Taphonomy and Site Formation on California's Channel Islands

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Inhabited by humans for over 12,000 calendar years, California's Channel Islands contain thousands of archaeological sites, ranging from dense shell middens and villages to small lithic scatters and camps. Similar to many islands around the world, the Channel Islands have a dearth of burrowing animals and limited historical development leading to generally good preservation of archaeological constituents and relatively high stratigraphic integrity. Despite these favorable preservation conditions, numerous natural and cultural processes have impacted the island's archaeological record. Channel Islands archaeologists, however, have given relatively limited attention to the effects of taphonomic and formation processes. The authors provide an overview of taphonomic and formation processes affecting Channel Islands archaeology, illustrating the importance of regional taphonomic syntheses in the management, preservation, and interpretation of archaeological sites. These data also demonstrate the significance of detailing formation processes in islands and other areas where burrowing rodents and other disturbances are thought to be absent or limited.© 2006 Wiley Periodicals, Inc.

INTRODUCTION

Studies of taphonomy, formation processes, and site disturbances have revolutionized the ways archaeologists reconstruct the past (Wood and Johnson, 1978; Gifford, 1981; Nash and Petraglia, 1987; Schiffer, 1987; Goldberg et al., 1993; Lyman, 1994; Waters and Kuehn, 1996; Dincauze, 2000; Stein, 2001). Interest in formation processes and taphonomy in North America has increased with the rise of cultural resource management, as researchers have sought better ways to manage, preserve, and interpret the archaeological record. Understanding the taphonomic processes that contribute to the integrity of archaeological sites and the structure of archaeological assemblages, in fact, is as crucial to evaluating the significance of sites as it is to reconstructing past behavior and environments.

Although archaeologists have made considerable strides toward understanding various processes that form and alter the archaeological record, continued research is needed to resolve a variety of issues. This includes regional overviews that complement detailed studies of formation processes affecting a single site. Global surveys provided by Wood and Johnson (1978) and Schiffer (1987) are landmark studies that

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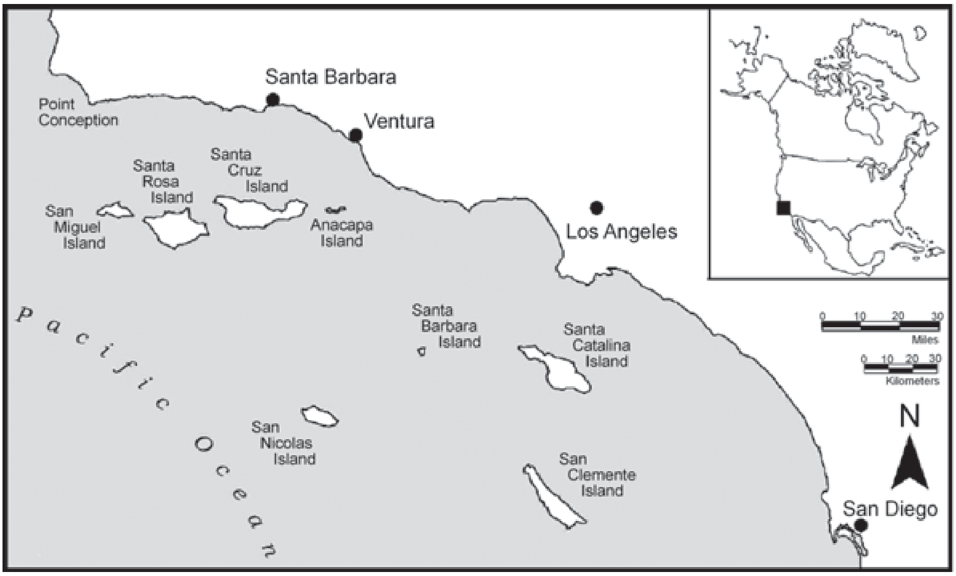

Figure 1. The Channel Islands and the southern California Coast.

pave the way for detailed research on a variety of topics. However, we argue that researchers should provide taphonomic overviews and syntheses for specific geographic regions or environments that augment the larger scale provided in these global syntheses (see Erlandson and Rockwell, 1987; Bar-Yosef, 1993; Stewart, 1999).

Southern California's Channel Islands contain a remarkable archaeological record, spanning at least 12,000 years, with thousands of well-preserved and stratified sites (Figure 1; Glassow, 1977; Erlandson et al., 1996; Johnson et al., 2002; Kennett, 2005). Similar to many island chains around the world, the Channel Islands have relatively few endemic mammals, a general dearth of burrowing rodents (gophers, badgers, etc.), and limited historical development. The relatively high-resolution archaeological record of the Channel Islands contrasts with the often heavily disturbed record of the coastal mainland, where many sites are bioturbated (Erlandson, 1984; Johnson, 1989), plowed, and have been ravaged by over 150 years of historical development. These disturbances result in coastal mainland archaeological sites that are often highly fragmented, containing stratigraphically mixed assemblages with low chronological resolution (Erlandson and Rockwell, 1987; Erlandson et al., 1988). Because the Channel Islands generally lack the intensive historical development and major burrowing animals of the mainland, they are thought to contain an archaeological record minimally affected by disturbance processes (Glassow, 1980, p. 79; Salls, 1991, p. 63; Arnold, 1992, p. 65; Erlandson et al., 1996; Porcasi et al., 2000, p. 203; Rick, 2004).

Despite this potentially well-preserved archaeological record, numerous agents are actively impacting Channel Island archaeological sites, including sea-cliff retreat caused by wind and water erosion, argilliturbation, bioturbation, and historical activities.

While Glassow (1977) and Greenwood (1978) highlighted the need for additional research on site disturbances and formation, Channel Islands archaeologists have not provided an in-depth survey and analysis of these processes, despite more than a century of archaeological research in the area (e.g., Schumacher, 1877). In this article, we present an overview of the taphonomic and formation processes operating on Channel Island archaeological sites, providing insight for archaeologists and researchers working in coastal, island, and other dynamic environments. Our survey and analysis illustrates the importance of regional taphonomic syntheses for guiding the management, preservation, and interpretation of archaeological resources.

CHANNEL ISLANDS ENVIRONMENTS AND ARCHAEOLOGY

Separated from the adjacent mainland by varying distances throughout the Quaternary, the Channel Islands contain a distinct terrestrial flora and fauna, lacking many of the animals and plants that are common on the mainland (Schoenherr et al., 1999). The eight Channel Islands, located offshore between Point Conception and San Diego, are divided into northern (Anacapa, Santa Cruz, Santa Rosa, and San Miguel) and southern chains (San Clemente, Santa Catalina, San Nicolas, and Santa Barbara), and are owned and managed by a variety of federal and private agencies. The Northern Channel Islands and Santa Barbara Island form Channel Islands National Park, with the western portion of Santa Cruz owned by the Nature Conservancy and San Miguel owned by the U.S. Navy. San Nicolas and San Clemente are both administered by the U.S. Navy and contain naval installations. Santa Catalina is privately owned and contains the only formal city on the islands (Avalon). Other than these relatively small developments, and a long history of ranching, the islands remain largely undeveloped.

The Channel Islands range in size from about 2.6 to 249 km^2 and are between about 20–98 km from the mainland coast (Schoenherr et al., 1999, p. 7). The Northern Channel Islands form an east–west trending line along the Santa Barbara Channel and were one large island land mass (Santarosae) during the glacial periods of the Pleistocene. In contrast, the Southern Channel Islands are considerably more dispersed and isolated. All of the islands have a Mediterranean climate, with mild summers and cool, wet winters. Channel Island soils are generally neutral, alkaline, or slightly acid (see Johnson, 1972; Muhs, 1982a, 1982b). The combination of a relatively arid climate and neutral soils has promoted good preservation of most archaeological constituents.

Compared to the mainland, the Channel Islands contain a relatively limited terrestrial fauna and flora. The largest endemic land mammals—the island fox (*Urocyon littoralis*) occurring as a discrete subspecies on all of the islands, except Anacapa and Santa Barbara, and the island spotted skunk (*Spilogale gracilis*) found on Santa Rosa and Santa Cruz—are each about the size of a house cat. During the Pleistocence, pygmy mammoths (*Mammuthus exilis*) lived on the Northern Channel Islands, but until the Historic period, the islands were devoid of most of the herbivores, carnivores, and rodents found on the mainland coast. This includes a number of burrowing animals (gophers, badgers, etc.) that have bioturbated mainland archaeological sites for millennia (Erlandson, 1984; Johnson, 1989). Although there are few terrestrial mammals, the islands are home to thousands of land and sea birds. Until historic times, the island deer mouse (*Peromyscus maniculatus*) was the only rodent to occur on all the islands, with the harvest mouse also found on Santa Cruz and Santa Catalina and occasional reports of shrews and woodrats on Santa Catalina (Schoenherr et al., 1999). The only other indigenous mammal on the islands is the ground squirrel, found only on Santa Catalina. The dearth of mammals, particularly burrowing rodents, has generally promoted high stratigraphic integrity of Channel Island archaeological sites. As we demonstrate, however, many of the island's native animals (birds, mammals, insects, etc.) are capable of producing a significant impact on island archaeology. Moreover, historically introduced mammals (pigs, sheep, cattle, etc.) have had a profound impact on island ecology.

Channel Island vegetation communities are also unusual, including a number of endemics and relict species. Introduced grasses currently dominate the islands, with considerable effort devoted to reestablishing native species. A number of vegetation communities are found on the islands, including coastal sage scrub, oak, and pine woodland, and chaparral. The greatest ecological diversity is found on the larger and more topographically diverse islands (Santa Catalina, Santa Cruz, and Santa Rosa). Ravaged by more than a century of historical overgrazing, island soils have periodically been exposed, causing widespread deflation, gullying, and scouring of the landscape. Johnson (1972, 1980) provided a detailed discussion of these processes of landscape evolution for San Miguel, but similar processes have also affected the other Channel Islands.

The marine environment of the Channel Islands is exceptionally productive, with the upwelling of nutrient-rich waters supporting large populations of pinnipeds, cetaceans, seabirds, shellfish, and fishes. These productive and diverse marine environments have fostered human occupation spanning the last 12,000–13,000 years (Raab and Yatsko, 1992; Erlandson et al., 1996; Johnson et al., 2002). This includes thousands of archaeological sites, ranging from large shell middens and housepit villages to small lithic scatters. At the time of European contact, the Northern Channel Islands were inhabited by Chumashan-speaking peoples, while the southern islands were inhabited by Uto-Aztecan–speaking peoples.

TAPHONOMY AND SITE FORMATION

In this section, we discuss the major taphonomic and formation processes operating on the Channel Islands (Table I). Our intent is to provide an overview that can guide future detailed research on these and other processes. We focus on the impact of cultural and natural processes, relying on published and unpublished data and our own field observations. When possible, we also outline procedures for interpreting and combating the effects of these processes. Most of our research has been conducted on the Northern Channel Islands, but we also draw on research and data from the Southern Channel Islands.

Marine and Coastal Processes

The destruction caused by marine erosion has long been recognized by archaeologists working on the Channel Islands and in coastal areas around the world. Daily

Table I. Major taphonomic and formation processes on the Channel Islands.

Process	Description	Impact on Archaeology
	Natural processes	
Animal transporters	Deposition or removal of materials in a site by animals	Introduce noncultural materials, remove some cultural materials
Argilliturbation	Shrinking and swelling of clay soils	Mixing of constituents
Eolian processes	Erosion and deposition of materials by wind, abrasion, and production of ventifacts	Deflation/destruction of sites, deposition of "new" sites
Faunalturbation	Burrowing and mixing of deposits by animals	Mixing, fragmentation, erosion
Floralturbation	Disturbance and mixing of deposits by plants	Mixing, fragmentation, erosion
Fluvial processes	Erosion and deposition of archaeological deposits by stream, creek, or other freshwater runoff	Destruction of sites, introduction of materials from other areas
Marine processes	Erosion and deposition of archaeological deposits by tidal surges and wave action	Destruction of sites, scouring of light fraction, introduce materials
Mass wasting/ gravity	Landslides, cliffing, etc.	Erosion, redeposition, and burial of archaeological record
	Cultural processes	
Prehistoric human activities	Construction, cleaning, trampling, cooking, etc.; excavation of houses, storage areas, burial pits, etc.	Mixing, fragmentation, and destruction of archaeological record
Historical impacts	Building or road construction, agriculture, bombing, looting, etc.	Movement, fragmentation, and destruction of archaeological record
Introduction of exotic animals	Overgrazing, stripping of vegetation and soils, trampling, burrowing, rooting, etc.	Fragmentation, mixing, deflation/ erosion

tidal surges and periodic storms result in the loss of many of the island's sea cliffs and headlands every year. Periodic storms during El Niño and other events deplete the sand on many island beaches, making marine erosion particularly severe. Perched on top of many of the island's eroding sea cliffs, or located along the shoreline, are numerous stratified archaeological deposits (Figure 2). Although sea-cliff retreat rates vary across space and time, Muhs (1987, p. 566) suggested that most California sea cliffs retreat at rates averaging between about 0.01 and 0.05 m per year, with much of the retreat punctuated during storms or other events.

Over the last several years, we have monitored erosion at several Channel Island archaeological sites. At CA-SRI-2, a large housepit village situated roughly 20–50 feet above the ocean on a heavily eroding sea cliff on the northwest coast of Santa Rosa Island, we established a series of stakes along the sea-cliff edge and in gully walls to monitor erosion. Our research at CA-SRI-2 and observations at other key sites demonstrates that marine erosion is often punctuated. At two of our CA-SRI-2 monitoring stations, virtually no change was noted over the course of a year. At a third station, however, roughly 50 cm of the sea cliff had retreated. Coastal erosion can also be

Figure 2. Sea-cliff retreat eroding a shell midden on Santa Rosa Island.

catastrophic, resulting in large landslides and other mass-wasting events. Such massive erosion events are evident in the Cuyler Harbor area where several sites are present on slump blocks in inverted soils about 100 feet below the terrace on which they were deposited. Arnold (2001, p. 34) has also noted the severity of marine erosion at Channel Island archaeological sites. Her research at several coastal villages on Santa Cruz Island revealed an estimated 1–20% loss in site area from marine erosion over about 20 years of observation.

Sea-cliff retreat not only results in the erosion and destruction of the archaeological record, but it can also result in the deposition and introduction of materials from either archaeological sites or natural sources into other archaeological sites. For example, at CA-SRI-95 on Santa Rosa, wave action and tidal surges have destroyed much of the site but are also depositing driftwood and other debris (plastic bottles, metal, etc.) across the site surface. Pinnipeds (seals and sea lions) also frequent this beach, and it is conceivable that the bones of sea mammals and other animals could also be introduced to this site by tidal activity. In 2003, we observed numerous *Olivella* shell fragments, used by the Chumash to make shell beads, at CA-SMI-193 in beach sand recently deposited on the site surface.

Marine erosion is particularly devastating because little can be done to stop it. Marine erosion is both natural and inevitable; therefore, relatively little systematic attention has been paid to mitigating its effects, except in isolated cases (see Erlandson and Moss, 1999). This ignores the fact that coastal erosion often has been exacerbated by human activities, including dam building, jetty or riprap construction, overgrazing, and even sea-level rise induced by global warming. Continuing sea-level rise currently poses a global threat to the coastal archaeological record. Much of the early Channel Island coastal archaeological record (pre-5000 years ago) has probably already been inundated by rising sea levels following the last glacial period (see Fairbanks, 1989; Bard et al., 1990; Porcasi et al., 1999).

We argue that the best strategy to preserve what remains of the near-coast archaeological record is to conduct salvage excavation from eroding portions of archaeological sites. In particular, we suggest that radiocarbon samples be collected from these sites before they are permanently lost (Erlandson and Moss, 1999). Obtaining these materials allows for the collection of basic information that can help reconstruct regional cultural developments and prioritize sites for further data recovery. Further monitoring of erosion at key sites over the years will also help develop more effective strategies to combat this process. Ultimately, when interpreting the archaeological record of sites that have been impacted by marine erosion, it is important to recognize that portions of an archaeological site may have been destroyed, which can alter fundamental conclusions about its size, structure, and function. Lithic scatters, for instance, surround many California shell middens, and some small or low-density lithic sites capping sea cliffs may be the remnants of once-larger shell middens.

Fluvial Processes

Fluvial processes also greatly affect the formation and preservation of Channel Island archaeological sites. Among the more prominent fluvial processes is the erosion of sites by streams and creeks, and sheetwash and runoff from storms. Operating in much the same way as marine erosion, freshwater runoff and stream gradation can easily destroy the archaeological record and result in mass wasting. At CA-SRI-147 in Jolla Vieja Canyon, Santa Rosa Island, three photographs taken of the site in 50-year intervals between 1901 and 2001 illustrate the disturbance of portions of the site (Figure 3). This site contains midden deposits exposed in the arroyo walls that have significantly eroded over the last 100 years. The changes depicted at this site in just a century illustrate the complexity of site formation in this dynamic environment.

Research by Erlandson on San Miguel Island has documented numerous small Early Holocene shell middens. Most of these sites are being dramatically impacted by runoff and sheet wash during storms, which are probably exacerbated by increased rainfall during El Niño and other climatic events. In one case, most of the remnants of a 9000- to 8600-year-old shell midden were lost to sheet wash in two consecutive wet seasons (see Erlandson et al., 2004).

Fluvial processes can also introduce materials into sites, including sediments, floral and faunal remains, and artifacts and ecofacts (e.g., bones, shells, plant remains) from other sites. Mammoth bones have been widely redistributed in alluvial deposits, for example, and some spurious "associations" with archaeological assemblages have resulted. The introduction of materials via fluvial processes is most likely at sites that are located downslope from other sites or at the base of steep cliffs. Again, combating the erosion of archaeological sites by non-marine fluvial processes is a difficult endeavor. In most cases, we recommend obtaining ^{14}C dates and conducting salvage excavation before these sites are permanently lost. On the Channel Islands, revegetation following the removal of domestic livestock is also effectively slowing the erosion of many sites.

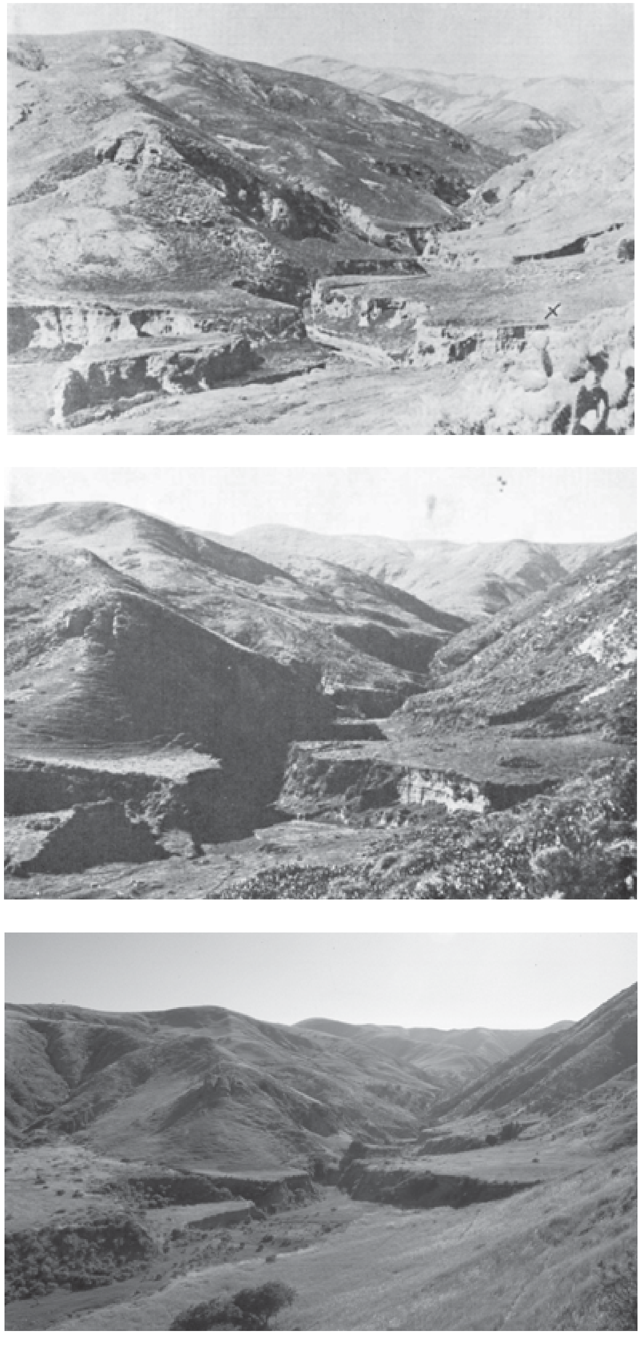

Figure 3. Stream erosion at CA-SRI-147, Jolla Vieja Canyon, Santa Rosa Island over the last century. (a) Photo taken in 1901 by P. Jones. (b) Photo taken in 1951 by P. Orr. (c) Photo taken in 2001 by T. Rick. (Photos (a) and (b) adapted from Orr, 1968., Figure 79, p. 232.)

Eolian Processes

Northwesterly winds batter the Channel Islands, especially on the outer, less sheltered islands (i.e., San Miguel, San Nicolas, and San Clemente). A study of wind speed and gust for San Miguel and Santa Cruz islands, for example, indicates that average monthly wind speeds are as much as three times stronger on San Miguel (Huckins, 1995). Exacerbated by periodic droughts, Channel Island environments are highly susceptible to wind deflation (Johnson, 1980; Rick, 2002; Erlandson et al., 2005). Combined with the loss of much of the island's vegetation by historic overgrazing, wind poses a significant threat to island archaeological sites. In some areas of the islands, there is also deposition of sediments (see Muhs, 1992), which buries sites and may help preserve their contents. On the south coast of San Miguel Island, for example, sites are often buried under a meter or more of sediment—some of which was stripped from the dunes in the northern portions of the island—helping to preserve these sites (Braje et al., 2005). Revegetation is stabilizing many archaeological sites across the Channel Islands, but several large site complexes are still actively eroding. A National Park Service (NPS)-sponsored study by Snethkamp (1984) attempted to stabilize archaeological sites by covering them in vegetation, sandbags, netting, and fabric, which, unfortunately, did not hold up to weathering.

Rick (2002) described the effects of wind on the preservation and distribution of faunal remains at CA-SMI-87 on northern San Miguel Island. At CA-SMI-87, wind erosion has a number of impacts on archaeological materials, including decreased stratigraphic integrity, the loss of all but the heaviest artifacts and ecofacts, the development of a patina or sheen on the surface of artifacts, shells, and bones that obscures their original form, and the movement of constituents around a site. It is often easy to identify deflated archaeological sites, but in some instances, the effects of wind can be quite subtle, necessitating careful evaluation during excavation and laboratory analysis (Rick, 2002). Moreover, because sites are currently capped by vegetation and may be somewhat protected by the wind, this does not mean that they have always been covered. Beyond the obvious presence of deflated archaeological materials, wind disturbances can be documented through the analysis of artifacts and faunal remains for signs of battering or abrasion by windblown particles, or the density of materials left behind.

Argilliturbation

Argilliturbation—soil mixing caused by seasonal shrinking and swelling of clay-rich smectite soils—can significantly alter the original depositional context of archaeological sites (Johnson and Hester, 1972; Wood and Johnson, 1978; Muhs, 1982a, 1982b; Erlandson and Rockwell, 1987). Vertisols are argilliturbated soils that have large vertical cracks and operate primarily in alternating wet and dry climates, similar to the Mediterranean climate regimes of the Channel Islands. Argilliturbation can cause downward movement of archaeological constituents through soil cracks (generally small materials) and the upward movement of site materials during swelling episodes. Argilliturbation can also produce stone pavements that may have little to do with the human occupation of a site (Johnson, 1972, 1989; Wood and Johnson, 1978).

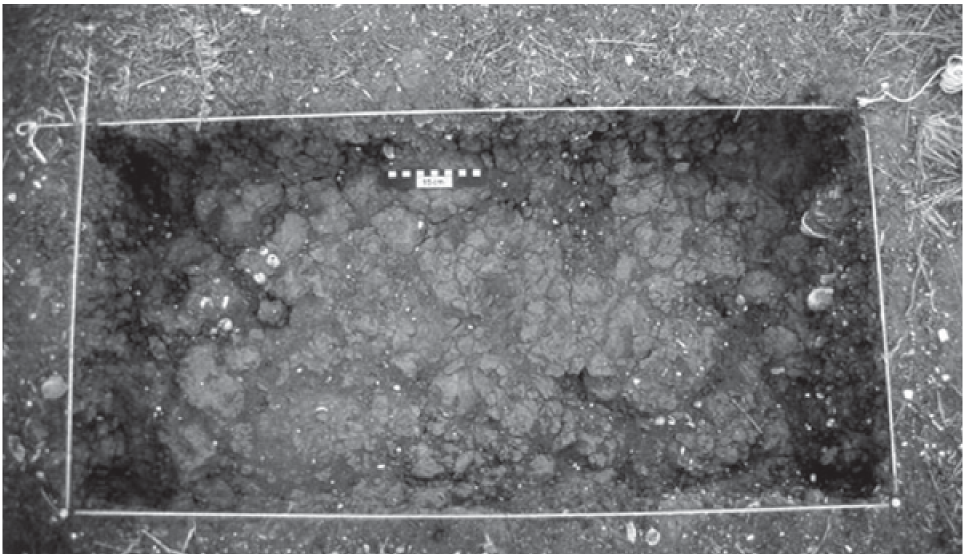

Figure 4. Argilliturbation at CA-SBI-12, Santa Barbara Island (adapted from Rick and Erlandson, 2001, Figure 2, p. 299).

We have identified argilliturbation operating in numerous Channel Island sites. For example, research conducted by Snethkamp and Morris in the 1980s on Santa Barbara Island noted vertisols at virtually every site they observed (Rick and Erlandson, 2001). At CA-SBI-12 on Santa Barbara Island, where Snethkamp described argilliturbation as moderate, soil cracks up to 2.5 cm wide were noted (Figure 4). CA-SBI-12 appears to be a single component site, but in other island sites, argilliturbation can mix materials from strata dated to different periods of time (Erlandson and Rockwell, 1987). At CA-SMI-1, a multicomponent site on San Miguel Island, argilliturbation is also severe with noticeable signs of soil cracking and midden disturbances.

Faunalturbation

The impact of faunalturbation—mixing of soils by animals—has long been recognized by a number of archaeologists working around the world (see Wood and Johnson, 1978). As Butler (1995) illustrates, numerous animals act as agents of geomorphic change, causing erosion, trampling, deposition, and ultimately landscape evolution. From burrowing mammals (gophers, badgers, etc.) to earthworms, Jerusalem crickets, beetles, and other insects, numerous animals burrow and degrade the archaeological record (Stein, 1983; Erlandson, 1984). On the coastal California mainland, burrowing caused by gophers (*Thomomys bottae*) and a number of other animals has heavily impacted the archaeological record, often producing mixed deposits with low chronological resolution and high fragmentation (Erlandson, 1984; Erlandson and Rockwell, 1987; Johnson, 1989; Glassow, 1996, pp. 8–10).

The Channel Islands are largely devoid of the burrowing rodents that plague mainland California archaeological sites, including pocket gophers. However, a number of native and introduced animals that burrow, dig, or disturb deposits exist on the islands (Table II). The impact of these animals on Channel Island sites is limited compared to the mainland, but we have noticed burrowing in archaeological sites on many of the islands. Most of this burrowing appears to be limited in depth, although more severe burrowing or rooting has been done by introduced animals. The high organic content and well-drained soils of many Channel Island shell middens may attract animal burrowers and excavators.

Determining the types of animals responsible for this burrowing is complicated by a variety of factors. Most of the burrows we have observed are relatively small in size (5 cm or less in diameter; Figure 5). A number of organisms use abandoned burrows, making it difficult to determine the animal responsible for burrowing. For example, excavation of a small burrow with a roughly 4-cm diameter hole to a depth of about 25 cm on San Miguel Island uncovered two beetles and a Jerusalem cricket. In other burrows, we have observed island deer mice. Extensive burrowing is also present in vertical midden exposures in island sea cliffs, arroyo cuts, and road exposures where small birds have been noted around burrows. At CA-SMI-470 and CA-SMI-606 on San Miguel Island, bees have been noted burrowing in low-density shell middens. Among the biggest excavators on the Channel Islands is the Island spotted skunk, which digs dens in a variety of substrates (Crooks, 1994). We have shown photos of small burrows to Channel Islands biologists, most of whom suggested that island deer mice and introduced black rats are probably responsible for digging burrows. Unfortunately, relatively little is known about the burrowing habits of either animal (see Collins, 1979; Collins, Storrer, and Rindlaub, 1979). Future live trapping near some of these tailings would help determine the perpetrators, scale, and intensity of such burrowing.

Pinnipeds (seals and sea lions) have also been observed hauling out on archaeological sites, leading to erosion and fragmentation of archaeological deposits. Pinnipeds are most abundant on San Miguel and San Nicolas islands. At CA-SMI-602, a late and protohistoric period village on the Point Bennett pinniped rookery on San Miguel Island (Walker et al., 2002), pinnipeds have severely eroded much of the site. Their use of the site for hauling out, along with coastal and eolian erosion, has caused severe destruction of the site deposits and exposed domestic features and human burials.

One of the greatest impacts to island sites is the digging, trampling, and other activities of introduced animals. At least 19 mammals, primarily large herbivores, have been introduced to the islands (Table III). The grazing and browsing behavior of cattle, pigs, sheep, goats, horses, deer, elk, and bison denudes the islands of much of their vegetation, resulting in widespread erosion of island soils and archaeological materials. Through the efforts of Channel Islands National Park, the U.S. Navy, the Nature Conservancy, and other groups, most of the introduced mammals have been removed from the islands (except Santa Catalina). A number of studies have documented the impact of introduced animals on island environments and native animal populations (e.g., Schwartz, 1994; McChesney and Tershy, 1998; Roemer et al., 2002), but comparatively few have systematically assessed their impact on island archaeology (but see Arnold, 2001, p. 33).

Table II. Select native animals that burrow or disturb Channel Islands archaeological sites.

Taxon	Distribution[a,b]	Potential impact on archaeology	Reference
		Land and sea birds	
Athene cunicularia (Burrowing owl)	All	Some secondary excavation of existing holes	Howell (1917); Schoenherr et al. (1999); Alsop (2001); Jones and Collins (2006)
Cerorhinca monocerata (Rhinoceros auklet)	SM	Burrowing and excavation	Howell (1917); Alsop (2001); Jones and Collins (2006)
Larus spp. (Gulls)	All	Roosting, stomping, and vegetation disturbance lead to erosion	Howell (1917); Alsop (2001); Jones and Collins (2006)
Pelecanus occidentalis (Brown pelican)	All	Roosting and vegetation disturbance cause erosion	Howell (1917); Alsop (2001); Jones and Collins (2006)
Ptychoramphus aleuticus (Cassin's auklet)	SB, A, SC, SM	Extensive burrowing and excavation	Howell (1917); Alsop (2001); Jones and Collins (2006)
		Land mammals	
Peromyscus maniculatus (Island deer mouse)	All	Burrowing, mixing, erosion	Collins et al. (1979, p. 11.54)
Spermophilus beecheyi (Catalina Island Ground Squirrel)	C	Burrowing, mixing, erosion	Schoenherr et al. (1999)
Spilogale gracilis amphialus (Island spotted skunk)	SC, SR	Den excavation, burrowing, mixing, introduce/remove materials	Crooks (1994)
Urocyon littoralis (Island fox)	C, SC, SCL, SM, SN, SR	Den excavation, burrowing, mixing, introduce/remove materials	Laughrin (1973)
		Marine mammals	
Phocidae/Otaridae (Seals and sea lions)	All	Haul out/erode sites, fragmentation, introduce materials	Schoenherr et al. (1999)
		Insects	
Cnemotettix spp. (Silk-spinning crickets)	A, SM, SC, SR, C	Burrows	Schoenherr et al (1999)
Coelus pacificus (Island dune beetle)	All?	Burrows in sand dunes	Schoenherr et al. (1999)
Okanagana hisuta (Cicada)	A, SC, SR	Burrows	Schoenherr et al. (1999)
Stenopelmatus spp. (Jerusalem cricket)	All?	Burrows	Schoenherr et al. (1999)

Note. A = Anacapa, C = Catalina, SB = Santa Barbara, SC = Santa Cruz, SCL = San Clemente, SM = San Miguel, SN = San Nicolas, SR = Santa Rosa.
[a]Distribution data obtained from: Schoenherr et al., (1999); Jones and Collins, (2005); and sources cited therein.
[b]Many bird distributions have changed historically and are often heavily seasonal. The data we provide are the current best estimate. Anything noted with a ? means that we found limited distribution data for that species.

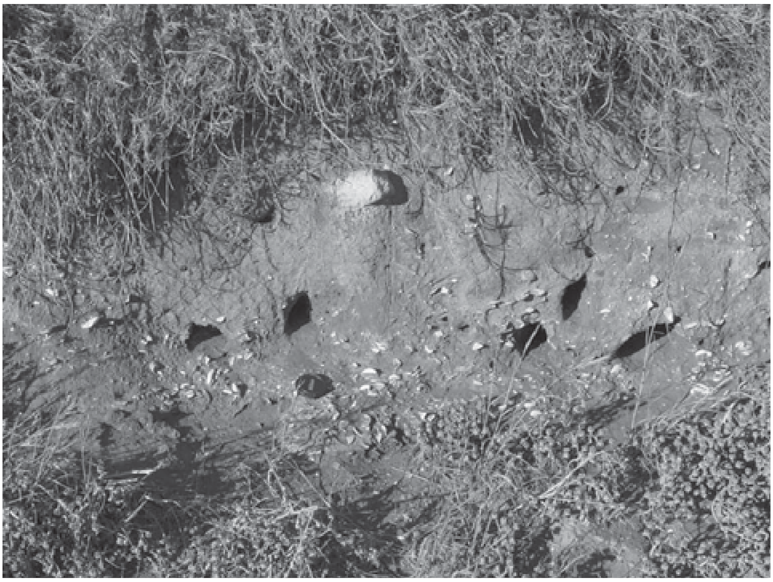

Figure 5. Animal burrows (possibly made by a deer mouse) in vertical midden exposure in roadcut at CA-SRI-77, Santa Rosa Island (note camera lens cap for scale).

Trampling and wallowing are among the most prominent destructive activities of introduced herbivores. Kennett (1998, pp. 263–265) suggested that some cattle wallows may have been misinterpreted as Chumash housepits by early scholars. On Santa Cruz Island, feral pigs root and dig in numerous sites causing widespread mixing and displacement of archaeological materials (Arnold, 2001, p. 33). The black rat, probably introduced to San Miguel, Anacapa, and San Clemente by 19th- and 20th-century shipwrecks, poses a significant threat to many of the bird species on the islands (Collins, 1979; McChesney and Tershey, 1998) and appears to disturb island archaeological sites. Much of the burrowing we have attributed to rats, however, appears to be limited largely to the upper 20 cm of site deposits.

Animal Transporters

Erlandson and Moss (2001) demonstrated that a wide variety of animals can deposit the remains of aquatic organisms. This appears to be particularly problematic in caves and rockshelters commonly used by these animals. At Daisy Cave on San Miguel Island, for example, a probable cormorant roost located in the cave contained hundreds of otoliths and other fish bones from taxa similar to those found in the cave's archaeological deposits (Erlandson and Moss, 2001, p. 419). The remains from the cormorant roost were heavily weathered and relatively easy to distinguish from the archaeological materials, but the presence of unmodified rodent bones, lizard bones, and land-snail shells in these deposits has also been interpreted as the

Table III. Introduced mammals and their impact on Channel Islands archaeology.[a]

Taxon	Common name	Distribution	Impact on archaeology
Antelope cervicapra	Black buck antelope	C	Vegetation stripping, trampling, rooting
Bison bison	American bison	C	Vegetation stripping, trampling, rooting
Bos taurus	Cattle	C, SC, SCL*, SM*, SR*	Vegetation stripping, trampling, rooting
Canis familiaris	Domestic dog	C, SC, SCL, SN*, SR	Digging, trampling, introducing materials
Capra hircus	Goats	C, SCL*, SB*	Vegetation stripping, trampling, rooting
Cervus elaphus	Wapiti	SR	Vegetation stripping, trampling, rooting
Equus asinus	Donkey	C, SB*, SC, SR, SM*	Vegetation stripping, trampling, rooting
Equus caballus	Horse	C, SB*, SC, SR, SM*	Vegetation stripping, trampling, rooting
Felis domesticus	House cat	C, SB*, SCL, SM*, SN, SR	Introducing materials
Lepus europaeus	European hare	A*	Burrowing, vegetation stripping
Microtus californicus	Meadow mouse	SCL	Burrowing
Mus musculus	House mouse	C, SCL	Burrowing
Odocoileus hemionus	Mule deer	C, SCL*, SR	Vegetation stripping, trampling, rooting
Oryctolagus cuniculus	European rabbit	SB*	Burrowing, vegetation stripping
Ovis aries	Sheep	A*, SB*, SC*, SCL*, SM*, SN*	Overgrazing, trampling, rooting
Rattus norvegicus	Norway rat	C	Burrowing
Rattus rattus	Black rat	A*, C, SCL, SM	Burrowing
Reithrodontomys megalotis	Harvest mouse	SCL	Burrowing
Sus scrofa	Wild pig	C, SC, SCL*, SR*	Vegetation stripping, trampling, rooting

Note. A = Anacapa, C = Catalina, SB = Santa Barbara, SC = Santa Cruz, SCL = San Clemente, SM = San Miguel, SN = San Nicolas, SR = Santa Rosa.
* Indicates animals that have been removed. Removal of black rat from Anacapa Island is in process.
[a]Distribution and removal data obtained from Schoenherr et al. (1999).

result of natural rather than cultural deposition. Finally, although Guthrie (1980) attributed numerous cormorant bones found at Daisy Cave to human hunting, we found the site littered with cormorant nests and carcasses during an El Niño event that devastated the colony that nests there.

In open-air contexts, animals may also transport materials to sites and be integrated into archaeological deposits. Interestingly, the distribution of mice, lizards, and other small animals is relatively uncommon in open-air sites. During the investigation of Early Holocene sites on Santa Rosa and San Miguel, rodent and lizard bone were common in cave sites and in a 9300-year-old component at CA-SRI-6, an open-air site (Erlandson et al., 1999). In roughly four other open-air Early Holocene middens, however, only trace amounts of rodent and lizard bone have been identified. They are also relatively rare in island shell middens of Middle and Late Holocene age. The abundance of these animals in sites relates to a variety of factors, including the extent of human occupation, available area for roosting, etc. Where human occupation appears to have been relatively intense (e.g., large villages), the deposition of faunal remains by animals is probably lower than at other sites where occupation may have been brief, at least in relation to the large amounts of cultural debris.

We have also recently observed dead birds (sea gulls, cormorants, etc.), island foxes, mice, rats, and marine shells in various stages of decay at island archaeological sites. Over time, some of these remains will become integrated into the cultural deposits. Careful analysis of bones for signs of modification (cut marks, burning, etc.) and weathering can help distinguish between natural and cultural deposition of faunal assemblages. Studies of element distribution and bone density can also elucidate these processes (see Stewart, 1991; Butler and Chatters, 1994). Evidence for digestive traces on the bones may help determine if they were deposited as animal stomach contents, but it is often difficult to determine differences in the digestive traces of humans and other animals (Butler and Schroeder, 1998). The upper-site deposits have the greatest probability of containing minerals from noncultural activities.

Analysis of shellfish, bird, fish, and mammal remains from a historic bald-eagle nest on San Miguel Island also provides important information on the types of materials that can be incorporated into Channel Island archaeological sites by animals (Erlandson et al., 2003). This bald-eagle nest is located within the recorded boundaries of an archaeological site, and a flake, asphaltum, and sea grass were recovered from the nest complex during excavation (Erlandson et al., 2003). The shellfish, fish, bird, and mammal bones recovered from the midden in many ways mirror the types of materials found in archaeological sites, and in the absence of a large nest, could easily be interpreted as the result of human, rather than animal, deposition of materials (Collins et al., 2005).

Finally, a preliminary experiment suggests that mice may play an important role in determining what organic materials are preserved at Channel Island archaeological sites. After noting that mice ate or destroyed a variety of organic materials (leather, felt, plastic, etc.) left at Daisy Cave, we left a sample of fibers (human hair, leather, raffia, yucca, and sea grass) tied to a board at the site. When we returned several months later, only the sea grass remained. Hundreds of woven sea-grass artifacts have been recovered from the site, but the only basketry from other materials (tule) had been intentionally buried as part of an artifact cache.

Floralturbation

Floralturbation is the mixing of soils caused by the growth and decay of plants, which often form root casts or bring materials to the surface when a tree or other plant overturns (Wood and Johnson, 1978). Given the relative dearth of large trees on the Channel Islands, most of the impacts of plant growth and decay on archaeological deposits are subtle. Roots penetrating through surfaces can etch bones, shells, and artifacts (see Lyman, 1994), and even move archaeological constituents. Like many of the previously described processes, floralturbation is most severe in the upper portions of site deposits where root and plant growth is most dense.

Photos of CA-SRI-141 (see Figure 3) also illustrate vegetation change on the site, including growth and retreat of prickly pear and grassland. These vegetation changes also have impacts on the preservation and stabilization of archaeological deposits. While plant growth and decay can disturb archaeological sites, ground cover by plants has an important role in stabilizing site constituents from erosion by wind, water, and other processes (Rick, 2002). Further research into the effects of plant growth and decay on Channel Island archaeological sites will help determine the extent and scope of this process.

Fire

Periodic fires can have a devastating effect on archaeological sites. On the Channel Islands, wildfires can result in vegetation stripping, which exposes underlying soils and archaeological deposits to deflation and erosion. Moreover, fires can also disturb the surface archaeological record by burning constituents and possibly even destroying some materials. Numerous localized red stains, some loosely associated with the remains of pygmy mammoths and stone tools found on Santa Rosa Island, were argued by Orr and Berger (see Orr, 1968) to be prehistoric "mammoth roasting pits." In some instances, including a poorly documented locality at Running Springs on San Miguel Island, mammoth bones show clear evidence of burning. Research by Glassow (1980), Cushing et al. (1984, 1986), Wendorf (1982), and others has suggested that these associations are probably the result of overturned burning trees or chemical changes in the soil rather than human cooking of mammoth remains.

Ancient Human Disturbances

Human-induced disturbances to archaeological sites are among the most severe impacts on the Channel Islands. The activities of ancient people who occupied the same area as older archaeological sites often had a profound postdepositional impact on the location, preservation, and disturbance of the older site. As Erlandson and Rockwell (1987) noted, the excavation of housepits, storage pits, graves, and other holes often disturbed and mixed older archaeological deposits and caused stratigraphic reversals. Human use of previously occupied areas can also lead to fragmentation of the archaeological constituents. It is also likely that people reused artifacts from old sites (Erlandson, 1994). Such curation of artifacts as curios is often difficult to detect in the archaeological record. Through radiocarbon dating of shell and perishable artifacts, it is often possible to highlight curation behavior (Rick et al., 2005), but even in these cases, it is difficult to determine the origin of the artifacts. Many large sites of the Late and Middle Holocene, with huge accumulations of cultural debris, may also obscure the generally smaller sites occupied by Early Holocene peoples.

Historical Impacts

The most recognizable impacts on Channel Island archaeological sites are caused by historical disturbances. These include construction activities, plowing and other agricultural activities, road cutting and vehicle traffic, looting, introduction of exotic plants and animals, military actions, the work of early antiquarians or archaeologists, and other activities. The direct impacts of building, airfield, and road construction are especially severe. Numerous extant and historic roads on the islands cut directly across or through sites, causing redeposition, erosion, and fragmentation of archaeological materials. Historical dwellings also exist on top of, or adjacent to, archaeological sites, illustrating further disturbance and incorporation of materials not associated with the original occupation of the site. Agricultural activities have also impacted island archaeology, including mixing and fragmentation of constituents. Rozaire (1978, pp. 7, 9) briefly described these processes at CA-SBI-9 on Santa Barbara Island. Looting and unfilled excavation units also cause heavy erosion of some island sites. For example, at CA-SRI-2 on Santa Rosa Island, an unfilled 8 × 100 foot trench excavated by Orr in 1952 has caused severe slumping and erosion of site deposits.

Prior to federal legislation protecting archaeological sites, the U.S. military caused unmitigated disturbances to island archaeological sites through construction, military activities, and periodic bombing. These effects are most pronounced on San Clemente and San Nicolas, but sites on San Miguel, Santa Cruz, and Santa Rosa have also been impacted by military activities. Eel Point (CA-SCLI-43B) on San Clemente Island has a trans-Holocene occupation with one of the earliest-dated coastal occupations in North America (see Salls, 1991; Raab and Yatsko, 1992). The intact portions of this site have excellent stratigraphic integrity and preservation (Salls, 1991, p. 63; Porcasi et al., 2000, p. 203), but other areas have been impacted by military foxholes (Axford, 1981), marine erosion, and the effects of successive cultural occupations.

DISCUSSION AND CONCLUSIONS

Despite the generally good preservation of the Channel Islands archaeological record, our survey of taphonomic processes operating on island sites illustrates that numerous cultural and natural processes are actively degrading the regional archaeological record. Many of the agents described above work in concert with one another, creating dynamic environments that are constantly reshaped and altered. As with archaeologists working anywhere in the world, Channel Islands archaeologists should establish frameworks for investigating such problems on a variety of scales. Although archaeologists have worked on the Channel Islands for over a century, our survey of taphonomic processes is the first to detail the impact of a variety of natural and cultural agents on the regional archaeological record.

On the Channel Islands, several major processes significantly affect the archaeological record. These include natural processes, such as marine and stream erosion, slope wash, eolian disturbances, argilliturbation, and bioturbation, as well as cultural processes, such as ancient and historical landscape modifications, construction activities, and the introduction of exotic species. Despite the effects of these various agents, the Channel Islands contain a remarkable archaeological record, with thousands of finely stratified archaeological sites with excellent integrity. These sites often provide one of the few resources for understanding long-term cultural changes in coastal California with high precision and chronological resolution. Nonetheless, researchers on the Channel Islands (and elsewhere) should be cautious in interpreting archaeological materials during field and laboratory work, and cognizant of the many processes that can affect the materials we study. Identifying some of these processes can also be difficult (or impossible) when small excavation techniques (augers, shovel test pits [STPs], or small pits) are used. Moreover, detailed studies of a single process or groups of processes affecting a single site are needed to expand on, and enhance, the regional survey provided here.

The dearth of research on formation and taphonomic processes on the Channel Islands may lead to unwarranted confidence in interpretations of cultural and environmental changes. A classic example of how taphonomic studies have improved our interpretations of Channel Islands archaeology is Orr's (1968) ardent assertion that he had identified associations of human artifacts or agency with Pleistocene fauna, including pygmy mammoth remains dating to more than 40,000 years. Careful taphonomic studies of Orr's evidence suggests, however, that his fire areas were natural features caused by burning trees or chemical interactions in the soils (see Glassow, 1980; Cushing et al., 1984, 1986) and that other spatial associations were actually in secondary erosional exposures. Recent analysis of a bald eagle nest on Santa Rosa Island has also demonstrated that eagles transported large abalone shells and other marine fauna found in archaeological sites to their nests (Erlandson et al., 2003; Collins et al., 2005). Orr (1968) argued that only humans could have transported large abalone shells to inland areas of the islands.

A less widely known example concerns the effects of argilliturbation at CA-SMI-1. Soil cracking at this multicomponent site has probably mixed deposits of Early, Middle, and Late Holocene age (Erlandson, 1991). Hildebrandt and Jones (1992, pp. 386–387), however, used the faunal data from this site to argue for marine mammal overhunting through time. Because of the high probability of stratigraphic mixing at this site, without direct dating of some of these bones, the chronology of marine mammal overhunting remains very much in question. Rick's (2002) hypothesis that declines in fish bones at CA-SMI-87 were caused by partial wind deflation rather than human overhunting is another example of taphonomic research improving interpretations of Channel Islands archaeology. Kennett (1998, pp. 263–265) has also suggested that several "pit features" described by Orr (1968) as prehistoric housepits are actually the result of historic cow wallows.

We are not suggesting that these and other examples should force archaeologists to assume that Channel Islands sites are poorly preserved. However, they demonstrate that researchers need to actively conduct taphonomic and geoarchaeological research on the islands and all areas of the world. Without adequate descriptions of site-specific and regional taphonomic and formation processes, archaeological interpretations are greatly impaired.

There is considerable overlap between the processes impacting sites on various Channel Islands. For example, marine and freshwater erosion, eolian processes, animal transporters, floralturbation, and other processes affect all of the Channel Islands. However, the degree to which each of these processes affects a single site or area of a site will vary. Some sites with relatively rapid deposition may be less impacted by animal transporters and other processes. When sites are sealed rapidly through the deposition of materials by the site occupants, or alluviation and other natural processes, they are generally less susceptible to these impacts. The effects of most of these processes (e.g., marine and creek erosion) will relate heavily to the location of the site. The variability of disturbance processes affecting a single site underscores the importance of understanding formation processes on a variety of scales (site, region, etc.).

Some of the most apparent disturbances to the archaeological record are caused by historical impacts. The construction of houses, roads, and the introduction of exotic plants and animals has rapidly transformed island ecosystems and greatly impacted island archaeology. Most of the Channel Islands are currently recovering from historical impacts. During the last 25 years or so, for instance, much of San Miguel Island has gradually revegetated. The results are a landscape where vegetation cover is much denser than historically recorded and where island soils and archaeological sites are stabilizing. These changes will be even more dramatic in the years and decades to come, changing perceptions of island environments and the place of people within the Channel Islands landscape.

The Channel Islands example demonstrates several important issues for researchers working on islands and other areas of the world where relatively limited attention has been given to formation processes and taphonomy. Our study builds on larger global overviews provided by Wood and Johnson (1978), Schiffer (1987), and others by illustrating the importance of regional analyses and syntheses. It is important for researchers to continue to study taphonomic and formation processes on single sites, but these can be augmented or guided by regional taphonomic overviews and analyses. As we demonstrated for the Channel Islands, such studies are effective for highlighting the major agents responsible for the formation and disturbance of the archaeological record. These overviews are also effective management and research tools that can document areas where studies that are more detailed are needed, where salvage excavation should be conducted, and how the archaeological record can be better preserved and interpreted.

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