The merging of archaeological evidence and marine turtle ecology: A case study approach to the importance of including archaeological data in marine science

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Introduction

In "ecology through time" Jackson et al. (2001:561–748) highlight the importance of including paleoecological, archaeological and historical data in ecological research. The authors note that few modern ecological studies consider the former abundance of large marine vertebrates, and focus instead on local field studies, lasting only a few years, without including a long-term historical perspective. An historical perspective would help clarify both the underlying causes and rates of ecological change, but also the theory that ecological extinction caused by overfishing precedes all other anthropogenic disturbances to coastal ecosystems. Archaeological evidence is also required to encompass the full life histories of many important species and to document environmental disturbances such as tsunamis and cyclones, geologic events such as uplift and subsidence, and prehistoric overfishing (Jackson et al. 2001:561).

In this paper I present the results of an initial examination of archaeological evidence from the Pacific Islands regarding the marine turtle, a vertebrate with a very long history of high cultural — often spiritual — significance. I look specifically at prehistoric Pacific Islander use of and impact on marine turtle populations. I present information collected from marine turtle remains in archaeological faunal assemblages that indicate presence / absence, abundance, and decline in numbers of marine turtles. And in one case, possible evidence for the implementation of conservation measures regarding marine turtles is described. In the first section, archaeological evidence from the case studies is presented. In the second I discuss the significance of this evidence in demonstrating a trend of overfishing by the initial colonisers of several Pacific Islands that led to the rapid initial decimation of marine turtle populations. I conclude that:

- marine turtle populations were extremely vulnerable and easily depleted;
- the affected populations did not recover to pre-contact states;
- those effects may be related to the ratio of human population to marine resource base; and
- the inclusion of prehistoric evidence indeed reinforces the theory that ecological extinction caused by overfishing precedes all other anthropogenic disturbances to coastal ecosystems.

The archaeological evidence

In this section I present evidence from the archeological record of the relationship between marine turtles and prehistoric Pacific Islanders. The islands discussed are Niuatoputapu, Tikopia, Tongatapu, Tahuata, and Utrõk Atoll.

Niuatoputapu, a Tongan outlier

The evidence for the Polynesian island of Niuatoputapu, an outlier of the Tongan archipelago, has been well documented by Kirch (1988:1–287). Niuatoputapu is a high island with an extensive system of pristine reef flats, barrier reefs, and lagoons. It is located at the edge of the Tonga Trench and is being upthrust as the Pacific plate slides under the Fiji plate. This uplift has resulted in a 312 per cent increase in land area and a 50 per cent decrease in reef and lagoon habitat. The land area of the island at the time of settlement was 4.9 km^2 and is now 15.2 km^2.

The settlement sequence of Niuatoputapu has been delineated into four phases: Phase I, the Lolokoka Phase (1400 / 1200–500 B.C.); Phase II, the Pome'e Phase (500 B.C.–A.D. 800); Phase III, the Niutoua Phase (A.D. 800–1550); Phase IV, and the Houmafakalele Phase (A.D. 1550–1830). At the time of initial occupation, the island had high numbers of marine turtles and colonists relied for subsistence on the intensive exploitation of the rich marine resources. During this phase, the targeted marine species suffered significant population reductions owing to regular exploitation

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(Kirch 1988:241). Phase II showed a clear reduction in marine resources — although turtle was well represented in this phase, it was below that of the early phase. Kirch (1988:242) suggests that this reduction reflects a decline in marine resources owing to continual human predation.

By Phase III, tectonic uplift had resulted in the progradation of the leeward shoreline and the emergence of broad reef and lagoon flats in portions of the island. This uplift eliminated extensive areas of reef and lagoon habitat. The archeological record reflects both this elimination of inshore habitat and continued human predation, as remains of marine resources, including marine turtle, decline substantially in this phase (Kirch 1988:243). Phase IV marks the boundary between prehistory and history, A.D. 1550–1830.

Kirch (1988:221) documented osseous carapace and plastron fragments, limbs, and cranial fragments of marine turtle. He found a reduction over time in the distribution of turtle bone as follows: from the early site, NT-90, Kirch found a density of 1.39 bones m^{-2}; at the slightly later site, NT-100, 0.53 bones m^{-2} and at site NT-93, 0.27 bones m^{-2}. The sharp reduction in turtle from the initial colonisation NT-90 site suggested to Kirch (1988:221) a sizeable nesting colony of marine turtles and a corresponding initial situation of high resource abundance for the first settlers that was quickly depleted.

Tikopia, a Polynesian outlier

Kirch and Yen (1982:1–396) documented archeological evidence for the Polynesian outlier of Tikopia. Tikopia is a small, isolated, high island surrounded by a fringing reef. The island experiences shoreline progradation from tectonic uplift and especially from the transport of material across the reef flats during cyclones and storms. Kirch and Yen (1982:325) found stratigraphic evidence of prehistoric peoples adding to this shoreline aggradation by initiating and intensifying erosion through the use of fire in forest clearance. At the time of settlement, the land area of Tikopia was 38 per cent less than at present, and the area of exploitable reef habitat was 70 per cent greater.

The settlement sequence of Tikopia has been delineated into three phases: Phase I, the Kiki Phase (900–100 B.C); Phase II, the Sinapupu Phase (100 B.C.–A.D. 1200); and Phase III, the Tuakamali Phase (A.D. 1200–1800). During initial occupation there existed a deep bay, open to the sea across a broad reef flat, and there was a heavy reliance on the abundant marine resources (Kirch and Yen 1982:106, 325). The authors suggest that this occupation marks the initial colonisation of a previously uninhabited ecosystem, citing the great abundance of turtle bone and the abundance of and large size of mollusks as indicating that the marine resources had not previously experienced intensive predation. The impact of these initial settlers on the marine turtle resources of the area was the virtual decimation of the turtle populations (Kirch and Yen 1982:327).

Phase II is characterised by the complete absence of turtle remains as well as those of sharks and rays (Kirch and Yen 1982:329–330). Phase III is characterised by substantial aggradation of the island’s shoreline, expansion of the north and north-western coasts and the transformation of the deep saltwater bay to a brackish lake (Kirch and Yen 1982:333).

Kirch and Yen (1982:284–285) document a reduction over time in the distribution of turtle bone. The initial colonisation TK-4 site had a dense concentration of turtle bones, at 59.2 m^{-3}. There followed a sharp reduction (to 14.5 and then to 10.0 m^{-3}) and the complete absence of turtle remains in the succeeding phase II deposits. Finally, there occured an increase from 0.0 to 1.1 to 5.3 bones m^{-3} in the later phase III deposits. The later concentrations of turtle remains corresponded to contemporary data at the time of the study. Kirch and Yen (1982:284–285) suggest that the sharp reduction in turtle remains from the initial colonisation TK-4 site is the result of intense exploitation of a large nesting population, but they further suggest that the abrupt total absence of turtle remains in the Phase II deposits was more likely related to *tapu* restrictions. Kirch and Yen (1982:356–358) suggest that the combined absence of sharks, rays, and turtles for 1000 years during phase II and their reappearance in phase III is unlikely to reflect simultaneous local extinction of such a wide range of species adapted to both shallow and deep waters. They suggest that food prohibitions (*tapu)* that class turtles, and especially sharks, as inedible for having spiritual or totemic value were likely responsible.

Tongatapu, Kingdom of Tonga

The third case study presents the archeological evidence documented by Spennemann (1987:81–96) in a study he conducted on mollusc shell samples excavated by Poulsen (1967, in Spennemann 1987) on the island of Tongatapu, as well as evidence documented by Burley et al. (2001) conducted a re-excavation and assessment of the Nukuleka and Ha‘ateiho sites in Fanga ‘Uta Lagoon on Tongatapu, and a survey of the Lapita-age paleoshoreline of the lagoon. The largest Tongan island, Tongatapu is a flat coral limestone island with a shallow lagoon with no passages, fringing coral reef on three sides, and a patch reef on the other. Like Niuatoputapu and Tikopia, the environment of Tongatapu has undergone natural changes since initial settlement. Owing to a fall in sea level, part of the lagoon became brackish, and it became smaller compared to its size at time of initial occupation (Spennemann 1987:82–83).

The settlement sequence of Tongatapu has been delineated into three phases: early, middle and late. Arriving at a large protected bay around 1500–1300 B.C., the initial colonists of Tongatapu spread outward to eventually establish a continuous distribution of sites around the Fanga ‘Uta Lagoon shoreline (Spennemann 1987:82–83; Burley et al. 2001:103).

According to Spennemann (1987:82–83), middens from the early phase sites demonstrate that the initial occupants relied heavily on lagoon and reef resources such as molluscs, marine turtles and fish. Based on a systematic collection of column samples (50 x 50 cm) from the northern and southern excavation units of Ha‘ateiho, Burley et al. (2001) found that early phase faunal collections contained a relative abundance of marine turtle that were “less abundant or absent in the upper strata” (Burley et al. 2001:100–102). The authors suggest that the initial colonisers at Ha‘ateiho were exploiting the natural resources “to their maximum capacity” with an intensity that had an immediate negative impact on the surrounding environment. They conclude that the short-term consequences of human settlement were numerous extinction events and probable depletions in “even the most abundant” resources (Burley et al. 2001:100–103).

Tahuata, Marquesas

Rolett (1998) presents the archaeological evidence of Hanamiai, a prehistoric settlement on the island of Tahuata, in the southern Marquesas. Tahuata is a high island with no coastal plain, no lagoons and virtually no coral reefs. This lack of reefs distinguishes Tahuata, and the rest of the Marquesas, from other Polynesian islands (Rolett 1998:20–21).

Rolett suggests that the initial inhabitants relied heavily on wild foods, as shown by the abundance of ground-nesting seabirds, flightless landbirds, and a greater frequency of turtle and porpoise-sized whale remains than either dogs or pigs. Rolett suggests that the marine turtle population at Hanamiai was depleted during initial colonisation. Deposits in the initial phase (3.1% of total NISP) were more than twice those in any other phase (Rolett 1998:103).

Utrõk Atoll, Northern Marshall Islands

Weisler (2001) conducted an archeological study at Utrõk Atoll, near the northern limit of permanently inhabited atolls in the Marshall Islands. Based on radiocarbon age determinations and physical characteristics of the islets, Weisler suggests that Utrõk islet was colonised first and the smaller islets only visited during the earliest period of colonisation. The less inhabitable islets, including Allok and Bikrak, have cultural stratigraphy that suggests only periodic, short-term visits.

A total of 13,545 bones were collected, including those identifiable only to vertebrate (0.9%) and bones of marine turtle (0.7%) (Weisler 2001:124). Using the identified bones that were spatially associated with the unidentified vertebrate bones as reference, Weisler (2001:126) believes that the unidentifiable specimens are most likely those of human, marine turtle and large fish. He also believes that many, if not all, of the 98 marine turtle remains (77 from site 1, 21 from site 5) are probably those of the green turtle (*Chelonia mydas*), which still nests on several of the islets of Utrõk Atoll. Approximately 79 per cent of all turtle remains were recovered from nine units at site 1. Several bones were associated with an 890 ± 50 age determination (Beta-103908), whereas others were recovered from the upper spits of TP 15 and 21 (Weisler 2001:126). This suggests to Weisler (2001:130) that turtle was consumed over a 1000-year period without decimating the stocks — “that is, there is not a declining frequency of turtle bones from throughout the cultural layers.”

Discussion

What is the significance of the evidence described above in demonstrating a trend in the use of and impact on marine turtle populations by prehistoric Pacific Islanders? In Table 1, I present a summary of the impact on marine turtles that the faunal remains contained in the archaeological record suggested to the archaeologists involved.

A clear trend is suggested. In each of the first four cases, the archeologists involved suggest that marine turtle populations were decimated during the initial occupation phase, owing to intense human predation. In the fifth case, Weisler (2001:130) suggests that turtle was consumed over a 1000-year period without decimating the stocks. However, Weisler (2001:129) also notes: “As marine resources were depleted near the main villages on Utrõk and Aon, the smaller islets would have provided campsites for staging forays along the adjacent reefs or conducting fishing sorties beyond the oceanside coast, progressively farther

Table 1. Reduction of marine turtle remains by case.

	Impact on marine turtles suggested by author(s)
Niuatoputapu	Initial decimation from heavy initial exploitation and continued reduction in numbers over time of a nesting colony.
Tikopia	Initial decimation from heavy initial exploitation, followed by absence of remains owing to *tapu* restrictions for 1000 years, followed by resumed exploitation of a nesting colony.
Tongatapu	Initial decimation from heavy initial exploitation and continued reduction in numbers over time.
Tahuata	Initial decimation from heavy initial exploitation and continued reduction in numbers over time.
Utrõk Atoll	Turtle consumed over a 1000-year period without decimating the stocks.

from the main settlements." This may indicate that the consistency he perceives in marine turtle consumption may be related to the relationship between a small human population and a large marine resource base. In contrast to the other high volcanic and raised limestone islands, atoll environments have a uniquely high ratio of reef to land area. Utrõk Atoll is no exception. Utrõk Atoll, with a land area of only 2.4 km^2, has a 57.7 km^2 lagoon, and 86.7 km^2 of ocean and lagoon side reefs. The extremely small estimated population density (Weisler 2001:131) coupled with that huge expanse of lagoon and oceanside reef habitat makes it likely that prehistoric inhabitants of the atolls never needed to overuse their marine resource base. In addition, fishing forays to other islets would have increased their resource base beyond what the land-limited population could affect. Weisler (2001:111) presents ethnographic evidence for these types of fishing expeditions for marine turtle when he discusses the two atolls farther north, Bokak (Toangi) and Pikaar, which "were not inhabited year-round in prehistory but, today, are visited occasionally to harvest sea birds and turtles."

In the second case study, Kirch and Yen (1982:356–358) suggest that food prohibitions (*tapu)* that class turtles as inedible for having spiritual or totemic value were likely responsible for the complete absence of turtle remains for a 1000 years during phase II. Might this be archaeological evidence for the implementation of indigenous conservation measures regarding marine turtle? According Firth study (1967) of Tikopia rituals, turtles were *tapu* to all but the people who claimed it as their totem, the Fangarere. The Fangarere could eat them, whereas others regarded the marine turtle as disgusting and believed that should they eat it, "they will vomit" (Firth 1967:256, 362).

The Tikopia case perhaps also provides a natural experiment on the vulnerability of marine turtle to even limited prehistoric overfishing. But there are problems with the authors' evaluation of the turtle faunal data as a ratio of the amount of sediment excavated: deposition clearly varies but does subsistence change in conjunction with it? If Kirch and Yen are correct that for a 1000-year period the take of marine turtle was severely limited by a *tapu*, there appears to have been no recovery of the population by the end of that period. The initial concentration of turtle bones (59.2 bones m^{-3}) was never approached in the later deposits. Even the level of exploitation shown at the end of the Phase I deposits (10.0 bones m^{-3}) was twice that found in later deposits. The highest concentration found, once exploitation resumed, was 5.3 bones m^{-3} in the late phase III deposits, which corresponded to contemporary data at the time of the study, 200 years later. This could possibly be confirmed from the archaeological record of Firth's ethnographic information, and therefore points to the period when turtle exploitation solely by the Fangarere began. Regardless of that, this is exactly the type of necessary information Jackson et al. (2001) were speaking of when they talk of the importance of including archaeological information to truly understand the life history of many marine vertebrates.

There is an interesting relationship between the Tikopia case and the contemporary impact of overfishing on particularly vulnerable marine species — those that take a long time to reach sexual maturity, like the marine turtle. Several studies conducted along the Great Barrier Reef demonstrated that all marine turtle populations heavily exploited during historic times rapidly collapsed, and all failed to regain more than a small fraction of their former abundance (Neil 1998; Jones 1980; Ganter 1994; in Jackson et al. 2001). But in those studies, the authors were discussing periods of only a few hundred years. The archaeological data presented by the studies cited in this article a much longer timeframe, and demonstrates the failure of some marine species to *ever* recover from even limited overfishing.

It would be remiss not to mention the limitations of the studies used here. In choosing survey methods the researchers cited here made several assumptions. First, they commonly limit their study to sample subsets of the site rather than attempting to study the entire area. So they assume that what they observed within these subsets is representative of the site as a whole (Hallacher 2002:1). To make suggestions regarding the state of the marine turtle population, the researchers targeted faunal remains of marine turtle found in the archaeological record. In focusing on these remains, they have assumed that the density of these target remains in their subsets represents their density in the greater community at that particular site. In addition, in quantifying and identifying the remains of marine turtle, the researchers relied on both the individuals on site (diggers, sifters, etc.) who gathered those remains and on the observers who were responsible for interpreting those remains. This assumes that every individual and observer had equal skills in terms of obtaining and identifying the data gathered — this may not be the case and should be considered when reviewing these findings. And what of the conclusion that the decimation of turtle stocks on both Niotaputopu and Tikopia represents extensive initial exploitation of a nesting beach? In delineating their methodology the authors do not state whether or not they conducted genetic testing on the turtle remains and determined a sex ratio biased toward females, or conducted analysis of the skeletal components to assess growth. If they did not, then the evidence for a nesting beach is not convincing.

Conclusion

The consistent initial decimation owing to heavy initial exploitation demonstrated by the above brief literature review suggests a trend rather than isolated incidences and provides a model of marine resources depletion at time of initial settlement. This model had long-term consequences for marine turtle populations and may be correlated with a ratio of human population to marine resource base; the lower the human population in relation to the resource base, the less its ability to deplete that base. The next task is a more thorough review of the relevant literature to verify these conclusions.

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