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Assessment of Livestock Grazing Impacts on Fuels and Cultural Resources at Mākua Military Reservation (MMR), Island of O‘ahu, Hawai‘i

Steven D. Warren, Ph.D.
Stephen A. Sherman, M.U.R.P., M.A.
and
James A. Zeidler, Ph.D.

CENTER FOR ENVIRONMENTAL MANAGEMENT OF MILITARY LANDS

Colorado State University
Fort Collins, CO 80523-1490

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PREFACE

This report represents the final deliverable for the project entitled *Assessment of Livestock Grazing Impacts on Cultural Resources and Fuels at Mākua Military Reservation*, carried out by the Center for Environmental Management of Military Lands (CEMML) at Colorado State University for the Environmental Division, Directorate of Public Works of the U.S. Army Garrison, Hawaii (USAG-HI). It was contracted through the U.S. Army Medical Research Acquisition Activity (USAMRAA) at Fort Detrick, MD, Program Assistance Agreement (PAA) No. DAMD17-02-2-0008, Task Order 0011, a cooperative agreement awarded to CEMML in 2002 for cultural resources technical support to DoD installations.

The project was developed by USAG-HI primarily as a pilot study to assess the use of livestock to manage vegetation growth at Mākua Military Reservation (MMR) on the island of O'ahu, Hawai'i. The objective was to determine the feasibility of reducing grass height to a range of 3 to 19 inches, and thereby reduce the threat of catastrophic wildfires on these important training lands as well as adjacent non-military lands. A secondary, but no less important consideration was the potential impact of systematic livestock grazing on the numerous cultural sites scattered throughout the MMR. Accordingly, the original project was to have included a series of small test plots where mock archaeological features and artifact scatters could be constructed so that grazing impacts on these *faux* resources could be quantitatively assessed in a controlled experiment. That way, no actual cultural sites would be impacted. This aspect of the project could not be carried out, however, due to strong objections of various Native Hawaiian organizations. In the end, potential grazing impacts on cultural sites had to be assessed through a thorough literature review only.

Given the disparate nature of these two studies and the inherent difficulties of integrating them into a single document, the present report is divided into two parts. Part 1 is entitled *Draft Grazing Plan for the Mākua Military Reservation (MMR), Island of O'ahu, Hawai'i* and is authored by Steven Warren, Ph.D., CEMML Associate Director for Land Rehabilitation and Maintenance. Part 2 is entitled *A Literature Review of Grazing and Archaeology: Implications for Grazing Prescriptions on the Mākua Military Reservation (MMR), Island of O'ahu, Hawai'i* and is co-authored by Stephen A. Sherman, CEMML Staff Archaeologist, and James A. Zeidler, CEMML Associate Director for Cultural Resources. It is hoped that these two studies will assist the U.S. Army in achieving the interrelated goals of safely and cost-effectively reducing fuel loads on the Mākua Military Reservation and ensuring the long-term protection of its valuable and non-renewable cultural resources.

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PART 1

Draft Grazing Plan for the Mākua Military Reservation (MMR), Island of O‘ahu, Hawai‘i

Steven Warren Ph.D.

1. INTRODUCTION

Military training operations utilizing live-fire have the potential to ignite wildfires where fine fuel loads are dry and sufficiently large to carry a fire (Beavers et al. 1999). Wildfires at the Mākua Military Reservation (MMR) have history of escaping into native forest, impacting endangered species and their critical habitat. There are 44 listed species at MMR and critical habitat for 35 plant species and one bird. Continued military operations at MMR are restricted by the USFWS Biological Opinion because of fire impacts to rare species and their habitats (USFWS 2007).

Livestock have been successfully used in other areas of the world to reduce fine fuel loads and hence reduce the risk of wildfire (e.g., Goldammer 1988, Yoder 2004). In order to limit the fine fuel load at MMR, the U.S. Army contracted with the Center for Environmental Management of Military Lands at Colorado State University to conduct a pilot project investigating the potential use of livestock to reduce the fine fuel load at MMR and to assess the impacts of the livestock on archaeological features typical of the Mākua Valley.

2. MATERIALS AND METHODS

2.1 Study area

The Mākua Military Reservation comprises approximately 4,856 acres (1,967 ha) near the western extremity of the Hawaiian island of Oʻahu. Use of Mākua Valley for military training was granted initially to the U.S. Army in May 1943 by the Territorial Government of Hawaiʻi. Since that time, MMR has been used by all branches of the Army Forces as a training site for aerial bombardment, ship-to-shore artillery, ground artillery, and infantry training. It is currently administered by the U.S. Army and used primarily for ground artillery and infantry training. However, due to its long history as a military training area, it is dotted with unexploded ordnance, rendering many traditional land management tools impractical and dangerous.

2.2 Stocking rate

Selection of an appropriate stocking rate is critical to the success of any livestock operation. Overgrazing may result in loss of biodiversity, invasion by undesirable weedy plant species, accelerated soil erosion, and poor animal health. Calculation of stocking rates involves the use of several terms that may be unfamiliar to those without experience in the management of livestock. An animal unit (AU) is defined as a mature 1000 lb (450 kg) cow. A typical AU is assumed to consume 20 lbs (9 kg) of forage (oven-dry weight) daily. The amount of forage consumed by one AU over a period of 1 month (30 days) is an animal unit month (AUM), or 600 lbs (270 kg) of forage. Mr. Harold Deever, who manages the Latigo Ranch to the south of MMR, suggested an appropriate stocking rate for the Mākua Valley area is between 0.6 and 0.8 AUM/ac/yr. For the purposes of this pilot project, we selected 0.75 AUM/ac/yr as our target stocking rate. The use of that stocking rate is equivalent to 1.3 ac/AUM/yr.

The animal unit equivalent (AUE) for sheep is 0.15, i.e., a mature sheep consumes approximately 0.15 the amount of forage consumed by a mature cow. Hence, the appropriate stocking rate for sheep at MMR is 0.2 ac/mature sheep/month.

2.3 Grazing system

There exists an almost infinite array of potential grazing systems, ranging from long-term continuous grazing to intensive rotational grazing where animals are rotated among a large number of pastures, spending from a few days to a few months on any given pasture before being rotated to the next pasture. Grazing systems may also be composed of multiple herds and multiple species of livestock grazing separately or together. For the purposes of this pilot project, in order to distinguish between the impacts of different species of livestock on the fine fuel, we elected to utilize both cattle and sheep, but in separate grazing systems. Due to the cost and safety constraints involved in erecting fences at MMR, we do not perceive it likely that complex intensive rotational grazing systems are feasible. Hence, we opted to simulate one pasture from two different 3-pasture, 1-herd systems, one for cattle and one for sheep. Under normal circumstances, the pastures would be grazed continuously for four months, and then the animals would be rotated to the next pasture. By concentrating all animals in one pasture (1/3 of the total area), they are effectively stocked at 3 times the normal rate, but for only 1/3 of the year (4 months).

2.4 Kind, number and source of animals

Cattle and sheep are the two most common classes of livestock in the Hawaiian Islands. Goats also occur on many of the islands, including Oʻahu, but escaped or feral goats have caused problems in many natural areas (Cox 1999), including Mākua Valley. For this reason, we opted to use only cattle and sheep for the pilot project. Cattle and sheep, not unlike humans, have individual dietary preferences, behavioral traits, and physical abilities (Holechek et al. 2004, Valentine 2001). To account for their innate variability, we opted to include 3 cows and 4 sheep in the pilot project. Cattle were borrowed from Mr. Harold Deever, who operates the Latigo Ranch to the south of MMR. Mr. Deever did not have the required number of mature cattle, but was able to provide a large steer and 4 yearlings for a combined weight of approximately 3000 lbs which supplied the desired 3 animal units (AU) needed for the experiment. The sheep were purchased from the Kauai Ranch on the island of Kauai.

2.5 Pasture design

To accommodate the desired number of animals, pastures of the following sizes were required:

Cattle:
3 cows • 1 AU/cow • 1.3ac/AUM • 1/3* • 4 mo = 5.2 ac

Sheep:
4 sheep • 0.15 AU/sheep • 1.3 ac/AUM • 1/3* • 4mo = 1.04 ac

*required to effectively triple the stocking rate to simulate a 3-pasture system

An area of the approximate required size was located along and just inside the chain-link fence marking the boundary of the MMR along Farrington Highway and north of the Range Control Office (Figure 1).

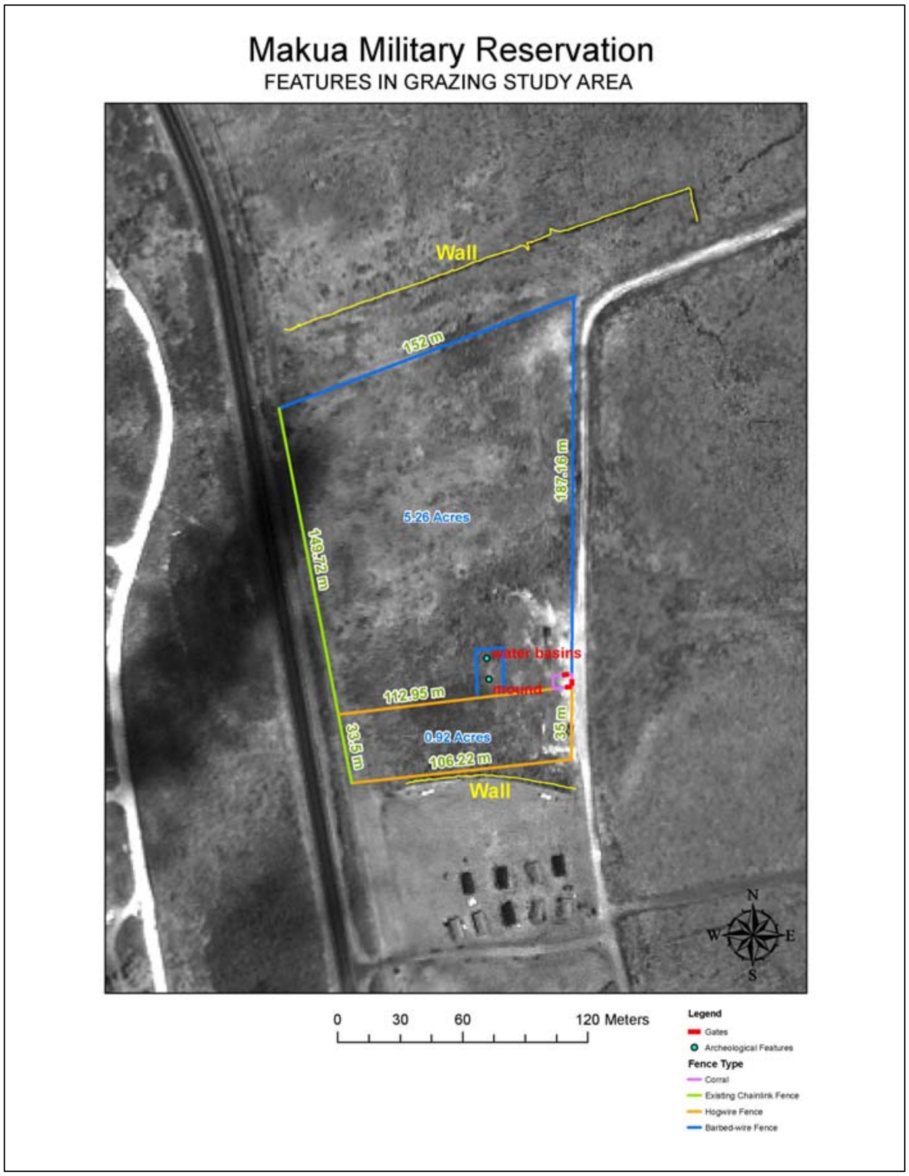

Figure 1. The location of the pastures utilized in the grazing study to evaluate the effectiveness of domestic livestock for removing fine fuels at Mākua Military Reservation.

2.6 Fencing

To minimize costs, the MMR perimeter chain-link fence was used as the western extremity of the study area. Fencing to contain the sheep was constructed with hog-wire and galvanized T-posts to ensure maximum containment of the animals. Fencing for the cattle was constructed as a 4-strand barbed-wire fence. Given the amount of woody vegetation present, fence lines were cleared with a rotary chopper prior to fence construction. Prior to clearing, the fence lines were evaluated by Explosive Ordnance Disposal (EOD) personnel to eliminate potential hazards to the work crews. Prior to fence construction, the location of each fence post was approved by EOD personnel using metal detectors. A single gate provided entry into the cattle pasture; access to the sheep pasture was provided by a gate from the cattle pasture.

2.7 Duration of grazing trial

Given the design of the grazing system, it was expected that the duration of the grazing trial would be approximately 4 months. The animals were introduced into the pastures on 07 March 2007, with the anticipation that they would be present until 07 July 2007. Unfortunately, feral dogs breached the sheep fence on 10 June and killed the sheep. The cattle were unharmed, but to maintain comparability between the pastures, the cattle were removed on 27 June 2007.

2.8 Determination of effectiveness of grazing

At the conclusion of the grazing trial, herbaceous biomass was harvested from ten 0.5 m^2 plots within each of the grazed pastures and from the area immediately adjacent to the pastures. Because the objective was to evaluate the effect of grazing on fine fuels, woody vegetation was not harvested. Harvesting was accomplished by clipping the herbaceous vegetation to ground level within each plot and collecting it into paper bags. The bags were transported to the Department of Natural Resources and Environmental Management at University of Hawai‘i where they were placed in a large drying oven for 24 hours at 72ºC.

After drying, the bags were retrieved from the oven and the contents weighed to the nearest 5 grams. The dry weight of fine fuel per bag was converted to tons per acre. Analysis of variance was calculated with the SYSTAT 10 statistical software to determine if treatment had a significant effect on biomass. Where significant differences were detected, post-hoc separation of means was computed using the Fisher’s LSD method with a probability level of 0.05.

3. RESULTS

Even though the grazing trial was terminated prematurely, the results indicate conclusively that grazing by either sheep or cattle significantly reduced herbaceous biomass compared to the ungrazed areas (Fig. 2). The difference between biomass remaining in the pastures grazed by sheep and cattle as only marginally different (P=0.043). However, the difference in the amount of fine fuel between the pastures grazed by cattle or sheep and the ungrazed area was highly significant (P=0.003 and P<0.001, respectively). The apparent difference between the sheep and cattle pastures was due, in part, to inherent differences in the pastures themselves. The sheep pasture was largely covered by a woody overstory which naturally limited the amount of biomass production by the herbaceous layer. The cattle pasture and the ungrazed areas, however, had significantly less woody canopy cover, and were, therefore, more similar prior to initiation of the study.

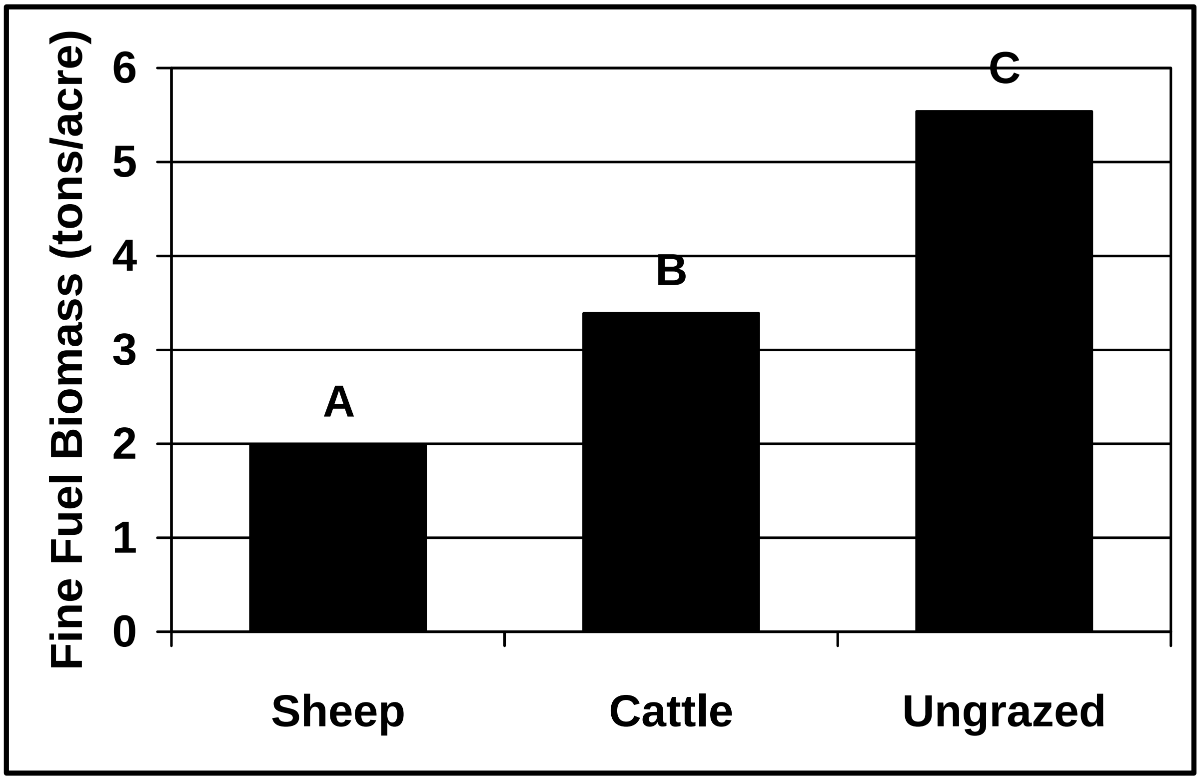

Figure 2. The amount of fine fuel biomass remaining in pastures grazed by sheep and cattle for approximately 3 months, and an adjacent ungrazed area at the Mākua Military Reservation.

In addition to the overall reduction of biomass within the pastures grazed by sheep and cattle, grazing affected the continuity of the fine fuel load. Guinea grass (*Panicum maximum*), one of the dominant grasses at MMR has a clumped growth form. Grazing has not been utilized as a management tool at MMR since its acquisition in 1943, and fires have been infrequent. This, coupled with the fact that the initiation of the grazing trial coincided with the end of the typical growing season at MMR, resulted in the fact that most of the clumps of guinea grass were old and rank. As a result, the grazing animals were able to defoliate the outer edges of the clumps and the interspaces between them, but were less able to remove biomass from the interior of the clumps. The result was a discontinuous distribution of biomass after the grazing trial (Figure 3). In addition to the overall removal of fine fuel, the discontinuity of the fuel load helps reduce the threat of a fast-moving fire.

Figure 3. Livestock were able to defoliate the edges of the large clumps of guinea grass (Panicum maximum) but found the rank interior to be unpalatable, thus leaving a discontinuous fuel load.

The dietary preferences and habits of sheep and cattle are different. Sheep prefer forbs, but will also consume grass and some woody species; cattle prefer primarily grasses, but will also utilize forbs and some woody species. Because there were relatively few forbs present in the pastures, the relative preferences were not evident. However, as palatable grasses became less available, both the cattle and sheep began to utilize large quantities of woody plants, primarily koa haole (*Leucaena leucocephala*). The sheep, however, preferred to strip the bark off of the small trees (Figure 4). This may be beneficial inasmuch as complete girdling of the stem may result in mortality. Cattle, on the other hand, preferred to eat the leaves. In order to access the leaves, they frequently pulled the branches until they broke (Figure 5).

The effects of grazing in the pastures grazed by cattle and sheep is visually apparent when compared to an adjacent ungrazed area (Figures 6 and 7).

Figure 4. The sheep had a tendency to consume the bark of the koa haole (Leucaena leucocephala) trees which may result in mortality.

Figure 5. The cattle broke many branches of the koa haole (Leucaena leucocephala) trees while trying to access the green leaves.

Figure 6. An area at Mākua Military Reservation immediately to the east of the grazed pastures illustrating the greater fine fuel load and absence of damage to koa haole (Leucaena leucocephala) in an area with a woody overstory where livestock are absent.

Figure 7. An area at Mākua Military Reservation immediately to the east of the grazed pastures illustrating the continuous cover and greater fine fuel load in a grassy area where livestock are absent.

4. CONCLUSIONS

Despite having to terminate the grazing trial earlier than planned due to the fact that dogs killed the sheep, several important pieces of information were obtained:

(1) Sheep may not be a viable alternative due to the presence of feral dogs. Should it be found desirable to include sheep in the future, there are several things that can be attempted to reduce the threat, including the use of sheep dogs, donkeys or llamas which have been shown to effectively protect sheep from predation (e.g., Andelt 2007).

(2) Although the study ended prematurely due to the death of the sheep, the data show conclusively that livestock can be a viable tool for reducing the amount and continuity of the fine fuels at MMR and, thus, the intensity and frequency of potential wildfires.

(3) The initiation of a grazing program may be initially difficult given the considerable overstory of woody plants in some areas and the rank nature of the dominant guinea grass in others. However, both cattle and sheep show some ability to damage the woody overstory.

5. RECOMMENDATIONS

(1) Cattle are probably the best and most readily available ungulate for implementation of a grazing strategy at MMR to control the fine fuel load and the frequency and intensity of wildfires.

(2) Sheep are not recommended at this time unless protected by sheep dogs or donkeys. Llamas, while potentially beneficial as guard animals for sheep, may have a tendency to range onto steeper slopes and consume threatened and endangered plants.

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PART 2

A Literature Review of Grazing and Archaeology: Implications for Grazing Prescriptions on the Mākua Military Reservation (MMR), Island of O‘ahu, Hawai‘i

Stephen A. Sherman, M.U.R.P., M.A.
James A. Zeidler, Ph.D.

1. INTRODUCTION

Military training operations have the potential to ignite wildfires where fine fuel loads are dry and sufficiently large to carry a fire. The Mākua Military Reservation (MMR), part of the U.S. Army Garrison—Hawai‘i (USAG-HI) training assets, is a fire-prone environment in large part due to the establishment of non-native grasses.

Livestock have been successfully used in other areas of the world to reduce fine fuel loads and hence reduce the risk of wildfire. In order to limit the fine fuel load at MMR, the U.S. Army has contracted with the Center for Environmental Management of Military Lands at Colorado State University to conduct a pilot project investigating the potential use of livestock to reduce the fine fuel load at MMR and to assess the potential impacts of the livestock on archaeological features typical of the Mākua Valley.

Domestic livestock grazing constitutes one of many potential natural impacts to the archaeological record (Wildeson 1982), and falls under the general rubric of *bioturbation*, as defined by Wood and Johnson (1978) (see also Fleischner [1994] and Trimble and Mendel [1995] on general ecological and geomorphological impacts of cattle grazing). The most prominent archaeological impacts resulting from grazing include both trampling and erosion. The intensity of the impacts may be directly related to the intensity, duration, and frequency of grazing as well as the nature of the archaeological matrix (the soil or lack thereof), and of environmental conditions while grazing occurs (e.g., wet versus dry conditions, etc.). Additionally, if grazing increases erosion, this may also have a significant secondary impact on the archaeological record by displacing surface artifacts, destroying archaeological site matrix, and/or exposing buried archaeological remains. It is important to consider that the grazing impacts and secondary erosional impacts may affect both surface and subsurface materials. As many researchers have noted (e.g., Osborn et al. 1987:28), there has traditionally been a lack of quantitative data to support many assertions about the potentially negative impacts of grazing on the archaeological record of a given area.

As initially designed, the Mākua grazing study was to include an experimental archaeological component that would provide such quantitative data for the special case of a U.S. Army Training Area on the leeward side of the Island of O‘ahu. This was to be achieved by creating experimental plots having simulated or mock archaeological features and artifact scatters within in the proposed grazing paddocks for cattle and sheep. Impacts on these features and artifacts from trampling and other animal behavior would then be examined and quantified. However, due to objections raised by various Native Hawaiian groups, this research component was cancelled.

In the absence of first-hand experimental archaeology within the Mākua Military Reservation (MMR), the impacts of grazing animals on the archaeology of the area can only be inferred based on observations and experimentation conducted elsewhere. What follows is a brief literature review of articles and reports that concern the impacts of grazing animals on archaeological sites. This is not an exhaustive review since there have been many more studies and experiments than are presented here. This review is intended to address the range of negative impacts as well as the beneficial uses of grazing on or near archaeological sites with the aim of providing food for thought as well as thoughtful guidance to a grazing program in which cultural sites may be affected.

In general there are two broad types of articles and reports focused on grazing and archaeology: 1) academically oriented studies focused on site formation process and interpretation; and 2) publications directed at management and guidance. The formation-interpretation studies are the largely academic and research oriented materials that often focus on the detrimental effects of trampling and its impact on subsequent interpretation. These studies often have the goal of outlining the means by which archaeologists can identify and account for the impacts of grazing when interpreting the archaeological record. For the most part it is trampling and erosion that concern archaeologist when it comes to grazing animals on, or near, cultural sites. In general, trampling has both direct and indirect effects on cultural resources. The direct impacts typically involve artifact breakage and displacement (both vertical and horizontal) through the movement of animals across a site. Indirect effects include erosion and exposure of cultural resources. In the case of cultural features, erosion may have the effect of severely defacing or removing the feature, while artifacts may become displaced. Exposure by removal of vegetation has the effect of increasing erosion and also making cultural sites more visible and accessible to vandalism. This is not to say the impacts are all bad since sites can also become buried as a result of upslope grazing-induced erosion, thus protecting them from further damage.

Management and guidance reports often emphasize that grazing can not only damage cultural sites, but may be used to manage cultural resources as well. Proper management of stocking level, thoughtful placement of grazing infrastructure (i.e. fences, salt licks, bedding grounds, gates, etc.), as well as the type of grazing animal can help minimize both the direct and indirect impacts to cultural sites. For example some reports suggested goats as a means of controlling damaging vegetation.

The academically oriented materials help to familiarize the reader with the concerns of the archeological community in regard to grazing while the management and guidance reports provide direction on how to address the various issues. Because, ultimately, the damage to sites is more related to animal behavior and management practices than to the nature of the cultural sites, these publications, though not specific to MMR, can provide practical and generally applicable management advice.

2. GRAZING AND THE INTERPRETATION OF THE ARCHAEOLOGICAL RECORD

It is probably safe to say that little good comes from exposing cultural resources to livestock trampling and grazing. Livestock, regardless of type, will break, trample, displace, and expose cultural resources. As with the proverbial bull in the china shop, it doesn’t take a scientific study to prove that a heard of sheep or cattle milling around on top of lithic tools or ceramic vessels will do some damage. The depth at which artifacts are buried as well as the intensity of the grazing will mediate the impacts somewhat, but not eliminate their effects entirely. In general, cultural resources become broken, smashed or crushed, displaced, eroded away, and exposed as a result of trampling related to livestock grazing.

The act of grazing may seem mundane, but the impacts to cultural resources are both physical and intellectual. The physical impacts include breakage, erosion and displacement while the intellectual impacts are those that affect the analysis or our understanding of the resource and its role in a larger cultural system. The object, whatever it may be, was created by someone now, likely, long dead. The connection to that person or his/her culture is derived from that object and its association with other related objects as well as the location at which it was found. The meaning may be debatable. It may be personal or it may be scientific. It may be as simple as the feeling one gets from being the first person in a thousand years to see or touch the object, it may be the sense of cultural continuity for the indigenous person who interprets the meaning it possess, or it may be the scientific value for its place in a theory of cultural development or environmental adaptation. No artifact is an isolated cultural fragment, but a piece of a larger picture puzzle. Take the pieces, break them, scatter them, lose them, and it becomes increasing difficult to see the larger picture. It doesn't really matter if that picture is personal, spiritual or scientific. Once it's gone, it's gone. The emphasis here will be on the cultural resources physical attributes and their archaeological value, but protecting cultural resources benefits those whose interests in them may not be of a scientific nature.

Without getting into the intricacies of intra-site spatial analysis, the fact is that artifacts will become more numerous, through breakage, and more spatially dispersed as a result of livestock trampling. Depending on the surface and subsurface matrix, artifacts may become dispersed to a greater or lesser extent both horizontally as the objects are kicked around and vertically as they are pushed into the subsurface. Confusion as to what are legitimate artifacts, human caused breakage, or livestock damage may also interfere with the analysis of an artifact assemblage. Stand-alone artifacts aside, ephemeral or small features such as stone alignments or fire hearths may become scattered beyond recognition. As an example a site that may have consisted of five bifaces, 30 pieces of debitage, the remains of structural supports, and cooking fires may become a blurred picture of 20 biface fragments, hundreds of pieces of debitage and no evidence for a habitation. The archaeological interpretation of the assemblage under the former site conditions may differ substantively from that of the latter.

There is little question that grazing has an impact on cultural resources, but what is the nature of that impact and how can they be ameliorated or eliminated? The answers to these questions will come from an understanding of both how the animals use space and how to modify that behavior to protect valuable cultural resources. In addition to behavior modification, what measures can be taken to stabilize cultural sites to withstand the animals' impacts?

The best way to protect cultural materials from the impacts of grazing, short of avoiding grazing altogether, is to divert the animals from the resources. This can be done using fences, barriers, or diversions to discourage the livestock from grazing or traversing the sites. Another means might be to propagate or encourage, on or around cultural sites, plant species that have little grazing value to the livestock and/or eliminating those that lure grazers to cultural sites. However, a preponderance of sites or their spatial distribution may make fencing and other site-specific protection measures impractical. So not only is it important to understand how the animals use space, but also how the cultural resources are distributed across the space that they use.

Another issue that seems at first to be merely administrative and functional is the setting of site protection priorities. That is, deciding what is a valuable cultural resource warranting protection. Deciding what stays and what goes is never easy and setting priorities is less a scientific endeavor than a political one. There may be no unbiased way to set these priorities when the value of the site is derived not only from it archaeological value, but its contemporary cultural meaning as well. From a strictly practical perspective, priorities will have to be set and this requires some basic administrative tools like site definitions, site boundary definitions, site conditions assessments, and National Register status. Not everything can be protected and if grazing does go forward, cultural resources will be lost in no particular order and with little regard for their perceived value regardless of whose values are applied.

3. THE ACADEMIC APPROACH

3.1 Trampling, Taphonomy, and the Archaeological Record

A large proportion of the literature concerning grazing animals and archaeological sites focuses on the impacts to individual artifacts or cursorily addresses other issues like compaction and erosion.

Perhaps the most important aspect of archaeological analysis is context. Knowing where an artifact came from, known as provenance, is the key to a more complete understanding of its cultural role or function. Though not always the case, an isolated object may not have much interpretive value. Certainly the function of some tools, a projectile point for example, can be reasonably understood in isolation but often an artifact is interpreted by its surroundings including other artifacts and features. To know an artifact it is important to understand the "company it keeps". Knowing an artifact's association allows the researcher to better understand the object's potential uses and its relationship to human behavior. But no site is a snapshot of a place in time. Change is the nature of life and death on this earth and an abandoned cultural site is no exception. Understanding what happened to an archaeological site and/or its components after abandonment allows a researcher to remove some of the bias in any subsequent interpretation of the remains. Therefore, it should be no surprise that site formation and taphonomy[1] are very widely studied. The full range of information concerning site formation processes and taphonomy are beyond the scope of this review and the focus will remain on the implication of grazing including trampling, displacement, and erosion.

In general, formation process related studies are concerned with artifact breakage and displacement often as a result of trampling. These studies are not limited to the impacts of trampling by grazing animals as some also consider human foot traffic. However, since human behavior is the ultimate object of most archaeological research, the effects of human trampling

[1] Taphonomy: (1) the science of the laws of embedding or burial; the study of the transition, in all details, of organics from the biosphere into the lithosphere…(2) the study of differences between a fossil assemblage and the community(ies) from which it derived; the nebulous region of conjecture constituting hypothetical assertions about the causes of the observed bias in fossil assemblages (Lyman 1994:515)

on artifacts are considered less detrimental to interpretation than that done by grazing animals (McBrearty et al 1998; Nielsen 1991; Stahl and Zeidler 1990). That is to say, how people trample and displace their own artifacts can provide insight into how people use space and partition various activities within a site.

Regardless of the source, or taphonomic agent, responsible, these studies often draw attention to the destructive implications of foot traffic and grazing as they pertain to trampling, compaction, and displacement. These activities can result in the loss of a site's integrity or of the site itself to future research. Schiffer (1983:678), on the other hand, points out that "formation processes do not just degrade artifacts [and sites], they can introduce patterning of their own". Another genre of trampling research focuses on distinguishing cultural from non-cultural modification to materials and artifacts during analysis and interpretation. For these types of studies the focus is on interpretation and analysis, not on management and site protection, and is more academic than pragmatic.

The first step toward recovery is to admit you have a problem; likewise the first step in assessing site formation bias in an assemblage is to admit there is bias. This concept was not new when Schiffer published his 1983 article entitled *Toward the Identification of Formation Processes.* Schiffer stressed the need for a systematic approach to assessing bias. He describes his site formation process approach as follows:

> …formation processes introduce variability into the archaeological record: patterns are destroyed or modified, new patterns are created; materials are destroyed or modified, new materials are added. Thus, in using particular characteristics of the archaeological record as evidence of specific behavioral or organizational phenomena, one must see to it that variability contributed by formation processes is understood and taken into account. Secondly, these studies emphasize that in order to take formation processes into account…, one must identify the formation processes…To "identify" a formation process is to infer that it occurred. Third, the analytical level at which this identification is achieved is the "deposit". Thus, as a prerequisite for making virtually all archaeological inferences, the archaeologist must identify the processes that gave rise to the specific deposits that are to supply relevant evidence (Schiffer 1983:678)

Much of the article broadly addresses the various types of cultural (c-transforms) and natural (n-transforms) processes that affect a deposit. Schiffer points out that there may be more than one explanation for an artifact's condition. That is, shape, size, orientation, use-life, and damage may be the result of cultural and/or natural agents.

Trampling by grazing animals is a natural agent responsible for introducing patterning into the archaeological record. For example, in situations where artifact size and orientation within the deposit may be considered important, it must be noted that "trampling (by people, animals, and machines) reduces artifact size in predictable ways" (Schiffer 1983:679) and "that trampling in loose substrates can create vertical or nearly vertical dips of long bones and presumably of other artifacts of similar shape and size", while "[t]rampling of smaller artifacts with less extreme shapes is likely to produce a nearly random distribution of dips" (Schiffer 1983:681). In the final analysis the researcher must understand the impacts of trampling on a particular deposit. In situations where it produced predictable patterning then any observed patterning, of that variety may be excluded from the analysis, while in other situations it may be that any culturally significant patterning in the record has been obliterated by the actions of grazing animals.

Trimble and Mendel (1995) provide a review of various geomorphologic studies of grazing impacts. Though not specifically concerned with archaeology, its relevance to archaeological interpretation should not be ignored. The authors note a lack of standardization in many grazing impact studies. They also point out that "…there can be no universal definitions of grazing intensities. These must vary by land capability, plant productivity and climate, among other variables" (Trimble and Mendel 1995: 234). They go on to discuss three effects of grazing: compaction, infiltration, and floral and faunal effects. Of these, the most relevant here is compaction.

With respect to compaction, the authors state that upland slopes are where cattle have their greatest effects. "The most common manifestation of direct force [compaction] is the path or trail…Being created by both compaction…and displacement to the sides, trails often resemble narrow, linear troughs with raised shoulders" (Trimble and Mendel 1995:235). Under wet conditions studies have shown that these troughs can reach depth of 30 cm, but that these depths are likely the result of the increase in erosion rather than strictly the result of compaction or trampling. In some instances the effect of this erosion is to create downslope gullies. Grazing has also been shown to increase soil bulk density as well as "reduce the density of grass cover…severe compaction often reduces the availability of water and air to roots, sometimes reducing plant vitality [and a] change from perennial to annual [species] and from deep-rooted to shallow-rooted [species]" (Trimble and Mendel 1995: 237). In general, they found that trampling impacts the upper 25 cm of soil.

In order to address the issues of trampling and other taphonomic impacts to cultural sites, many actualistic studies have been performed to determine the variables involved (Andrews and Cook 1985; Broadhead 1999; Gifford-Gonzalez et al. 1985; Haynes1983; Shea and Klenck 1993; Van Vuren 1982). Speaking in terms of the effects of trampling on bones, Lyman (1994: 377) describes these types of studies as"… [focusing] on three things: the creation of marks on bones, the fracturing of bones, and the spatial displacement of bones". He goes to on emphasize that "… ethnoarchaeological and experimental contexts… [have] indicated that the fossil record can be greatly modified from its depositional condition by trampling" (Lyman 1994:381).

Reports and formation process assessments often acknowledges that trampling represents one of many destructive agents affecting archaeological sites (Nickens 1991). Others have taken it a step further by creating experimental sites and trampling over them. Some studies have been opportunistic; that is, taking advantage of a "natural experiment" in which the researcher only need observe the outcome. One such study, conducted by Andrews and Cook (1985), describes observations made of a modern bovid death assemblage by tracking the decay of a carcass and subsequent displacement of the bones. Although they address a number of taphonomic agents, trampling of the bones by other grazing animals is discussed at length. This study, like Haynes (1983), is intended to show the effects of and means by which to identify trampling in an archaeological assemblage.

Van Vuren (1982) took advantage of a unique geographical situation on Santa Cruz Island. This article describes an experimental archaeology study comparing the impacts of feral sheep on the spatial distribution of artifacts. Van Vuren conducted his experiments in a 100 hectare area of rolling hills on Santa Cruz Island that had been divided by a fence. On one side of the fence were contained feral sheep at a density of 2 per acre; which the author considers to be high density. The other side of the fence had fewer feral sheep although the density is unspecified. The author laid out five 1 m^2 plots and placed simulated artifacts and specified intervals. Two plots were placed on the low density (control plots) and three on the high density sides of the fence. On the high density side the experiment targeted areas that could be expected to incur more extensive grazing impacts. Specifically, the author chose to locate his plots on sheep bed-grounds and the intersection of sheep trails while the control plots were established in an area of low sheep density/traffic. It is no surprise then that the plots in the high density areas showed a greater amount of artifact displacement.

> After six months, sites [plots] exposed to high sheep density had been destroyed; two-thirds of the flakes could not be relocated, and the remainder had been moved from their original positions. …Conversely, sites exposed to low sheep density were largely undisturbed; only 6% of flakes were lost, and more than two-thirds had been left untouched. The few disturbed flakes were found within 39 cm of their original positions, whereas flakes exposed to high sheep density were displaced as much as 2614 cm (Van Vuren 1982: 149).

The author concludes that the "[displacement] and loss of flakes could have been caused by several factors, all ultimately linked to feral sheep. Destruction of vegetation by sheep left flakes exposed…[contributing to] erosion, resulting in displacement of flakes with soil movement…[and] direct trampling and kicking [of artifacts] by sheep" (Van Vuren 1982:149). The experiment is not without its flaws, but the results are clear.

A similar experiment conducted by Broadhead (1999) involved cattle as opposed to sheep. He describes in a very brief summary report an experimental plot in which a modern archaeological site (a lithic scatter) was created and situated in an area wherein a portion of the site was exposed to grazing and a portion of the site was excluded from grazing. The results were as expected in that the area exposed to cattle movement showed a greater degree of artifact displacement and loss. Broadhead points out that loss may have been due as much to the vertical displacement of artifacts (they were pushed into the ground) as their horizontal movement out of the study area.

Osborn et al. (1987) describe a grazing study conducted in 1985 and 1986 at Capital Reef National Park, Utah in which both existing and experimental archaeological sites were subjected to grazing in an effort to quantify the impacts. Assessing the degree of damage to the existing sites was made difficult due to inadequate descriptions in the original site recordings. The experimental plots showed damage in the form of artifact breakage as well as vertical and horizontal displacement. The results also suggested that ceramic artifacts were more severely damaged than lithic materials. The authors of this study speculated that accumulations of animal dung posed a fire hazard to archaeological materials and that erosion due to loss of vegetation cover or trampling of stream banks further destabilized sites.

The effect of vertical displacement of artifacts is another important focus of actualistic trampling studies. Movement of artifacts within the substrate upon which they were deposited can be effected by the size and shape of the artifacts as well as the nature of the substrate itself. Stockton (1973) describes an early study focusing on artifact size and displacement by trampling. This study found that trampling had different effects on artifacts of varying sizes. Specifically, larger artifacts were moved upward while smaller artifacts were pushed downward in the sediments. Gifford-Gonzalez et al. (1985), though concerned with human trampling of archaeological sites, emphasized the nature of the substrate. In essence, the size and shape of an artifact in relation to the substrate upon which it originally came to rest combined with the intensity of trampling will effect its vertical distribution. In other words, trampling may have the effect of sorting artifacts vertically, thus influencing interpretation and possibly attributing human behavior to perfectly natural causes. Though not an aspect of this experiment, the important point to keep in mind is that grazing can have a similar effect.

Ultimately the goal of this type of research has been to factor out trampling induced bias at the time of analysis and interpretation. Haynes (1983) focused on the influence that naturally occurring modifications to archaeological materials have on a researcher's interpretations of an assemblage. In this case the modifications include trampling and bison wallowing that result in green bone breakage. Green bone breakage refers to fracturing of bones while still fresh (as opposed to old dried out bones that fracture in quite different ways). Often, green-breakage of bones from an archaeological site is attributed to human activity (such as marrow and grease extraction), but this cautionary tale points out that trampling may create some of the very same types of fractures. This, like similar studies involving lithic use-wear, serves to emphasize the need for caution and consideration of multiple taphonomic agents when interpreting a bone assemblage.

Shea and Klenck (1993) outline the results of trampling damage on interpretability of use-wear on artifacts. In general it deals little with trampling per se and more with the interpretation of use-wear and classification of tool use activities based on wear. The authors suggest that even relatively short-term trampling on a soft substrate can obliterate or significantly alter the visibility of use-wear and possibly bias the subsequent interpretation.

In sum, these and many other studies have shown the need to acknowledge the presence of bias, its nature, the agents of bias, and the ways of identifying it before it becomes a part of the site interpretation. Context, past and present, is everything to an understanding of archaeological sites.

4. MANAGEMENT STUDIES, PLANS, AND GUIDANCE

4.1 The Impact of Grazing and Baseline Data

Many studies and reports concerned with grazing and public lands, like Catlin et al. (2003:65), merely mention that grazing has "directly and severely threatened" cultural resources without citing evidence or examples. Other reports discuss the impacts of cattle grazing on cultural sites in great detail, but offer little in the way of management recommendations (Floodman 2000; U.S. Department of the Interior, National Park Service 1999). A National Park Service report describes the effects of grazing within the Glen Canyon National Recreation Area. In it, the authors emphasize the severe destruction wrought by cattle upon the area's cultural resources. They cite alarming statistics suggesting that in parts of the recreation area as much as 86% of sites have been affected. Along riparian systems within the recreation area, their data suggest that between 9 and 43 percent of archaeological sites have been trampled by livestock to some degree. All manner of site types including rocksheters, open sites, special activity areas, hearths, and other features have been damaged through displacement and erosion of materials and substrates, respectively. Floodman (2000) describes the range of site types affected by cattle grazing including cultural materials scatter, historic homesteads, stone circles, rock cairns, eagle trapping pits, as well as traditional cultural properties (TCPs). Though he discusses the proportion of sites for each type that have been impacted by cattle, there is no description of the impacts themselves in any great detail. Floodman (2000) provides little in the way of practical and specific means of mitigating the impacts of grazing animals on archaeological sites. What these report do is emphasize the need for practical management strategies and guidance.

Site formation is a dynamic process affecting cultural sites over extended periods of time, but to understand the nature and trajectory of change requires a baseline for comparison. A preliminary report by Todd et al. (2000) outlines an ongoing survey program conducted by Colorado State University and the Nebraska National Forest designed to address a series of research questions including, but not limited to, the effects of grazing by domestic cattle on surface and near-surface archaeological sites. At the time of the writing of this report, the data were insufficient to assess grazing impacts (Todd et al. 2000:2); however, a standardized method of ongoing site assessment is described in detail.

The authors recommend the use of what they term Modified Whittaker Plots in combination with high accuracy GPS to assess artifact distributions. The plots are highly structured and the survey controls are very precise. The authors advocate a multi-scale non-site survey approach in order to assess the distribution of artifacts across the landscape in a attempt to generate "baseline information to evaluate the impacts of grazing and other uses of the Oglala National Grasslands…(Todd et al. 2000: 18). They suggest a systematic assessment of the landscape using various survey intensities including the highly intensive Modified Whittaker survey plots. The idea is to quantify the distribution of artifacts (i.e., density per hectare) for longitudinal comparison between surveys and not as a discovery technique. They point out that "[b]ased on the preliminary results of fine-grained surface survey coupled with systematic testing…we would suggest that standard archaeological survey may not give a reliable indication of artifact densities and may not provide adequate data to assess the impacts of grazing or range improvement projects…"(Todd et al. 2000: 19). These, or similar, permanent plots are most useful as a long-term site condition assessment tool. Establishing these plots on known sites or features as part of an on-going evaluation process makes the most sense. They could provide quantitatively comparable longitudinal data indicating changes or trends in the site's condition or supporting any contention of site stability.

As for the impacts of grazing Todd and associates come to the same conclusions as most authors. They claim: "Our preliminary impressions are that the impacts of grazing are multidimensional. On the one hand, grazing may accelerate erosion of some areas, and may displace and damage artifacts. On the other hand, in some areas grazing may be one of the key factors in making archaeological materials visible and therefore accessible for archaeological research and management"(Todd et al. 2000: 20).

Floodman (2000) lays out a strategy for the classification of cattle grazing impacts within known sites, pastures, and range improvements constructed prior to implementation of cultural resource inventory requirements. Cattle affect cultural sties through both 1) trailing and 2) milling and trampling. Trailing relates to the movement of cattle across the landscape which often creates well defined linear scars. He further subdivides trails into three classes based on the depth to which they penetrate the surface and/or cultural horizons. Light and moderate trailing describes trails that are limited to the surface or have cut into the soil horizon, respectively, but have not impacted cultural materials. Severe trailing occurs when the pathway has begun to disturb cultural materials. Milling and trampling, as the names suggest, pertain to the impacts of cattle as they congregate in an area. The effects of milling and trampling are classified in the same way as trailing.

Floodman (2000) takes into consideration not only the direct effects of the animals but stock management activities such as maintenance and construction of range improvements. Range improvements include spring developments, water wells, pipelines, water tanks, stock dams, fences, corrals, and salt licks. Each of these attracts cattle, but also their construction and maintenance impact cultural materials (i.e., two track access roads, and ground disturbance during construction).

Classification of impacts is an important first step toward assessing impacts and generating baseline data. Reducing subjectivity in site assessment by defining impact categories and assessment strategies permits a greater degree of comparability between sites and within sites over time.

4.2 Guidance for Cultural Resources Protection

Some reports offer only minimal guidance for the protection of cultural resources under grazing. The East Bay Municipal Utility District (2001) management plan, for example, focuses on water and range quality and use of grazing animals for range management. Little attention is paid to cultural resources. However, Appendix C briefly outlines aspects of the plan pertaining to livestock grazing and cultural resources and mostly calls for avoidance, exclusions zones, survey and mitigation. The Bureau of Land Management (U. S. Department of the Interior, Bureau of Land Management 2001) provides very general guidelines for assessing existing conditions, managing known historic properties, locating unknown sites, monitoring known sites, handling human remains, and tribal consultation.

A leaflet produced by English Heritage Customer Services Department (2004) is intended to help landowners identify and protect cultural sites from grazing animals. Specifically, it addresses seven impacts to cultural sites in farmland setting that include: 1) Livestock poaching [overgrazing] or erosion; 2) Careless use of farm vehicles, 3) Grassland improvement; 4) Land drainage works; 5) Scrub or bracken encroachment; 6)Burrowing animals; and 7) New fencing, ponds or scrapes, and tree planting. Like other similar guidance, the authors recommend thoughtful and managed placement of structures (fences, water troughs, gates, sheds, barns, etc.) and appropriate stocking levels in order to avoid impacts to cultural sites. They suggest that erosion and trampling can be controlled in part by reducing the intensity with which gathering areas are utilized by the animals. As well, any contemplated improvements to pastures and even routine maintenance (vehicular traffic) must involve a consideration of the impacts to cultural sties.

The U.S. Department of Interior, Bureau of Land Management, California State Office (2004) outlines a programmatic agreement between the Bureau of Land Management's California State Office and the California State Historic Preservation Officer (SHPO) that is intended to streamline grazing permitting and lease renewals. Specifically, it addresses 1) Planning; 2) Inventory Methodologies; 3) Tribal and Interested Party Consultation; 4) Evaluation; 5) Effect; 6) Treatment; 7) Monitoring; 8) Disagreements; and 9) Reporting and Amending. In general, the document is very broad with the treatment section having the most specific guidance.

The outline of "Treatments" briefly addresses a) fencing and enclosures, b) relocation of livestock facilities/improvements to less sensitive areas, c) removal of natural attractant to grazing animals from cultural sites, d) exclusion of cultural resources areas from grazing allotments, e) livestock herding away from cultural sites, f) "Use of salting and/or dust bags or dippers placement as a tool to move concentrations of animals away from cultural sites", g) locating sheep bedding grounds to less sensitive areas, and h) an open-ended agreement to consult with SHPO on additional protective measures (U.S. Department of Interior, Bureau of Land Management, California State Office 2004). Like so many other guidance oriented documents, it is focused on managing stock to reduce impacts to cultural sites through careful consideration of the animal's behaviors and the methods of managing livestock (i.e., structures, herding, etc.).

More specific advice and procedures are described in Phillips (2003). This report addresses a number of threats to archaeological sites within the Mauao Historic Reserve in Tauranga, New Zealand. Grazing is addressed briefly and some management recommendations are made. Like Rimmington (2004) and Jones et al. (2003), the conclusion is that grazing can be used as a management tool to maintain a vegetative cover suitable to the protection and enjoyment of archaeological resources. Still he points out: "Stock management for maintenance of an archaeological landscape may not necessarily conform with accepted commercial practices of farming (Phillips 2003:33). Pasture maintenance requires tight control and monitoring of grazing and cooperation between the stock managers and archaeologists. Specifically, he suggests thoughtful paddock design and construction so that elements such as gates, water sources, and shelters are positioned away from archaeological sites and features. He also warns that fencing off of prominent archaeological features within a site, like a shell midden, may simply shift the stock damage to other more archaeologically sensitive areas. Basically, a thoughtful, well managed grazing plan that incorporates monitoring and periodic adjustments is a perfectly suitable archaeological management tool.

Rimmington (2004) addresses all manner of impacts to archaeological earthworks not simply the effects of grazing, with specific reference to the Hadrian's Wall World Heritage Site in England. The guidance addresses the methods of assessment, monitoring, and mitigation of the impacts of various management issues. The purpose behind the combination of assessment and monitoring is to determine "what is changing and the trend in that change, why it is changing, what management action is required [to mitigate the impacts] and what future monitoring is required" (Rimmington 2004:22). Rimmington offers very specific approaches to scoring impacts for consistency in monitoring trends over extended periods of time. Case studies are also provided.

The management issues they list include livestock grazing, recreation use, vehicular impacts, vegetation growth, burrowing animals, mineral extraction, fencing, road construction, water action and vandalism. As the title of the report implies, the focus is on managed grasslands. The grasslands in question have been maintained under grazing for generations and so are in themselves cultural features. For this reason these areas are not to be considered natural settings. The objective is to maintain them as grazing areas and through proper management also to maintain archaeological earthworks.

> Indeed, managing monuments for grazing is often seen as the ideal management for ensuring long-term preservation of the monument as it maintains the visibility of the monument and deters scrub growth…it can also have a detrimental effect on the survival of the archaeological earthworks and their settings. Often this is due to local factors such as stocking levels, season of stocking, type of livestock, and presence of focal points.
>
> The goal of livestock management on archaeological monuments is to achieve the right balance of grazing for its long-term preservation (Rimmington 2004:41).

Mismanagement of livestock grazing can lead to erosion and the development of damaging vegetation. Erosion of soils at focal points must be addressed. These focal points include shelter areas where animals congregate in inclement weather, feeding stations, movement pinch points created by gateways or scrub that concentrate animal movement, rubbing posts or other similar objects, waters sources and bare areas created by burrowing animals and used by livestock as wallows or mineral licks. These areas can be eliminated or moved to shift the animals away from sensitive archaeological features.

“The correct type and combination of grazing animal and the right timing and intensity of grazing are essential to overcome selective grazing”(Rimmington 2004:43).
That is to say that not only should the intensity of grazing be such that injurious vegetation will not have the opportunity to grow, but also the variety of grazing animals should be such that injurious plant species are not ignored by the dominant grazer and, subsequently, become well established.

The management guidance provided in Rimmington (2004) may or may not be applicable to the circumstances found at MMR since it is aimed at maintaining a grassland (non-natural) environment, but the types of disturbances and the means of controlling them are valid under any grazing management agenda.

Sheep have been suggested as a means of maintaining cultural sites by eliminating damaging vegetation. Canham and Chippindale (1988) describe the land-use pressures applied to cultural sites within the Salisbury Plain Military Training Area (SPTA), England. They point out that the most devastating pressure is not military but agricultural, with plowing being the primary offender. In fact, “…the primary land use in recent centuries has been for extensive sheep-grazing. This use is particularly kind to standing monuments: unlike cattle, sheep are too light…to cause much damage; their grazing prevents destructive regeneration of scrub and trees and involves no cultivation or direct human disturbance of grass cover” (Canham and Chippindale 1988:53). Like Rimmington, the authors emphasize that although the animals can contribute to site degeneration, they can also be utilized to control damaging vegetation.

Jones et al. (2002) is a discussion draft of proposed site protection and management guidance for New Zealand. Like Rimmington (2004), it outlines the threats to archaeological sites and provides management guidelines for sites under various ecological settings or land uses. Grazing and pasture care are addressed at length and though this guidance is intended for New Zealand, it is potentially applicable to grazing at MMR.

Jones et al. (2002) list the “[r]elevant factors in stock management on archaeological sites” as follows:

- Stock numbers—no more than 10 stock units (s.u.) per ha.
- Stock-type—sheep or goats, yearling cattle only.
- Permissible grazing seasons—not in winter or very wet weather.
- Set stocking is preferable to rotational grazing.
- Keep plenty of feed available; grass should be 6-10 cm in height…
- Fencing should not slice across a site.
- Top-dressing—soils should not be fertilized to maximize production but to maintain even grass cover and prevent erosion.
- Stock water and shelter—do not supply on the features of the archaeological site (Jones et al. 2002:32).

Monitoring of the animals’ impacts to the allotment is important in order to identify “erosion hotspots” so that they can be addressed as quickly as possible. The guidance suggests that grazing is a useful management tool, but that it “…should be carried out for particular site management objectives and strictly controlled." Specifically it should be used for general "…vegetation control, [keeping] height of grass down for site visibility and lessening fire risk [and for] [preventing] shrubland succession" (Jones et al. 2002:31). They also emphasize using smaller stock, namely sheep and goats, and dry season grazing.

The message to be gleaned from these various management reports and guidance is that the issue of livestock grazing impacts on archaeological and historic sites is well documented and that there are a number of options for both the mitigation of damaging impacts and the utilization of grazing for maintaining the integrity of cultural sites.

5. SUMMARY

Context is the key to understanding the meanings of cultural sites for both archaeologists and non-archaeologists alike. For many people, archaeological and other cultural heritage sites help to put both broader human history as well as their own personal history into context. The meaning and "usefulness" of these materials vary from person to person, but one thing is certain and that is that the physical remains of past human activities are ultimately ephemeral. As physical entities, they fade in the face of myriad agents bent on their destruction. Many of these factors are natural and act without forethought or malice, but many can also be managed or controlled and as such, sites can be protected--ideally in perpetuity. Grazing is one factor that impacts cultural sites and in a variety of ways. Proper management of grazing can help to avoid unnecessary damage and may also help to protect the resources as well.

The best management of archaeological sites within grazing allotments requires managers to first:

- Define the types of impacts;
- Standardize methods of assessing the impacts;
- Compile baseline data;
- Establish reliable and comparable methods of monitoring the impacts;
- Consider aspects of the grazing animals' behaviors that may impact sites; and
- Carefully consider the maintenance and construction of livestock infrastructure.

In the event that a grazing prescription is developed and implemented at MMR, it is highly recommended that the above mentioned factors be taken into consideration and duly incorporated into the grazing protocols.

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