency-required paleontological survey is illogical because erosion and exposure rates vary regionally and by rock unit (lithology), and are also related to the areal extent of rock exposures in an area. A time limit for CRM surveys exists but is highly variable depending on a number of factors. A 5-year expiration date for paleontological field surveys is an arbitrary but common agency recommendation, meaning that the survey has to be repeated if the project has not been built within 5 years.

Mitigation Recommendations

The purpose of mitigation paleontology, as discussed throughout this paper, is to preserve paleontological resources threatened by ground-disturbing activities by collecting them and placing them in curation facilities. For the sake of simplification and in the context of impact mitigation, there are two general settings in which paleontological resources occur: fully or partially on the surface and therefore readily visible during a field survey, or completely in the subsurface and therefore only discoverable via observation while monitoring construction excavations. Mitigation recommendations are an important component of project reports (see Table 6). They are a set of recommended actions and procedures that are designed to minimize adverse impacts to paleontological resources and recover fossils in a scientifically rigorous yet efficient and economically sensible manner.

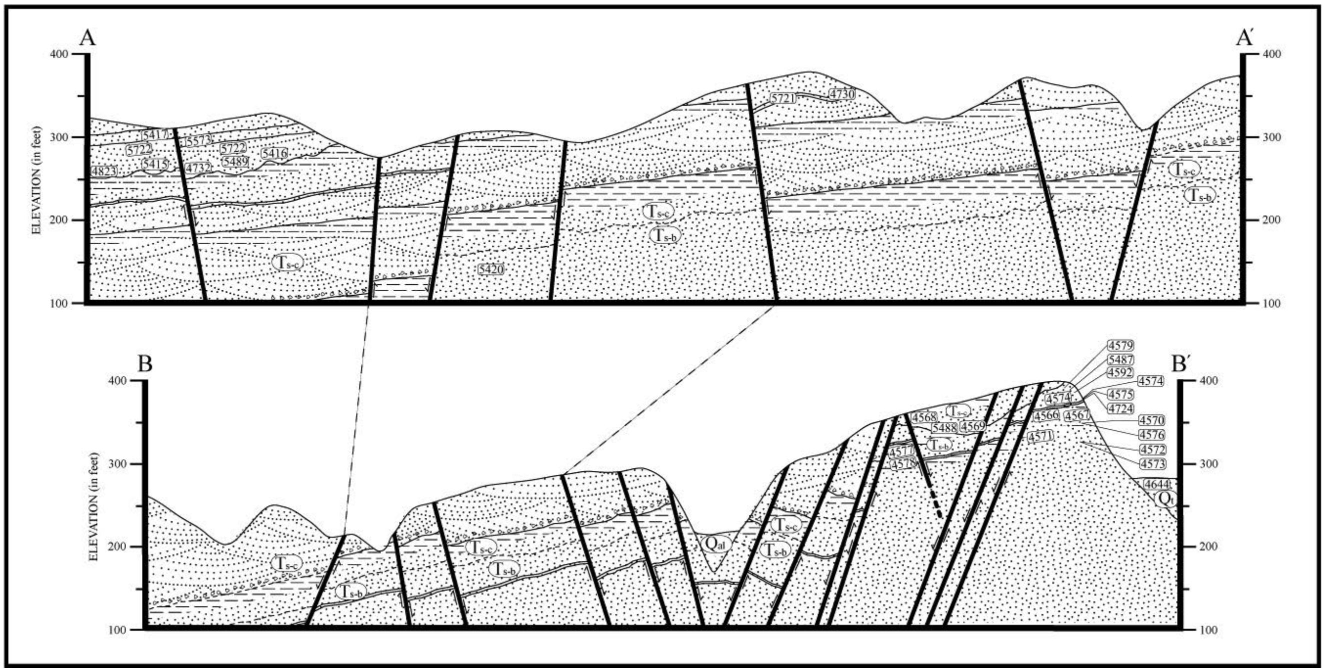

Figure 12. Diagrammatic cross sections through the Ocean Ranch project site, Oceanside, California. Diagram depicts lithologies, stratigraphic contacts, faults, and positions of fossil localities discovered within exposures of members B and C of the Middle to Upper Eocene Santiago Formation (Ts-b, Ts-c) and a Pleistocene stream channel deposit (Qt). The base of the maroon sandstone is the boundary between Santiago Formation members B and C. See Figure 10 for rock symbol legend. Diagram courtesy of the Department of PaleoServices, San Diego Natural History Museum.

Mitigation recommendations are often used as the basis for the development of formal mitigation measures that are included in environmental permitting documents including NEPA and CEQA reports. Mitigation recommendations should be prepared by, or minimally in consultation with, a professional mitigation paleontologist or an agency paleontologist with experience in mitigation paleontology. Basing formal mitigation measures on mitigation recommendations developed by a professional mitigation paleontologist or an agency paleontologist with mitigation experience is a best practice and will avoid the problems described below (Appendix 1, 8.10).

The majority of problematic or insufficient mitigation measures were not written by professional mitigation paleontologists, but by archaeologists, other resource specialists, or agency personnel with little or no experience in mitigation paleontology. Unless otherwise stated below, all aspects of paleontological mitigation work should be supervised by a professional mitigation paleontologist as defined herein (see Section 1). There are three primary but interrelated categories into which problematic mitigation measures fall:

- Insufficient or nonexistent mitigation measures. This category includes projects with anticipated adverse impacts to scientifically important paleontological resources, but which include inadequate mitigation measures or completely lack mitigation measures.

- Excessive mitigation measures. This category includes projects wherein suggested mitigation measures are unnecessary or greater than appropriate considering the paleontological resource potential.

- Insufficient qualifications. This category includes mitigation measures that permit the use of personnel who do not possess the minimum qualifications listed in Section 1 when working in geologic units with unknown, moderate to very high paleontological potential. It includes the use of so-called "cross-trained" or agency personnel without sufficient education and experience as paleontological surveyors or monitors as well as the use of construction personnel as paleontological resource monitors, as discussed below.

Construction personnel will most likely never see (or feel) a fossil that is unearthed (or impacted) by construction equipment before it is destroyed because they will not recognize it, and in some instances, they are under pressure not to report it. Therefore, what is often called the "standard stipulation" by agencies, which is essentially that construction workers and other project personnel self-report any fossils unearthed by construction, has resulted in the loss of scientifically important resources.

In geologic units, geographic areas, and in construction settings where the potential for scientifically important paleontological resources is low, preconstruction training should be provided for all construction personnel and paleontological monitors so that fossils can be recognized and reported if unearthed.

It is important to be aware that there is no one-size-fits-all solution for designing mitigation recommendations and developing formal mitigation measures. The standard mitigation recommendations listed in Table 7 appear straightforward as presented here but become far more complex when extended to large project areas and when taking into account such factors as amount of ground disturbance, specific agency and regulatory requirements, client objectives, potential for impacting scientifically important fossils, land ownership, and ongoing research projects in the area. Project complexity may well necessitate the development of novel project mitigation strategies. The best approach is to work closely with the agency (if any) and client while taking into account the paleontological resource potential of the project area and the standards of the designated curation facility. Effective mitigation measures in

Table 7. Standard mitigation recommendations.

Clearance	If adverse impacts to scientifically important paleontological resources are anticipated to be nonexistent or below the level of significance for a given ground disturbing project, a recommendation of paleontological clearance is typically appropriate.
Unpredicted paleontological discoveries	In project areas or portions of project areas with low paleontological potential, including those for which a clearance recommendation has been made, unpredicted paleontological discoveries have occasionally been made by construction workers. Therefore, a clearance recommendation should be accompanied by a contingency for unpredicted discoveries which includes notification and evaluation procedures and preconstruction worker orientation. Unpredicted paleontological discoveries are sometimes referred to as unanticipated discoveries.
Field survey	If the results of an analysis of existing data indicate that there is low potential for scientifically important paleontological resources to be present on the ground surface within a given project area, a predisturbance field survey should be recommended to document fossil localities within it and make further postsurvey recommendations (typically fossil recovery or avoidance).
Monitoring	If the results of an analysis of existing data or field survey indicate that there is the potential for scientifically important subsurface paleontological resources to be adversely impacted by ground disturbance within a project area, monitoring should be recommended.
Fossil collection	If scientifically important paleontological resources are discovered during field surveys or construction monitoring or are otherwise known to be present based on the results of an analysis of existing data and they are at risk of damage or destruction due to project disturbance, poaching, or vandalism, they should be collected and reposited in a curation facility. In general, and if possible, fossil collection is preferable to avoidance because it results in curation and permanent storage.
Avoidance	If the collection of scientifically important paleontological resources within a project area is not feasible due to size, abundance of resources, cost, and/or other factors, avoidance of a fossil locality by ground disturbing activity may be recommended, leaving the paleontological resources intact in the field.
Sampling	Scientifically important fossils of small or even microscopic size may be identified during field surveys or monitoring, or their presence may be tested for if they are not known to be present in a given geographic area or geologic unit. A sampling program may be recommended if tests indicate that scientifically important fossils of small size are present, and it is determined that statistically valid samples can be obtained by collecting and processing larger samples of matrix.

mitigation paleontology accomplish client objectives while meeting regulatory requirements and preserving (or at least reducing adverse impacts on) paleontological resources (Appendix 1, 8.11).

9. CURATION FACILITIES

In the mitigation and resource management world, museums are often referred to as repositories, or curation facilities, and mitigation paleontology would not be possible without them. However, not all curation facilities have the educational and outreach missions of museums—some are primarily designed for collections storage with access for research purposes. The purpose of this section is not to define the roles or responsibilities of curation facilities, but rather to discuss how the mitigation paleontologist should interact with them.

Curation facilities are the essential endpoint in the impact mitigation process as they are the final destination for mitigation-generated fossil collections (Figure 13). At these facilities, institutional fossil locality numbers are assigned, individual specimens or specimen "lots" are catalogued with unique specimen numbers, field data are entered into computerized databases, and fossil specimens are housed in museum cabinets or on storage shelves. Additional information about the role of curation facilities in mitigation paleontology has been provided by SVP (1996).

Like fossil collections made during research projects, mitigation fossil collections should, as a best practice and in many cases an agency requirement, be curated in an approved facility where they are available for research and educational purposes. As an example of an agency requirement, the Department of the Interior requires that a repository meet curation standards outlined in departmental manual 411 (DOI 2012), and also be approved by the permitting agency for a given project. In the absence of agency guidelines and guidance from curation facilities, there have been numerous cases of poorly documented and/or unidentified (or uni-

Figure 13. Adult and juvenile specimens of the brontothere *Parvicornis occidentalis* (with life-sized model) on display at the San Diego Natural History Museum. Both specimens were recovered from the Middle to Upper Eocene Santiago Formation during paleontological monitoring of mass grading operations at the Ocean Ranch project site, Oceanside, California.

dentifiable) mitigation fossil collections being delivered to curation facilities. While this continues to be a problem in some parts of California, the situation has greatly improved during the last decade with respect to fossils from federal lands (e.g., from BLM- and USFS-managed lands). Furthermore, in the absence of agency oversight, it is easy for mitigation paleontologists to produce "orphan collections," fossil collections that are never delivered to a curation facility. Mitigation paleontologists should ensure that all scientifically important fossils collected during mitigation projects are curated at an approved facility and should avoid the accumulation of orphan collections (Appendix I, 9.1).

Mitigation paleontologists should obtain curation agreements (also referred to as repository agreements) in advance of project scoping and obtaining paleontological resource use permits. When obtaining a curation agreement, mitigation paleontologists should discuss with the appropriate repository personnel the types and amounts of fossil specimens to be collected/curated, the geographic area and/or geologic units covered by the agreement, the level of preparation and documentation required, and delivery time frames (Appendix I, 9.2). Some institutions charge a fee for issuing curation agreements. To the best of our knowledge, most major regional museums require that every recipient of a curation agreement be a professional mitigation paleontologist (see Section 1). However, curation facilities can issue curation agreements to whomever they please. Theoretically, the role played by curation facilities represents an important additional check to the permitting process in ensuring that, in circumstances wherein curation agreements are required to obtain paleontological permits, only qualified paleontologists receive them. However, it is important to understand that regardless of one's qualifications, there is no obligation on the part of curation facilities to provide curation agreements or to accession fossils collected as the result of paleontological mitigation. The incentive to curation facilities to grant curation agreements is primarily to fulfill their mission, grow their regional scientific collections, and encourage their use for research and educational purposes. Curation facilities typically charge fees for collections curation and storage because of the additional costs related to processing the incoming collections, purchasing cabinets and curation supplies, and providing and maintaining the physical space for long-term preservation. While many institutions charge a one-time fee for curation and storage, the rates vary greatly between institutions.

Collections space is an ongoing concern for curation facilities, and many institutions have little or no space for expansion. Naturally, this limitation affects decisions about which fossil collections can be accessioned. Overall though, it has become increasingly apparent to curatorial personnel that mitigation fossil collections have a high degree of scientific value that justifies the space they occupy. Fossil collections need to be well documented (see Section 4) and consist of specimens with scientific importance (research potential) (Appendix I, 9.3), and not just "bone scrap" or "plant hash" (see Section 4). This issue underscores the importance of close communication between mitigation paleontologists, agency paleontologists, and the curation professionals with whom they work, especially with regard to an understanding of the curation facility's research focus and the types of fossils that the curators consider worthy of accessioning and that are pertinent to the research focus of the institution. If a curation facility is not willing or able to accession fossils that meet agency-defined scientific significance criteria, it is the job of the mitigation paleontologist to find an institution that will (Appendix I, 9.4). Currently, agency guidance for the disposal of non–scientifically important fossils collected on federal lands is lacking. This adds to the importance of ensuring that fossils collected during impact mitigation have scientific value and are worthy of curation.

Consider that most archaeological repositories were completely filled with artifacts prior to the 1990s, and many no longer accept collections—those that do are highly selective. This situation, dubbed the "curation crisis," (SAA 2003) fundamentally and permanently changed CRM so that now, archaeological artifacts are only rarely collected. There is a lesson to be learned here with respect to mitigation paleontology that has not been lost on curators and resource managers. The preservation of mitigation fossil collections depends on the ability of curation facilities to store these collections. Consequently, storage space remains a central focus of resource managers and curation facilities alike.

The degree to which fossils are prepared and identified should be included within the language of the curation agreement or otherwise communicated to the mitigation paleontologist prior to fossil delivery. Most curation facilities require fossils to be prepared prior to delivery and some require that specimen numbers be affixed to specimens prior to delivery, and that they arrive in archival trays of specific sizes or, in the cases of some small fossils (e.g., isolated teeth), mounted on pins (see discussion in Section 7, Phase 5).

Curation facilities also function as storehouses of associated paleontological data. Mitigation paleontologists should provide a complete set of the data recorded during a mitigation project (e.g., field notes, measured stratigraphic sections with plotted collecting localities, field maps with plotted collecting localities and locations of measured stratigraphic sections, field photographs documenting collecting sites and taphonomic conditions) and a copy of the final mitigation (survey or monitoring) report (Appendix I, 9.5). Fossil collections from the same project, and especially the same locality, should not be divided between different curation facilities unless necessary to meet permitting or curation requirements (Appendix I, 9.6). For example, localities from a project may be split between curation facilities if the project is located in multiple states and/or is managed by different agencies. Mitigation paleontologists must have a clear understanding of the expectations and standards of each of the curation facilities they work with as these standards vary greatly.

10. BUSINESS ETHICS AND SCIENTIFIC RIGOR

Ethical standards in mitigation paleontology involve individual professional mitigation paleontologists placing the purpose of impact mitigation—to preserve and minimize adverse impacts (per NEPA/CEQA) to scientifically important paleontological resources—at the forefront of their business decisions (Appendix I, 10.1). Adhering to rigorous scientific standards and following best practices is the best way to ensure that such decisions are ethical. The best practices described in this section are intended to provide general guidance only, since the issues involved are always evolving. Issues surrounding business ethics and scientific rigor in mitigation paleontology can generally be broken into three overlapping categories: 1) project scoping and implementation, 2) project personnel, and 3) external pressure.

Project Scoping and Implementation

Project scoping typically happens during the preparation of cost proposals or in preliminary discussions with clients about the amount and type of work that needs to be done. A scope of work contains the details of the work to be done, typically including some combination of an analysis of existing data, field surveying, construction monitoring, fossil collection, laboratory preparation, specimen identification, analysis, curation, and reporting. The proposal budget is an estimate of the amount of money needed to complete the scope of work. Because cost proposals are usually competitive bids, there is an obvious incentive on the part of consultants to scope the project in a way that lowers project costs as much as possible in order to capture as much business as possible. This is free enterprise and there is nothing wrong with trying to maximize efficiency, reduce costs, and make clients as happy as possible in a competitive marketplace. However, ethical concerns exist when proposals to undertake projects are scoped in a manner that is insufficient to properly accomplish the work in a way that is consistent with agency policies and guidelines, mitigation best practices (outlined in this paper), and accepted professional standards (SVP 1991, 1995, 1996, 2010). We refer to this as "underscoping." Underscoping is involved if a consultant knowingly underestimates the tasks and associated costs needed to properly complete a project. Often, underscoping in a cost estimate manifests itself as an insufficient level of effort to complete the tasks listed in the scope of work. An example of underscoping would be to lower proposal costs by scoping for a "windshield" survey rather than a pedestrian survey for a project location with obvious potential for surficial paleontological resources (as discussed in Section 5, there is very little that can actually be accomplished via a windshield survey other than locating rock outcrops along a road). However, low bids are not always problematic or unethical, since a consultant with greater local knowledge of a project area may submit a better-informed bid that is lower. Greater agency participation during the scoping process would be helpful. As allowed, it is advisable to consult with agency paleontologists, paleontology coordinators, or project managers during the scoping process, especially for large projects. A professional mitigation paleontologist should be provided with the opportunity to provide input on scopes of work that are developed by project managers or other personnel that lack paleontological expertise (Appendix I, 10.2).

An important and challenging aspect of preparing mitigation cost proposals is estimating the number, types, and costs associated with fossil discoveries made during a project, including the added costs of reporting and, if fossils are collected, the costs of lab work and curation. There are various ways to produce an informed estimate for fossil discoveries. For example, the results of previous mitigation projects completed in the same geologic units in the area provide a means of estimating the density of fossil localities, which can be used to predict the number of scientifically important fossil localities per area of disturbance, per mile of survey corridor, or per well pad location. The decision about whether to include the costs of fossil discoveries in a proposal or include an assumption that no fossils will be found significantly affects the project budget, and an assumption of negative findings will obviously result in a lower estimated cost. However, a client might not be pleased if fossils are then found and additional costs are incurred. While it does not necessarily imply an ethical concern and there is no single correct answer, a best practice is to accurately and in good faith reflect the likelihood of fossil finds and the resulting costs in proposals. If there is a low likelihood of fossils, then it is appropriate to include an assumption of negative findings. However, if there is a high likelihood of fossils being discovered, then an assumption of negative findings represents underscoping, is not a best practice, and risks alienating clients (Appendix I, 10.3). Keep in mind that some clients understand the risk and do not want fossil-related costs included in cost proposals, whereas others actually prefer an overestimate. These differences in client expectation and preferences underscore the importance of understanding a client's needs. Regardless of whether any aspect of a project is intentionally or accidentally underscoped, it may be necessary to negotiate a contract modification (cost change) with the client in order to, as a best practice, complete the project according to agency requirements and accepted professional standards (Appendix I, 10.4).

Overscoping is doing more work than is needed to accomplish the goals of a project and is also an ethical conflict that is not consistent with best practices. Overscoping is less common then underscoping since it typically makes a project cost more and results in the firm being less likely to be selected by a client. The reality is that clients rarely want to fund a research project, and often shy away from proposals that seem to include what they view as extraneous tasks that sound like scientific research. However, fossil collections made during mitigation projects should be collected in a way that supports future research. A well-scoped mitigation project should be designed to accomplish the objective of reducing adverse impacts on scientifically important fossils in a manner that anticipates future paleontological research objectives (see Section 3; Appendix I, 3.7). Another aspect of overscoping involves proposing to do work on a project that has no paleontological resource potential (i.e., there is little to no chance that paleontological resources will be impacted by a proposed action). An example would be a proposal for monitoring an area in which the substrate is composed of granite (or other geologic unit/rock type with extremely low or no paleontological potential). In cases of very low paleontological sensitivity, recommend to the agency and/or client that impact mitigation may not be necessary (Appendix I, 10.5). While the response in such cases may well be that the requirement is still in effect, it is ethical for a mitigation paleontologist to make a good faith effort to inform the parties about low paleontological resource potential when applicable. In summary, there are numerous potential ethical pitfalls that can befall a project during scoping and implementation, but they can all be addressed by closely adhering to a scientifically sound scope of work. In this way, scientific rigor and ethical standards are upheld.

Finally, professional mitigation paleontologists who prepare mitigation reports should, according to accepted scientific practice, properly cite all sources including scientific literature, agency policy, other technical reports, NEPA/CEQA documents, and museum record searches. Obviously, plagiarism and falsification are clear violations of ethical standards (Appendix I, 10.6).

Project Personnel

Making appropriate personnel decisions when staffing mitigation projects is the second category of ethical practices. As discussed in Section 1, it is critical to use trained and experienced paleontologists to staff all project tasks for which paleontological knowledge is necessary. While this may not necessarily include project management, it most certainly includes project scoping, existing data analyses, field surveys, monitoring, specimen preparation, identification, faunal/floral analysis, report preparation, and curation. All field monitors should be vetted in order to ensure that they are properly qualified. Hiring underqualified employees or overstating a worker's qualifications in order to put less-than-qualified people in the field, usually to avoid paying a professional's salary, is a persistent issue for federal, state, and local permitting officers. Additionally, professional mitigation paleontologists should be utilized to write paleontological resource reports (see Section 8) (Appendix I, 10.7).

No paleontologist is an expert in all paleontological subdisciplines and taxonomic groups. Recognizing the specialized nature of paleontology, subject matter experts, whether on staff or subcontracted, should be used to identify fossils collected during mitigation projects to the lowest possible taxonomic level that is required for curation and conduct faunal and floral analyses when applicable (Appendix I, 10.8), but also for obtaining information about a project area and its paleontological content (see Consultation with Local Technical Experts in Section 3, Appendix I, 3.6). With regard to permitting, the majority of agencies grant paleontological resource use permits to individual principal investigators, rather than to firms. It is important that project personnel be aware of this, since the responsibility to complete the work in compliance with regulations and according to accepted professional standards is the responsibility of the principal investigator. The principal investigator is the one who is held responsible for all project results and for the consequences of poor or fraudulent work.

External Pressure

External pressure that is brought to bear on a consultant by an agency or client is the third category of ethical concern. The concern is how the mitigation paleontologist responds to such pressure rather than the pressure itself. In recent years, the ongoing confusion between paleontology and archaeology has, in certain jurisdictions in California for example, resulted in agency-required (and even consultant-recommended) mitigation measures that stipulate archaeological shovel-testing procedures for ascertaining the presence of paleontological resources (see Section 5). Because there is no scientific basis for the use of such methods to inform the presence, content, or abundance of paleontological resources, the use of archaeological testing techniques for paleontological resources is not recommended. Mitigation paleontologists should avoid succumbing to pressure from uninformed overseeing agency personnel or clients to employ scientifically inappropriate methods (Appendix I, 10.9).

A frequently observed example of unethical pressure concerns agency personnel or clients asking mitigation paleontologists to change their mitigation recommendations. A professional mitigation paleontologist should develop mitigation recommendations that are consistent with the objectives of resource preservation and stand by them. If an overseeing agency or client wishes to modify the recommendations, it is appropriate for the consultant to listen, negotiate in good faith, and modify the recommendations or mitigation measures based on new information, if appropriate. Any modifications along with associated justifications should be documented in the final project report (Appendix I, 10.10). However, downgrading mitigation measures as the result of pressure from either clients or agencies is not a best practice because it will increase the likelihood of adverse impacts to the resource. Mitigation recommendations from a consultant are just that—if an agency or client wishes to ignore them that is their prerogative. Professional mitigation paleontologists should think twice about working on a project that does not follow accepted professional standards, as this association will jeopardize one's reputation and put future work at risk.

CONCLUSIONS

Adopting and consistently following the details of the best practices provided here will result in a sustainable and professional field of applied mitigation paleontology that stands on its own apart from other fields of paleontology, and that is clearly distinct from archaeology and CRM. Maintaining professional and ethical rigor is a constant challenge, from the point of project scoping and budgeting, through project initiation and implementation, to project completion. However, adopting these best practices will result in a consistent, professional, and higher-quality job of mitigating impacts and preserving nonrenewable paleontological resources.

Another benefit to adopting best practices will be the development of a more cohesive community of professional mitigation paleontologists that works together with agency and museum partners to achieve the common goals of resource preservation and the management of paleontological resources using scientific principles and expertise, while also successfully achieving the objectives of project proponents. Ultimately, the industry-wide adoption of and adherence to scientifically rigorous and ethical best practices will require the combined efforts of mitigation paleontologists, policy makers, resource managers, and museums. The development of best practices is the necessary first step and is a process that all other more established resource disciplines have undergone during the course of their evolution.

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The motivating force behind this project was the need, as expressed among many mitigation paleontologists in the course of countless conversations over the years, for a comprehensive set of best practices to help create and ensure universally high scientific standards for the purpose of preserving paleontological resources via impact mitigation. Thus, foremost, we are thankful to all professional mitigation paleontologists and the amazing work they have done throughout North America over the past several decades. Their legacy has established the groundwork and provided the inspiration for this paper. We are also indebted to the efforts of the many professional museum paleontologists across the continent who have made critically important contributions by directing numerous fossil recovery projects, and whose institutions are the repositories of the specimens, the data, and ultimately, the scientific knowledge generated by mitigation fossil collections in the form of research publications. We are grateful for the tireless efforts of the paleontologists who serve in government agencies and acknowledge their essential role in the stewardship of nonrenewable paleontological resources.

Finally, we dedicate this paper to Dr. Lanny H. Fisk, our dear friend, colleague, and coauthor who passed away unexpectedly as this paper was approaching completion. Lanny was passionate about the development of best practices in mitigation paleontology and the professionalization of the field of mitigation paleontology. He shall be missed!

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APPENDIX I

NOTE: For each of the bullets listed below further discussion is provided in the text of the paper with a callout for the specific best-practice number.

Qualifications

1.1 The following are suggested as minimal requirements for paleontological principal investigators, field supervisors, field paleontologists, and laboratory paleontologists. Paleontological principal investigators and paleontological field supervisors are considered to be qualified professional mitigation paleontologists. The field paleontologist is an introductory-level position needing further training and/or experience to achieve the level of professional mitigation paleontologist.

Paleontological Principal Investigator

- An advanced academic degree (M.A., M.S. or Ph.D.) with course work emphasizing paleontology and sedimentary geology or demonstrated equivalent professional experience (e.g., minimum of 3 years of experience, or 75 projects, with paleontological resources is considered equivalent to an advanced degree).

- At least 2 years (or 50 projects) of demonstrated professional experience and competency with paleontological resources mitigation projects at the level of field supervisor.

- A working knowledge of how paleontological resources and their associated data are used in conducting and publishing professional paleontological research (such as is demonstrated by having a record of peer-reviewed paleontological publications).

- Participation in professional scientific organizations.

- Ability to be responsible for obtaining all necessary federal and state agency permits, for preparing and submitting any and all required progress and final mitigation reports, and for ensuring compliance with all scientific and operational requirements of the project.

- Knowledge of federal, state, and local laws and procedures that apply to all aspects of mitigation paleontology.

Paleontological Field Supervisor

- An advanced academic degree (M.S., M.A., or Ph.D.) with an emphasis in paleontology (Table 1) or demonstrated equivalent professional experience (e.g., minimum of 3 years or 75 projects of project experience with paleontological mitigation is considered equivalent to a graduate degree).

- At least 1 year (or 25 projects) of experience with paleontological mitigation from project initiation to fossil discovery to fossil collection, laboratory preparation, fossil inventory, specimen identification, and curation under the supervision of a principal investigator.

- Field experience in impact mitigation procedures and strategies (including fossil recovery/collection).

- Junior or senior authorship of mitigation reports.

- An understanding of the regulatory environment, including knowledge of federal, state, and local laws and procedures that apply to mitigation paleontology.

- An understanding of project management.

- An understanding of the business of mitigation paleontology.

- Ability to manage field paleontologists (on field survey and/or mitigation projects), supervise fossil recovery operations, and communicate with construction foremen and superintendents.

- Ability to evaluate scientific importance and make decisions regarding the mitigation of impacts on paleontological resources.

- Ability to ensure that field notes and observations are routinely completed, that the stratigraphy of project areas is accurately and completely recorded, and that fossil localities are positioned on stratigraphic sections as appropriate to the project.

Field Paleontologist (Technician/Surveyor/Monitor)

- Academic training (B.S., B.A., M.A., or M.S.) with an emphasis in paleontology (see Table 1) or demonstrated equivalent experience (e.g., 2 years of cumulative professional or nonprofessional work in laboratory preparation, curation, or fieldwork in paleontology, as well as documented self-taught knowledge of the discipline of paleontology).

- Ability to find fossils in both undisturbed and disturbed (construction) settings.

- Knowledge of fossil collection and recovery techniques.

- Ability to identify fossils to a basic level (higher-level taxon and element).

- Ability to identify and describe sedimentary rocks and stratigraphic relationships.

- Ability to effectively communicate information about discoveries to the principal investigator and/or field supervisor.

- Ability to record the basic taphonomy of fossil assemblages and recognize and describe unusual depositional or preservational conditions and associations.

- Ability to interpret the basic depositional environments based on site geology and paleontology.

- Ability to properly complete field forms, operate a GPS receiver, apply basic mapping and navigational skills, photograph fossils and localities, and plot localities on grading plans when applicable.

- Ability to comply with safety requirements and use proper personal protective equipment.

Laboratory Paleontologist

- Demonstrated experience in fossil preparation, specimen curation, and data entry and management.

- Familiarity with the use of archival chemicals and fossil preparation tools, and a basic understanding of paleontological resource conservation.

Land Ownership and Permitting

2.1. Determine the land ownership and the pertinent regulatory agency (if applicable).

2.2. Be sure that no work is undertaken without the proper permit or other required authorization. This includes understanding all land ownership issues and trespass laws prior to fieldwork.

2.3. If there is a need for additional land access after a project initiation (e.g., a fossil locality extends outside of originally approved access), consult with the agency, landowner, and client and obtain new or modified authorization.

2.4. For fossils discovered during field surveys, provide landowners with the choice to keep the fossils, donate them, or leave them in place waiving the project proponent of any liability in the event of damage.

2.5. For fossils discovered during construction monitoring, unless the landowner can be reached immediately, collect all fossils with scientific importance by default.

2.6. Obtain an excavation permit if required.

Analyses of Existing Data

3.1. By reviewing geologic maps at the most precise scale available, determine the geologic units within a project area and their areal distribution.

3.2. Apply the appropriate paleontological resource classification system to the project area.

3.3. Complete a thorough literature review using an appropriately sized search area.

3.4. Complete a paleontological record search using an appropriately sized search area.

3.5. Conduct an aerial image review to determine locations of potentially paleontologically sensitive bedrock exposures.

3.6. Consult with local technical experts for information on the paleontology and geology of the area.

3.7. Design every impact mitigation program around a theoretical framework that places it in a scientific context, and that facilitates later research activities. It should serve as road map that guides the implementation of the mitigation work, including the development of the threshold criteria for scientific importance, which fossils are collected, how they are collected, and the types of associated data that are collected. The theoretical framework should be considered when developing project scopes of work and budgets, and the actual framework should be presented in paleontological resource impact mitigation evaluation reports and paleontological resource monitoring and mitigation plans.

3.8. Synthesize the results of the analysis for use in determining the need for impact mitigation measures. Make recommendations for consideration by the agency, project proponent, and/or landowner.

Field Data Collection

4.1. If working with a crew or multiple crews, design and use forms (hard copy or digital) for data capture during fieldwork. Use field notebooks for supplemental information or duplication.

4.2. Always use a GPS receiver to record geographic coordinates. While sub–meter-level precision may be needed in certain field applications, a position error of less than 6 m is recommended for most situations.

4.3. Use a standard geographic coordinate system unless directed by an agency to use a project-specific coordinate system. Make sure all crew members understand the system they are working in and verify that their GPS receivers are set the same.

4.4. Record fossil localities as points, lines, or polygons, taking into account the size of the locality.

4.5. Provide prefield training and project orientation on data recording procedures, parameters for important versus nonimportant localities, and criteria for field mitigation recommendations to field crew members.

4.6. Using field data, photographs, and/or GPS track logs or polygons, document all areas that were physically surveyed or monitored regardless of whether fossils were found, as well as those areas cleared visually or through desktop review.

4.7. In addition to scientifically important fossil localities, document non–scientifically important localities as defined based on the paleontological resource abundance and preservation of the geographic area and/or geologic unit.

4.8. Avoid unnecessarily or improperly disclosing any project information, including survey and monitoring data, as required by law or client confidentiality.

4.9. Fully complete all client- and company-required paperwork including vehicle inspection forms, job hazard analyses or other safety related forms, and project daily logs.

4.10. Ensure that field data captures information in order to meet the needs of clients, the requirements of agencies, and the scientific standards of curation facilities. This includes paleontological locality documentation consistent with accepted professional and scientific standards, and documentation that the scope of work was fully and properly completed.

Field Surveys

5.1. Thoroughly prepare all field personnel for fieldwork: provide existing data and key publications, maps and design plans, field equipment needs, safety concerns, survey schedule, survey area priorities, and chain-of-command for notification in case of discoveries.

5.2. Ensure that the field personnel have copies of access authorization as well as all required permits.

5.3. Ensure that field paleontologists do not collect any objects for personal use from a project area, regardless of land ownership or legal status.

5.4. Ensure that the ground surface is free of snow and not saturated with water (e.g., flooded or too muddy) prior to initiating any field surveys.

5.5. Typically, confine survey activities to the project area; however, in some circumstances exposures of the same units outside of the project area may have important information and should be inspected if access has been approved.

5.6. In rocks and surficial deposits with high and very high sensitivity, survey all exposures. However, in rocks with moderate or unknown sensitivity, spot-checking of exposures of rocks and surficial deposits is an acceptable level of effort.

5.7. In most cases, ensure that field surveyors do not walk transects; they should spread out to cover as much ground as possible and focus their inspections on exposures of fresh and weathered bedrock and surficial deposits. Slope exclusions are not appropriate for paleontologic surveys; however, crews should exclude areas that cannot be accessed safely.

5.8. Do not perform windshield surveys: they are unacceptable and are not a best practice since they are not useful for finding fossils. If they are used to provide visual clearance for a portion of a project area, in the field survey report be sure to differentiate between areas that were subject to pedestrian versus visual survey.

5.9. When possible and cost effective, recommend fossil collection rather than resource avoidance for the greater goal of resource preservation. Block surveys provide the client with the greatest flexibility for avoiding scientifically important fossils if that is their preference. However, a client is under no obligation to mitigate impacts to paleontological resources that will not be affected by the project, because there will not be any project-related impacts. Be cognizant of the resource management policies and objectives of all landowners with regard to fossil collection. Never collect fossils on private land without written permission from the landowner.

5.10. Typically, consider extensive fossil discoveries (those that are not anticipated) to be outside of the scope of work of normal mitigation. Exclude complete collection and documentation of extensive fossil discoveries from scopes of work, but be sure to communicate the rationale and possibility of their occurrence to clients. If discovered, clients typically choose to avoid them with their project. If they elect to mitigate impacts to the locality (usually in the form of an excavation to recovery the fossil[s]), preparation of a locality-specific mitigation plan may be required. If avoided, the mitigation paleontologist or agency should report the locality to an institution or researcher with an interest in it.

5.11. To prevent confusion, avoid the CRM term "unanticipated discovery"; instead, use the term "predicted fossil discovery" for fossils that are expected and "unpredicted fossil discovery" for fossils that are not expected. An additional and related term that should be applied to paleontological localities is "extensive fossil discovery."

5.12. If requested to perform exploratory archaeological type shovel testing for paleontological resources or similar inappropriate techniques, educate the requestor about scientifically defensible paleontologic procedures.

Construction Monitoring

6.1. Ensure that monitoring is a mitigation requirement when construction will disturb bedrock units or surficial deposits with a high potential to contain fossils of scientific importance. Full-time monitoring is generally stipulated for geologic units with high and very high sensitivity, whereas spot-checking is generally stipulated for geologic units with low, moderate, and unknown sensitivity.

6.2. Ensure that the principal investigator has the ability to increase or decrease the monitoring level of effort. The agency and project manager should be notified, and approval requested, for a such change in level of effort. Prior to decreasing the monitoring effort, written agency approval should be obtained.

6.3. If the opportunity is available, have monitors do a final surface check immediately prior to ground disturbance to ensure that no scientifically important fossils were missed during the preceding field survey.

6.4. Ensure that monitors are aware of the effects of certain types of construction equipment on bedrock and contained fossils.

6.5. When equipment is not running, instruct monitors to use the opportunity to examine the excavation, document the stratigraphy, and check through spoils piles.

6.6. Ensure successful monitoring by requiring monitors to be within visual range of the excavation where they have access to freshly disturbed rock, ideally 5 to 20 feet, but no greater than 30 feet (even at that distance fossils may not be visible). The exception would be if the monitoring area is not safely accessible. In such cases, spot-check spoil piles as an alternative.

6.7. Ensure that monitors strictly adhere to all project and Occupational Safety and Health Administration (OSHA) safety requirements (or Cal-OSHA in California), particularly with regard to working around heavy equipment and entering project excavations. As a general rule, monitors should never do anything that they perceive to be unsafe. Monitors should understand the movement patterns of construction equipment. Monitors should establish eye contact and use hand signals to communicate with operators. Establishing a good relationship and open communication with all project personnel is critical to the success of the monitoring effort.

6.8. Regardless of whether fossils are found, require that monitors document the stratigraphy of the project area for the purpose of interpreting its paleontological record, as well as facies relationships and depositional environments. All fossil localities should be tied to the stratigraphic section for use in the monitoring report when such documentation is geologically possible.

6.9. Require monitors to be on site at all times during project excavations in paleontologically sensitive bedrock and/or surficial deposits. Monitors and the firms they represent should educate clients and construction personnel about monitoring practices, particularly with regard to safety, but also with regard to the need to be within view of the active cut.

6.10. When a potentially scientifically important fossil is discovered, ensure that the monitor immediately alerts the equipment operator and after an initial evaluation, makes any other project-specific notifications. Cordon off the fossil locality, if applicable, and mobilize additional personnel as needed to support monitoring and locality exploration and evaluation. Direct construction away from the locality with a minimum buffer of 20 feet, although the buffer size should be increased if the monitor determines that the locality is larger, or for safety reasons.

Fossil Specimen Recovery: From Collection to Precuration

7.1. Following fossil discovery, perform a preliminary evaluation based on predetermined threshold criteria for scientific importance, the purpose of which is to determine whether or not the fossil(s) discovered warrant salvaging.

7.2. If the preliminary evaluation determines that the fossil(s) at the locality have scientific importance or appear to have scientific importance based on what is visible, initiate locality exploration. Locality exploration could result in a determination that the fossil(s) lack scientific importance, in which case the fossil(s) should be recorded as nonimportant and no further action is required. If one or more of the fossils at the locality are scientifically important, record the locality as significant.

7.3. For localities discovered during field surveys, practice one of the three standard mitigation options—typically collection, deferred collection, or avoidance. If avoidance is the preferred option, survey an alternate route or project location that avoids other scientifically important fossil localities.

7.4. Collect scientifically important fossils. Unlike field surveys, mitigation by fossil collection is typically the only option for scientifically important fossils discovered during construction monitoring.

7.5. For all important fossil localities, always use recovery techniques appropriate to the size and preservation of the fossil remains. All field paleontologists should be knowledgeable of fossil recovery and sampling techniques and properly equipped. Medium- to large-sized specimens or groups of specimens should be excavated encased in matrix to provide stability, expedite the excavation, and minimize construction delays. Construction equipment can be used to expedite fossil excavation so long as the equipment does not come into direct contact with the fossil(s) and can also be used to lift heavy jackets onto vehicles for transport off site. Properly label all containers and jackets prior to removal from the locality.

7.6. Consider wet screen-washing for small fossils (vertebrate, invertebrate, and plant); this is a critical procedure that has been demonstrated to yield results unobtainable via any other means and has greatly increased the taxonomic diversity and number of specimens available for study in geologic units wherein it has been employed. However, because of variation in fossil density within and between geologic units, smaller samples are often sufficient based on the results of rarefaction analysis, or in cases in which the locality contains exceptionally high concentrations of fossils or has less matrix available for sampling. Rarefaction is a statistical procedure that estimates the point at which the taxonomic diversity of a fossil assemblage has been fully sampled. But do to the nature of mitigation paleontology, including the short period of time during which fossiliferous exposures are available for sampling, it is usually not possible to apply the results of rarefaction analyses to a fossil locality found during construction.

7.7. Recognize that it is the responsibility of a professional mitigation paleontologist to document and fully collect or otherwise mitigate impacts to all scientifically important localities from within a project area; design the project scope of work and budget to accommodate this.

7.8. When working on Native American tribal lands, respect all tribal policies and work within tribal representatives to reduce impacts. Document all fossil localities, and if locality avoidance is the only mitigation option, consider implementing field specimen replication protocols, such as molding, photogrammetry, or other method that allow the maximum amount of scientific information to be recorded for specimens with high scientific value with proper authorization.

7.9. From the time fossils are collected until they ultimately arrive at a curation facility, ensure that fossils are properly and appropriately housed in a secure environment with the proper documentation. This also includes keeping fossils secure and having the proper documentation during transportation.

7.10. Once transferred from the field to the laboratory, properly prepare fossils to the point of curation in accordance with the repository agreement and agency protocols. Matrix samples should be washed, floated if appropriate, and sorted to remove fossils, and all fossils should be identified to the level of genus or lowest taxonomic level possible by a paleontologist with technical expertise with that taxonomic group. Complete any additional analyses within the scope of work. Precuration work should also include preparation of a fossil catalogue, entry of field and laboratory data into a computerized database and labeling and packaging fossils in preparation for transport to the curation facility.

Data Management and Reporting

8.1. Ensure that data management strategies emphasize efficient data entry, accuracy, regular backup, and efficient retrieval of information.

8.2. Project reporting requirements vary by agency; prepare final project reports to meet or exceed agency standards. If there is no agency involvement or the agency involved does not have standards, then follow the best practices as presented here.

8.3. Ensure that paleontological survey and monitoring reports include the results of the existing data analysis if it was not included in a prior stand-alone project report.

8.4. Base monitoring and mitigation plans on an existing data analysis and/or field survey and ensure that they make detailed recommendations on monitoring locations and procedures, and fossil recovery procedures.

8.5. Ensure that all paleontological reports, including NEPA/CEQA sections, are written by or at a minimum, reviewed by, a professional mitigation paleontologist.

8.6. Ensure that mitigation paleontologists always treat all fossil locality data as confidential. Locations (i.e., legal descriptions, coordinates, photographs) of fossil localities in client copies should be prepared in a confidential appendix of locality data for agency and repository copies as required by local, state, and/or federal law.

8.7. Report all paleontological resources, both scientifically important and nonimportant.

8.8. Ensure that all field survey and monitoring reports include documentation of areas that were surveyed or monitored, regardless of whether fossils were found.

8.9. Using local paleontological knowledge and experience, provide recommendations regarding the frequency of repeated field surveys and provide justification to land managers in field survey reports and end-of-year permit reports.

8.10. Ensure that mitigation recommendations and mitigation measures are prepared by, or minimally, in consultation with, a professional mitigation paleontologist or an agency paleontologist with experience in mitigation paleontology.

8.11. Develop recommendations, including mitigation measures, by working closely with the agency (if any) and client while taking into account the paleontological research potential of the project area (see Section 3) and the standards of the curation facility. Effective mitigation measures accomplish client objectives while meeting regulatory requirements and preserving (reducing adverse impacts on) paleontological resources.

Curation Facilities

9.1. Ensure that all scientifically important fossils collected during mitigation projects are curated at an approved facility and should avoid the accumulation of "orphan collections."

9.2. Obtain curation agreements in advance of project scoping and obtaining paleontological resource use permits. When obtaining a curation agreement, mitigation paleontologists should discuss with the appropriate repository personnel the types and amounts of fossil material to be collected/curated, the level of preparation and documentation, and delivery timeframes.

9.3. Reposit only paleontological resources that have scientific importance.

9.4. If a curation facility is not willing or able to accession fossils that meet agency defined scientific significance criteria, find an institution that will.

9.5. Ensure that all fossils are properly documented according to the terms of the curation agreement and the standards of the institution. Documentation should include copies of field notes, data sheets, annotated maps, photographs, and other associated data.

9.6. Ensure that fossil collections from the same project, and especially the same locality, are not divided between curation facilities unless necessary to meet permitting or curation requirements.

Business Ethics and Scientific Rigor

10.1. Recognizing that mitigation paleontology is a business, make all decisions, including scoping of projects and formulation of budgets, in a manner that promotes the intrinsic scientific value, research potential, and long-term preservation of nonrenewable paleontological resources within the project footprint.

10.2. Consider that it is advisable to consult with agency paleontologists, paleontology coordinators, or project managers during the scoping process, especially for large projects. Also, ensure that a professional mitigation paleontologist provides input on all scopes of work and budgets developed by personnel who lack paleontological expertise.

10.3. If there is a high likelihood that fossils will be found during a project, incorporate this into the scope of work and budget rather than building a no-findings assumption into the proposal. If there is little to no paleontological potential, a negative findings assumption may be appropriate.

10.4. Obtain contract modifications/change orders as needed in order to ensure that all mitigation work is properly completed, and that all scientifically important paleontological resources are properly collected, prepared, identified, and curated.

10.5. In cases of very low or no paleontological sensitivity, recommend to the agency and/or client that impact mitigation may not be necessary.

10.6. Cite (but never plagiarize) paleontological resources and other types of reports and never falsify reports.

10.7. Employ only properly trained and experienced paleontologists to do mitigation work and avoid the use of so-called "cross-trained" personnel unless they are legitimately qualified and have the demonstrated expertise to perform the work. Only professional mitigation paleontologists as defined in Section 1 should be used to conduct record searches and prepare paleontological technical reports.

10.8. Recognizing the paleobiodiversity of the fossil record, utilize subject matter experts to ensure that fossils recovered during mitigation are accurately and properly identified to the lowest possible taxonomic level required for curation and for conducting faunal and floral analyses when applicable.

10.9. Avoid succumbing to pressure from an uninformed regulatory agency or client to employ archaeological or other scientifically inappropriate methods.

10.10. Avoid letting clients or agencies alter recommendations or impact mitigation measures in a manner that conflicts with the objective of paleontological resource preservation.