

Three millennia of human and sea turtle interactions in Remote Oceania

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Abstract Sea turtles are one of the largest vertebrates in the shallow water ecosystems of Remote Oceania, occurring in both sea grass pastures and on coral reefs. Their functional roles, however, over ecological and evolutionary times scales are not well known, in part because their numbers have been so drastically reduced. Ethnographic and archaeological data is analysed to assess long-term patterns of human–sea turtle interactions (mainly green and hawksbill) prior to western contact and the magnitude of turtle losses in this region. From the ethnographic data two large-scale patterns emerge, societies where turtle capture and consumption was controlled by chiefs and priests versus those where control over turtle was more flexible and consumption more egalitarian. Broadly the distinction is between societies on high (volcanic and raised coral) islands versus atolls, but the critical variables are the ratio of land to shallow marine environments, combined with the availability of refugia. Archaeological evidence further highlights differences in the rate and magnitude of turtle losses across these two island types, with high islands suffering both large and rapid declines while those on atolls are less marked. These long-term historical patterns help explain the ethnographic endpoints, with areas that experienced greater losses apparently developing more restrictive social controls over time. Finally, if current turtle migration patterns held in the past, with annual movements between western foraging grounds and eastern nesting beaches, then

intensive harvesting from 2,800 Before Present in West Polynesia probably affected turtle abundance and coral reef ecology in East Polynesia well before the actual arrival of human settlers, the latter a process that most likely began 1,400 years later.

Keywords Sea turtles · Human impact · Pacific prehistory · Lapita colonisation · Polynesia

Introduction

The important ecological functions of sea turtles in shallow water marine environments have only recently been recognised (Bjorndal and Jackson 2003; Jackson 1997). Given their large size and often high densities their effects can be profound. The mainly herbivorous green turtles intensely graze sea grass meadows and on coral reefs, algae and invertebrates, while the carnivorous hawksbills consume vast quantities of sponges, a sometimes coral competitor (Bjorndal 1997). In addition to their roles as consumers and predators, sea turtles can also affect nutrient cycling within, and between, marine habitats, sometimes over vast distances given their annual migrations of up to several thousand kilometers. They also serve as substrates for epibionts, and hosts for parasites and pathogens. Moreover, they physically modify coastal landscapes (Bjorndal and Jackson 2003), sometimes to the point where they arguably function as “ecosystem engineers” (see Allen 2003). Bjorndal and Jackson (2003, p. 269; see also Jackson 1997) emphasize, however, that the functions of sea turtles in the evolution and maintenance of marine ecosystems often have been unrecognised and are still poorly known because their numbers dramatically declined prior to systematic scientific study.

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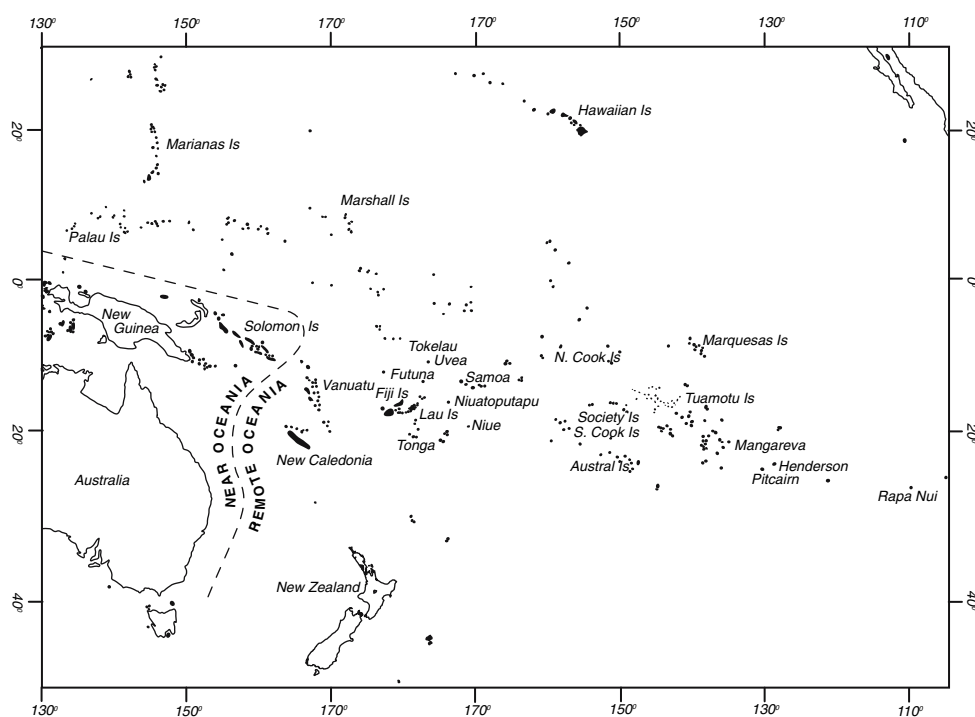
The significant size of sea turtles, particularly the green turtle, has made them attractive to human populations as well (see Frazier 2003). In traditional Pacific societies, these “charismatic” marine megafauna held a central place, contributing not only to local subsistence economies, but also figuring prominently in chiefly wealth and ritual life. Archaeological research, particularly in Remote Oceania (Fig. 1), indicates this is a long-standing relationship and suggests historically recorded declines are the tail-end of a much longer process, one that began with human settlement nearly three millennia ago. Within this region, however, the magnitude and rate of turtle loss may have been patterned by both environmental and cultural variability.

This paper assesses human–turtle interactions in central Remote Oceania, focusing on their interface at coral reefs and beaches, a locality popular for early human settlement and where turtles both feed and nest. Two sources of quite different data are utilised. Ethnographic studies and historical accounts (mainly from Fiji and Polynesia) inform on the rich social context of turtle use and traditional management practices; an effort is made to not only outline broad regional patterns but also to highlight geographic and cultural differences that have historical and ecological relevance. This is a departure from earlier reviews which often focus on single island communities (e.g., Tippet 1968; Emory 1975; Balazs 1983) or synthesize patterns for the Pacific at large (e.g., National Marine Fisheries Service and US Fish and Wildlife Service 1998, pp. 6–7; Luna 2003). The second source of data is

archaeological which, although more coarse-grained with respect to social practices, greatly extends the temporal depth of our observations. In these discussions, a distinction is made between West Polynesia (defined here as Fiji, Tonga, and Samoa) and central East Polynesia (islands east of Samoa), the former having been settled ca. 2,800 years ago while the latter were probably colonised 1,300–1,800 years later (see discussions in Kirch and Ellison 1994; Anderson and Sinoto 2002; Green and Weisler 2002; Allen 2004).

The potential contributions of this analysis are three-fold. The two anthropological data sets are used to construct a simple model which predicts where turtle populations were/are most vulnerable to over-exploitation and why strict social and religious controls arose in some islands and not others. The analysis also provides a foundation for further inquiries into the impact of sea turtle losses on coral reefs. Specifically, the distribution and densities of Pacific sea turtles in pre-human times, and how these patterns were affected by human arrival, is considered. Finally, the review of traditional practices related to turtle capture and consumption may assist on-going efforts to conserve and restore Pacific turtle populations to their native habitats while protecting indigenous rights and traditions (e.g., National Marine Fisheries Service and US Fish and Wildlife Service 1998; Johannes 2002; Bjorndal and Jackson 2003; Lutz et al. 2003; Balazs and Chaloupka 2004; Kinan and Dalzell 2005).

Fig. 1 Map of the Pacific and localities mentioned in text



Sea turtle habitats and behaviours

There are five main sea turtle species in the central Pacific: Green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Olive Ridley (*Lepidochelys olivacea*), Loggerhead (*Caretta caretta*), and the Leatherback (*Dermochelys coriacea*). All are listed by the World Conservation Union as endangered, except the loggerhead which is considered vulnerable (Seminoff 2002). Some suggest that global populations of green turtles in particular may have been reduced by more than 50% over the last 150 years (Seminoff 2002). Green and hawksbill turtles were apparently the most important to indigenous Polynesians, but both ethnographic and archaeological sources usually lack information on the species targeted. Traditionally, green turtles were prized for both their meat and eggs, while the eggs and shells of the hawksbill were sought-after but the strong-smelling meat less so (see Johannes 1981). The large body size of green turtles in particular, sometimes exceeding 250 kg (in Pritchard 1995, p. 253), meant they were a “high return” prey for traditional Pacific communities. This, combined with their K-selected maturation and reproductive patterns, and readily accessible eggs, has made them quite vulnerable to human predators.

Worldwide, green turtles are well known from sea grass habitats, as for example, in the Caribbean, on the Australian shelf, and in the Indian Ocean. In Remote Oceania, both seagrass beds and coral reefs are utilised (Balazs 1983; Brill et al. 1995; Pritchard 1995; Bjorndal 1997). However, the latter are more common in the western Pacific, with a sharp drop-off in both seagrass diversity and suitable seagrass habitat east of Samoa (Stoddart 1992; Craig et al. 2004). As a result, in the eastern islands coral reefs variably function as both feeding grounds and nesting localities (e.g., Balazs 1995; Pritchard 1995; Musick and Limpus 1997, p. 151; Craig et al. 2004). In both environments, their combination of large body size and often high population densities is such that they can significantly affect the structure and composition of local ecosystems, changing faunal densities and altering predator–prey relationships (Bjorndal 1997; Jackson et al. 2001; Bjorndal and Jackson 2003). Further, because seagrass beds often play a critical nursery role in coral reef fisheries, impacts here potentially have flow-on effects for coral reefs.

Turtles, especially green turtles, have strong fidelity for both feeding and nesting grounds (Lutz and Musick 1997 and papers therein) and their movements between the two are seasonal. One impact of this is that they transport significant “packages” of nutrients (in the form of eggs) over long distances, between their rich foraging grounds and nesting beaches. Egg-laying often correlates with spring tides (new and full moons) and four to six clutches are typically laid at ca. 2-week intervals (Emory 1975; Johannes 1981, p. 57;

Lutz and Musick 1997), with each clutch containing, on average, more than 100 eggs (Miller 1997, p. 65).

Today there are estimated to be 150 green turtle nesting colonies worldwide and of these 10–15 are composed of more than 2,000 individuals. None of the Pacific island colonies are this large, although 4,000 females are thought to nest on Great Barrier Reef (National Marine Fisheries Service and US Fish and Wildlife Service 1998, p. 8; <http://swr.nmfs.noaa.gov/PIR/feis/Appendix%20C.PDF>: 504). Important feeding grounds are, however, located in the central Pacific, including the extensive seagrass and algal pastures of Fiji and Tonga (Pritchard 1995; Craig et al. 2004). Significant nesting beaches lie in American Samoa (Rose Atoll), the northern Cook Islands, and French Polynesia (Craig et al. 2004). At Scilly Atoll, the only nesting site of any magnitude in French Polynesia today, 300–400 annual nesters are estimated, of which local residents are allowed to take 50 adults each year (Craig et al. 2004).

The omnivorous hawksbills feed in shallow coral reef environments and mangrove estuaries. Their emphasis on sponges, a major contributor to reef biomass (and sometimes important coral predator), is such that they too affect diversity, biomass, and succession in reef communities (Musick and Limpus 1997, pp. 152, 212; Leon and Bjorndal 2002; Bjorndal and Jackson 2003). This species also regularly migrates between feeding and nesting sites. They produce four to seven clutches at roughly two-week intervals (Plotkin 2003, p. 230). However, rather than concentrating in rookeries, they have a dispersed nesting habit which makes them less vulnerable to human predation in some respects (King 1995). Nonetheless, Johannes (1981, p. 26) observed that hawksbills seem to have less stamina than green turtles, making them an easier prey.

Ethnographic context

Turtle consumption

Pacific islanders and sea turtles, now and in the past, interface at two important points in the turtle’s life cycle, at feeding grounds and at nesting beaches. As a prey, they were relatively accessible in near-shore waters, clumsy and vulnerable on land, and highly predictable in both their diurnal feeding and resting behaviours, and their seasonal nesting patterns. Moreover, their common concentration in nesting rookeries was an advantage for human hunters. They were a substantial source of flesh, which was quite nutritious and rich in fats, especially female green turtles; in some islands, only human flesh was more highly valued (Emory 1975, p. 40). Traditional accounts of turtle butchery and cooking (Thompson 1940, p. 72; Emory 1975; Balazs 1983) indicate that nearly all fleshy parts were consumed

(meat, developing eggs, and organs) along with the blood which was drunk after warming. Further, specific names were given to various kinds of intestines and at least nine fats differentiated on the basis of their location in the body, an indication of their cultural importance.

From a purely economic perspective, the high value placed on turtles is logical. Yet, the often marked and elevated status of these animals, their place in Polynesian ritual life, and their frequent restriction to high-ranking individuals suggests that non-economic factors also were operative. In some contexts, turtles were considered sacred and incarnates of deities (Williamson 1924; Handy 1927, p. 46; Firth 1967, pp. 556–558; Tippett 1968, p. 117; Goldman 1970, p. 333; Ferdon 1981, p. 200; Kirch and Green 2001, p. 260). In Fiji they were *ika bula* or *ika tamata*, specifically “living fish” or “breathing fish.” On Mangareva, like men and houses, they were counted singly because of their importance (Buck 1938, p. 416). In the Marquesas they were acceptable substitutes for human sacrifices (Jardin 1862, p. 74; Handy 1923, p. 240). While the ethnographic literature is largely mute as to why turtles assumed such an elevated place in Polynesian cultures (as well as many Micronesian and Melanesian ones), their habits of breathing, bleeding, crying, and tenaciously holding on to life, paralleling human characteristics, were probably important (see Deane 1921, p. 176; Thomas 1990). Rolett (1986) makes the further point that unlike most animals, turtles bridge two worlds, the deep sea and land, and as such may have been viewed as a particularly appropriate means of communicating with the gods and, in his Marquesan example, assisting spirits with passage to the after world.

While universally valued, there was regional variability in the rules and social practices surrounding turtle capture and consumption. In many Polynesian islands turtle consumption was restricted to high-ranking individuals, usually male chiefs and priests (Table 1); violators might be punishable by death, as in Fiji (Tippett 1968, p. 126). Women were rarely allowed to eat turtle meat, it being strictly prohibited in Hawaii (Bryan 1938, p. 67; Malo 1951), the Societies (Ferdon 1981, p. 199), Tongareva (Buck 1932, p. 92), and probably elsewhere. However, in some instances, as in the Tuamotus and Pukapuka (northern Cook Islands), all males occasionally had access to turtle meat, including boys as young as nine or ten (Beaglehole and Beaglehole 1938, pp. 69–70; Emory 1947, p. 88). On Rakahanga (northern Cook Islands), turtle was allowed to all but one sub-tribe and Buck (1932, p. 214) notes its role in religious ceremonies was reduced relative to nearby Tongareva. Even on Tongareva, chiefly control over turtle varied over time, with individuals sometimes being allowed to keep their catch (Buck 1932, p. 50). And in Tokelau, turtle was divided equitably among the entire population (MacGregor 1937; Balazs 1983; Huntsman and

Table 1 Traditional restrictions on turtle consumption in Polynesia

Locality	Primary Island type	Access	Source
Tikopia	High	Everyone but only eaten by some clans	Firth (1967)
Fiji	High	Chiefs	Deane (1921) and Tippett (1968)
Tonga	Raised coral	Chiefs	Williamson (1924, p. 255)
Tokelau	Atoll	Everyone	MacGregor (1937)
Samoa	High	Chiefs	Buck (1930)
Uvea	High	Chiefs, priests	Burrows (1937)
Futuna	High	Chiefs, priests	Burrows (1936) and Goldman (1970, p. 333)
S. Cook Is.	Mixed	Chiefs	Buck (1927)
Societies Is.	High	Chiefs	Handy (1927, p. 129) and Ferdon (1981, p. 200)
Tuamotu Is.	Atolls	Men	Emory (1975)
Pukapuka	Atoll	Men	Beaglehole and Beaglehole (1938)
Mangareva	High	Chiefs, priests	Buck (1938, p. 91)
Marquesas Is.	High	Chiefs, priests	Handy (1923, pp. 173–174, 1927, p. 129)
Rapa Nui	High	Not known	Metraux (1957)
Hawaiian Is.	High	Chiefs, priests	Kalakaua (1888)

Hooper 1996), although women were not involved in their butchery (Balazs 1983, p. 17).

There were also rules regarding the distribution of specific body parts. Typically the head was the most sacred part and usually presented to the most powerful chiefs, as in the Lau Islands, Tokelau, Samoa, and Tuamotus (Thompson 1940, p. 72; Balazs 1983; Buck 1930, p. 123; Emory 1947, p. 41, respectively). Samoans also reserved the front flippers and abdominal cavity juices for chiefs (Buck 1930) and on Pukapuka only older men could consume the belly fats and internal organs (Beaglehole and Beaglehole 1938).

Although turtle meat was often reserved for high-ranking individuals, even amongst the elite its consumption was generally restricted to special occasions such as chiefly inaugurations, births and deaths of high-ranking individuals, and peace-making rites (Handy 1927, p. 277). Turtle was often considered an appropriate offering for the gods (e.g., Buck 1932; Ferdon 1981, p. 200) and turtle skulls adorned Marquesan religious structures (Porter in Rolett 1986, p. 83). Even in the Tuamotus, where much of the male population had access to turtle meat, it could only be eaten when shared with the gods on the *marae* or temples (Emory 1975, p. 4).

Uses of turtle bone and shell

In contrast to turtle meat, use of turtle bone and the keratinous scutes, the latter commonly referred to as “turtle shell” (see Frazier 2005), was less strongly regulated. Artefacts made from the hard parts of turtle are found in both ethnographic and archaeological contexts. The wide flat bones of the carapace and plastron were made into a variety of utilitarian objects including spades, adzes, and thatching needles, scrapers (e.g., MacGregor 1937; Emory 1975, p. 38; Sinoto and McCoy 1975; Summers 1990, pp. 27–31; Rolett 1998, pp. 231–235; also additional sources in Frazier 2005). The keratinous scutes of the carapace were also used, particularly those of the hawksbill which were considered superior to the green turtle (see Johannes 1981, p. 12; Frazier 2005). These scutes or turtle shell were used in the manufacture of various kinds of fishhooks, as well as net gauges (e.g., Firth 1967, p. 543; Emory 1975, pp. 199–213, 192; Ferdon 1981, p. 213). In the Marquesas, intricately carved turtle shell plaques were a central part of festival head-dresses (*pa’e kaha*) which were considered family heirlooms and used by chiefs, warriors, and male dancers (Handy 1923, pp. 283–289; Steinen 1925–1928; Ivory 2005, pp. 33–34).

Harvest technologies

In Remote Oceania, turtles were captured by several techniques but some may be recent innovations. Netting and grappling are the two most commonly mentioned, both still in use today (see Pritchard 1995). Turtle nets were typically large communal constructions representing major financial and social investments. Tippett (1968) provides a detailed account of the social context of production and use of a traditional Fijian turtle net. The largest and strongest of all nets, the turtle net was made by specialists and both its manufacture and use were surrounded by elaborate ceremonies and much expense (Thompson 1940). Measuring up to 180 m in length, with depths of 3 m, these were dragged by canoes outside the reef. Oral traditions suggest that even before Western contact, the strong social fabric of traditional Fijian turtle net manufacture and use was beginning to erode, with new capture technologies allegedly being introduced from Tonga in late prehistory (Tippett 1968). Turtle nets are also reported for the islands of Lau, Futuna, Uvea, southern Cooks, Mangareva, Marquesas and Rapa Nui (Thompson 1940; Burrows 1936, p. 148; Burrows 1937, p. 105; Buck 1927, p. 297; Buck 1938, p. 91; Handy 1923, p. 174; Metraux 1957, p. 70, respectively).

Grappling, although technologically simple, could be dangerous as fully grown turtles are large and cumbersome. Occasionally divers were carried to great depths and drowned, or pierced by the tails of large males (Beaglehole

and Beaglehole 1938, pp. 69–70; Balazs 1983, p. 14). Turtles lying on the sea floor were sometimes dragged to the surface with an iron hook and line, the former inserted into the back of their neck and the latter attached to a canoe. On Tongareva, turtles were driven into the shallows (Buck 1932), while a variety of grappling or hand techniques were used in the Tuamotu Islands (Emory 1975). Spearing and harpooning are also recorded but generally considered modern techniques (see Tippett 1968; Emory 1975, p. 188; Balazs 1983, p. 15). Adults were often held in shallow water enclosures until needed, sometimes for several months (Handy 1923, p. 174; Hocart 1929, p. 118; Tippett 1968, pp. 123, 128; Emory 1975, p. 40).

There also are reports of animals being taken specifically during breeding and nesting while in a state of “reproductive stupor” (after Johannes 1981, p. 38). Some accounts (e.g., Hocart 1929, p. 118; Metraux 1957; Emory 1975, p. 217; Balazs 1983) imply that this was a traditional strategy, while others (e.g., Deane 1921, p. 179; Tippett 1968, p. 123) suggest otherwise. Archaeological records, however, leave little doubt that turtles were targeted at nesting locations. Importantly, predation on nesting individuals and eggs would have had long-term effects given turtles’ strong nesting site fidelity. Not only would populations be reduced but, over time, specific nesting aggregations probably became extinct with implications for turtle genetic diversity and local reef ecology.

Turtle capture was also aided by their predictable daily cycles of feeding and resting. During the hotter part of the day they commonly sleep on the sea floor, often in regular places (Johannes 1981, p. 58; Brill et al. 1995). Similarly, their breeding behaviours are regular and predictable, eggs being laid at night on natal beaches, usually during spring tides which coincide with full and new moons. Further, multiple laying episodes are typical, roughly spaced at two-week intervals. An accomplished turtle hunter could identify where a female was in her egg-laying cycle based on the texture and shape of the eggs, as those in the first and last clutches are usually small and sometimes misshapen. Skilled turtle hunters also monitored the process of calcification, as well as the size and state of the developing embryo (Hocart 1929 for Solomons; Emory 1975, p. 217 for Tuamotus; Johannes 1981, pp. 57–58 for Palau; Balazs 1983, pp. 15–16 for Tokelau).

Traditional management practices

Traditionally, turtle capture and use was controlled in a number of ways, including both direct management strategies and indirect social controls. While the ethnographies cited above have little to say about turtle conservation, Johannes’ (1981) ground-breaking research on fishing in the Palau Islands, raises the possibility that traditional

conservation practices were simply not recorded. Johannes (1981) identified three management strategies related to turtles: (1) allowing females to lay their eggs first before capturing them; (2) routinely leaving some eggs in a nest to insure future generations; and (3) waiting until an individual had laid multiple clutches. There is also evidence for simple turtle farming. In the Lau Islands, hatchlings were released into a tidal lake and allowed to mature (Thompson 1940, p. 137), while Pukapukans raised hatchlings in coastal pens (Beaglehole and Beaglehole 1938, pp. 209–210). Additional management practices are recorded elsewhere (e.g., Johannes 1978, 2002; Balazs 1995; Pritchard 1995; Kinan and Dalzell 2005) but in many cases they appear to be recent in origin. Perhaps the strongest protection afforded turtles was indirect, stemming from their sacred status and the numerous restrictions that surrounded their capture and consumption. Turtle hunting was often the purview of specialists, as in Fiji, Samoa, and the Marquesas (Handy 1923, pp. 173–174; Tippett 1968), and where turtle consumption was limited to high-ranking individuals and special occasions, harvesting pressures were greatly reduced.

Ethnographic accounts also offer insights as to mid-nineteenth to early twentieth century turtle abundances. In 1860, Williams reported seasonal takes of 50–100 turtles, presumably within any one of the seven kingdoms of Fiji (Tippett 1968, p. 121). In the Marquesas, Handy (1923, p. 174) suggests a turtle hunt might result in 10–20 individuals, although the impression given is that turtle fishing was not a common activity. Based on his 1930s observations in the Tuamotus, Emory (1975, p. 40) reports “in two out of three years an atoll was likely to receive them in such numbers as to enable the capture of 50–100” during the nesting season. These estimates of traditional harvests contrast with recent commercial accounts. For example, in the late 1960s as many as 1,000 adults were taken annually in French Polynesia and turtle meat was so abundant it was used as pig food (Balazs et al. 1995).

Significant declines in turtles appear to have begun soon after Western contact. Social and political structures were eroded or outright dismantled, by both population loss through introduced diseases and by enthusiastic missionaries; traditional economic systems were first challenged and then replaced by market economies, all with consequences for turtle populations. Tippett’s (1968, p. 122) analysis of the Fijian situation perhaps best demonstrates how the loss of traditional social controls led to unregulated capture and increasing turtle consumption by the population at large. Development of a market economy around turtle shell beginning in the early 19th century and extending into the early twentieth century also encouraged over-exploitation; turtle numbers plummeted relative to their proto-historic abundances.

Historical perspectives from archaeology

While turtles have declined markedly in Remote Oceania over the last 200 years, archaeological evidence suggests this is part of a long process, with a much earlier and possibly far more devastating set of impacts stemming from initial human settlement of the region. In considering the archaeological record, it is important to note that turtle remains are often fragmentary, hindering species determinations, as well as those of age, sex, and sometimes even body part identifications (but see Best 1984, p. 538; Leach et al. 1984; Frazier 2004). Additionally, lengthy well-dated temporal sequences with well analysed fauna are limited, and the quantitative measures used by specialists are varied, making inter-site comparisons difficult (see Allen 2003; also Table 2). Archaeological records may also be biased towards nesting sites, as coral sand beaches not only attracted turtles but also were favoured settlement areas for human populations and are the sedimentary contexts most likely to preserve faunal remains. Despite these limitations some interesting patterns can be discerned.

One of the more striking of these is the ubiquitous presence of turtle in early archaeological sites throughout the region. Not only is turtle present, but typically it is a significant component of early faunal assemblages. So repetitive is the pattern that Pacific archaeologists now consider an abundance of turtle bone part of a suite of diagnostic signatures that identify human arrival in a pristine environment (e.g., Kirch and Yen 1982, p. 325; Anderson 1995; Steadman 1995). Excavations have shown that turtles were one of several taxa that were quickly reduced or eliminated by the region’s first human colonists, undoubtedly unintentionally. Other affected fauna included colonial seabirds, native and endemic land birds, endemic land snails and, in the case of the more western islands, now-extinct crocodiles (*Mekosuchus* spp.), monitor lizards (*Brachylophus* spp.), a horned tortoise (*Meiolania* sp.), and a giant frog (Pregill and Dye 1989; Steadman 1995; Worthy et al. 1999; Steadman et al. 2002). While direct hunting contributed to these losses, the commensal species that accompanied human settlers (rats, pigs, dogs, and chickens) probably also played a crucial role. Rats in particular are known predators of turtle eggs and hatchlings (Balazs 1983, p. 12) and the commensal Polynesian Rat (*Rattus exulans*) is common in early sites.

One of the first well documented cases of early and intensive turtle use came from Ua Huka in the Marquesas Islands. Although much of the Ua Huka coastline consists of vertical cliffs, there are a few amphitheatre-headed valleys, one being Hane. The early occupation site (MUH1) found here lies in a low coastal dune derived from a small adjacent coral reef (Sinoto 1966), both rare features in these islands. Now dated to ca.

Table 2 Turtle remains in early Polynesian sites

Island	Site	NISP	MNI	Weight (g)	Density of turtle bones	Relative proportion of protein ^a (%)	Site location	Source
West Polynesia								
Tikopia Is.	TK-4 (Kiki)	1,349	na	na	59.2 NISP m ⁻³	6 ^b	Coastal dune	Kirch and Yen (1982)
Lakeba, Lau Is.	101/7/197	na	8	na	na	na	Rockshelter	Best (1984)
Lakeba, Lau Is.	101/7/196	na	28	na	na	na	Open site	Best (1984)
Niuatoputapu	NT-90 (Lolokoka)	71	na		2.84 NISP m ⁻³		Coastal flat	Kirch (1988)
Lifuka Is, Ha'apai Group, Tonga	Tongoleleka	na	na	na	414 g m ⁻³	63 ^c	Coastal dune	Dye (1988, 1990)
Lifuka Is, Ha'apai Group, Tonga	Fakatafenga	na	na	na	1,693 g m ⁻³ (Unit 58N2E)	55 ^c	Coastal dune	Dye (1988, p. 118)
East Polynesia								
Aitutaki Is.	AIT-10: Zone G (Ureia)	6	na	4.2	2.5 NISP m ⁻³	9 ^d	Coastal flat (no dune)	Allen (1992)
Huahine	(Fa'ahia)	na	25	na	na	58 ^c	Coastal dune	Leach et al. (1984) and Dye and Steadman (1990)
Henderson Is.	Hen-11	na	na	6182 ^e	na	na	Coastal dune	Weisler (1995)
Ua Huka	MUH-1, Layer V-VI (Hane)	na	na	497	na	na	Coastal dune	Kirch (1973)
Tahuata Is.	TH1: Zone GH/H (Hanamiai)	20	na	177	3.9 NISP m ⁻³	10 ^f	Coastal dune	Rolett (1998)

na not available, NISP number of identified specimens and MNI minimum number of individuals

^a These values cannot be directly compared because they have been calculated in a variety of ways, a general problem recently reviewed by Allen (2003)

^b These values are kg m⁻³ usable meat weights for all protein sources

^c These values are based on total dietary meat weights, including shellfish

^d These values are based on non-fish vertebrate bone weights only, thus excluding both shellfish and fish

^e This sample is not limited to an early cultural context

^f These values are based on total vertebrate bone weights only, and thus exclude contributions from shellfish

AD 1100–1200 (Anderson and Sinoto 2002, p. 251), the Hane site is thought to represent first settlement in this valley and possibly on the island. Turtle bone is concentrated in the basal layers of the site, in association with other vulnerable fauna such as native birds and chitons (Kirch 1973; Steadman 1995). Although the absolute amount of turtle in the lower layers is small, it exceeds all subsequent layers in abundance.

On tiny Tikopia, a Polynesian outlier in the Solomon Islands, the Hane story is repeated. At the time of human settlement, this small volcanic island (4.6 km²) had a deep open bay, a fringing paleodune, and roughly 70% more reef flat than seen today (Kirch and Yen 1982, p. 325). Kirch and Yen (1982) detail a ca. 2,900-year sequence of human occupation, beginning with a distinctive pottery-bearing cultural complex known as Lapita, the original human settlers of Remote Oceania generally. Here turtle remains figured prominently in the earliest occupation, represented by three strata at two localities, Kiki (Site TK-4) and Sinapupu (Site TK-36), with turtle in both sites exceeding all other vertebrates in abundance.

Other archaeological studies also reveal intense exploitation of turtles at the time of first settlement. In Tonga, on Fakalofa Atoll in Tokelau, Huahine Island in the Societies, remote Henderson Island, and on Tahuata in the Marquesas, the pattern is replicated (Kirch 1973; Sinoto 1983; Dye 1988; Kirch 1988; Dye and Steadman 1990; Weisler 1995, 1998; Rolett 1998; McAlister 2002; D.V. Burley, personal communication 2006). Turtle bones were particularly abundant in two Tongan sites where Dye (1988, pp. 118, 143) reports densities of 1,693 and 414 g m⁻³. In the Lau Islands, a rockshelter first occupied by Lapita-age peoples contained only small amounts of turtle but here both hawksbill and green have been definitively identified (Best 1984, pp. 538–539). On Henderson Island both turtle bone and egg shell were found in an early context dated to ca. AD 1000, with over 15.9 kg of turtle being recovered from one earth oven (Weisler 1995, p. 396, 1998, p. 82). Meat weight reconstructions suggest that turtle may have represented as much as 50% of the protein intake of some early Polynesian settlers (Dye and Steadman 1990), a far greater contribution than any ethnographically recorded case.

A second pattern relates to the contexts in which turtle remains are found. In light of the numerous ethnographic accounts which identify the sacred and often chiefly nature of turtle, one of the more notable features of the early occurrences is the lack of either ritual or chiefly associations. To the contrary, turtle remains are typically found in domestic contexts along with a variety of other food remains and utilitarian tools. On Tikopia, Kirch and Yen (1982, p. 122) describe the early occupation as “best interpreted as a small permanent hamlet with at least two (and likely four or five) dwelling structures and associated cook sheds.” On Tahuata, the basal layers of Hanamiai are thought to reflect relatively ordinary domestic activities, while after western contact the site was transformed into a *tohua* or ceremonial centre (Rolett 1998)—a change which is reflected in the faunal assemblages by a reduction in food remains generally and no increase in turtle.

Finally, the most striking pattern of all is the dramatic and near-uniform decline in turtle over time. Drawing on evidence from a series of Tikopian sites, Kirch and Yen (1982) show that turtle is quickly reduced, probably within the first 100 or so years of occupation (Fig. 2). Of the two sites with stylistically early ceramics, turtle is only abundant in one, the Kiki Site (TK-4). In two successive strata at the second locality (Sinapupu, TK-36), the abundance of turtle remains is roughly one-third that observed at Kiki. While the radiocarbon dates from the two localities are indistinguishable, the diverse assemblage of sea and land birds (including an extinct megapode) and the presence of exceptionally large marine shells, all suggest that the early Kiki layer probably represents exploitation of a virgin landscape. Given these findings, Kirch and Yen (1982, p. 349) argue that significant declines in both the biomass and diversity of Tikopia’s native fauna, including turtles, probably occurred within a couple centuries of human colonisation if not less. The idea that early Polynesian impact on native fauna may have been quite rapid has gained increasing support in recent years from

avian paleontologists working in the region (Holdaway and Jacomb 2000; Steadman et al. 2002).

By the end of the Tikopia Kiki Phase at ca. 100 BC, turtle have altogether disappeared. Given that sharks and rays (other “sacred fish”) also disappear at this time, while offshore trolling persists, Kirch and Yen (1982, pp. 285, 356–357) originally proposed that the lack of turtle represented the development of food taboos rather than local extirpation. In light of more recent evidence for over-harvesting (see below), this idea is debatable; the shrinking coral reef flat may also have been a contributing factor. Only in late prehistory (after AD 1200) does turtle reappear on Tikopia and in much reduced quantities (Fig. 2). When ethnographer Firth (1967) visited in the late 1920s, turtles were rare, not specifically sought-after, and only occasionally taken in nets.

Evidence from elsewhere indicates that the trends seen on Tikopia are regional in character. Notably, many early sites are located on coastal dunes (Table 2), favoured areas for turtle nesting. On Niutopotapu (settled ca. 1200 BC), Tokelau (from ca. AD 1000), Ua Huka (from ca. AD 1100 to 1200) and Tahuata (from ca. AD 1200) successive stratigraphic layers, and/or archaeological sites, show marked reductions in turtle remains (Kirch 1988; McAlister 2002; Kirch 1973; Rolett 1998, respectively). At Tongoleleka (Tonga) and Hane (Marquesas) turtle persists into late prehistory, but is greatly diminished in abundance (Figs. 3, 4). On Tahuata (Marquesas), turtle is never particularly well represented but, as elsewhere, declines within the first century or two of human settlement (Rolett 1998). On Henderson Island, Brooke (1995) estimates ten females nest here today, while the archaeological evidence of Weisler (1995) speaks to a more substantial population on this isolated outpost at the time of human arrival. Notably, on Fakaofu Atoll, Tokelau turtle also declines, but the gradient of this downward trend is less marked than elsewhere (Fig. 5), as further discussed below.

Several patterns emerge from the foregoing discussion. Turtles were targeted by the first human settlers as a relatively easy but high return prey with varied and useful hard

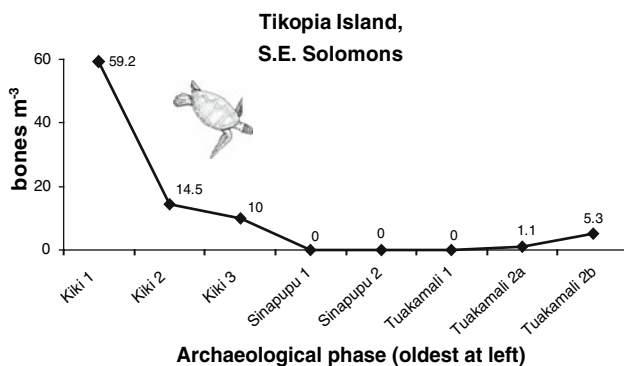


Fig. 2 Turtle bone abundance on Tikopia Island, southeast Solomons, from ca. 900 BC to AD 1800. (Data from Kirch and Yen 1982, 280, Table 40, p. 319; Kiki Phase: 900 BC–100 BC; Sinapupu Phase: 100 BC–AD 1200; Tuakamali Phase: AD 1200–1800)

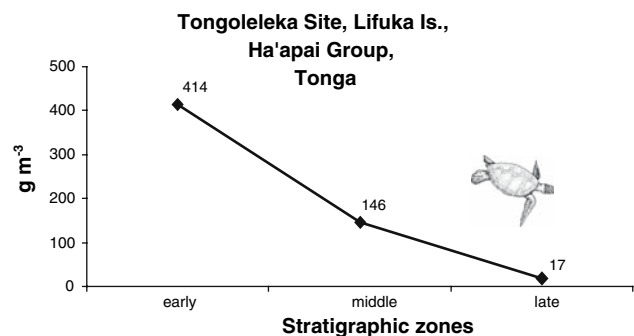


Fig. 3 Turtle bone abundance over time at Tongoleleka, Ha’apai Group, Kingdom of Tonga (data from Dye 1988)

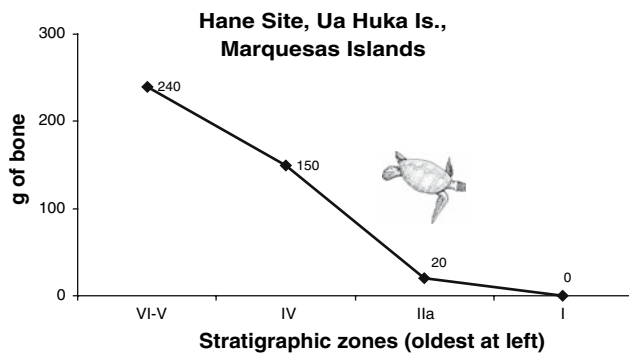


Fig. 4 Turtle bone abundance at Hane, Marquesas Islands, ca. AD 1150–1700 (data from Kirch 1973, 31, Table 5, Site MUH-1, Area A, Unit R108W). In units not shown here turtle persists in small amounts into the historic period

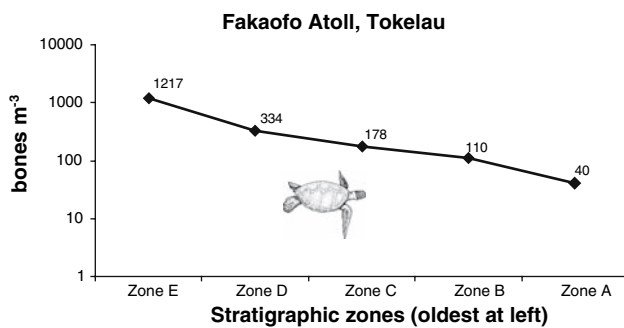


Fig. 5 Turtle bone abundance over time on Fakaofu Atoll, Tokelau from ca. AD 1000 (data from McAlister 2002, 57, Table 5.7, TP4; only Zone E has been dated)

parts. In these early settings, there is little evidence that the processing of turtle meat was handled differently from other food or its consumption restricted to either chiefly or religious contexts. Where chronological sequences are available, there is unambiguous evidence for dramatic declines in turtle. These declines were apparently quite rapid and there is little indication that populations ever recovered, with the possible exception of those on Tikopia Island. Importantly, given the millennia or more of turtle harvesting in western islands, practices there may have had significant consequences for turtle populations in East Polynesia even before human settlement. It is also possible, however, that prior to human arrival, there was a larger resident population in the eastern Pacific. Despite the heavy harvesting pressures placed on turtles under traditional regimes, they nevertheless continued to form a small part of many indigenous Polynesian diets at western contact.

Discussion and conclusions

In Remote Oceania, sea turtles held a special place in the region's traditional societies but despite this, have declined

dramatically in abundance since the advent of human colonists ca. 2,800 years ago. In examining the ethnographic accounts, two broad patterns have emerged. On one set of islands, there were highly formalised and strictly enforced socio-political and religious controls over turtle capture and consumption, as for example, in Fiji, Samoa, Tonga, and the Society and Marquesas Islands. On other islands, however, cultural controls over turtle were less stringent (e.g., Pukupuka, Rakahanga, and the Tuamotu Islands) or temporally variable (Tongareva), and in at least one case all members of the society were allowed turtle flesh (Tokelau).

The differences appear to stem from environmental variability rather than historical (homologous) relationships. While the distinction is broadly between high islands (volcanic and raised coral ones) and atolls, there is a great deal of variability encompassed within these two groups and many high islands have suitable habitat for turtles. More specifically, the critical variable appears to be the ratio of shallow marine areas to land, the former affecting turtle resources and the latter, the size of predator populations. On islands where shallow marine environments are limited, opportunities for both turtle foraging and nesting are low. Atolls, in contrast, offer both an abundance of sand beaches, some suitable for nesting, and extensive shallow water areas where food resources are potentially plentiful. Indeed, the largest extant nesting grounds in Polynesia today are found on Rose Atoll in Samoa and Scilly Atoll in French Polynesia.

Land area in turn affected the abundance of predators, humans foremost, but also rats and other commensal species. At western contact most of the larger islands in Remote Oceania supported sizable human populations (Rallu 1990) who, over time, placed intense pressures on local coastal fisheries in general (Allen 2003). On atolls, in contrast, human populations were traditionally small, limited not only by the amount of available land but also by poor soils, a lack of fresh water, and periodic sea inundation. Atolls also offer turtles refugia with some islets typically being too small for permanent human habitation and distantly located from major settlements. Recent studies, in fact, highlight how increased motorised access to uninhabited islets has led to turtle declines in atoll settings (e.g., McCoy 1995, p. 279).

The archaeological evidence complements the model developed from ethnography. Specifically, it provides evidence for significant human impacts over millennial time scales on islands with high land-to-shallow-water ratios and ameliorated ones where land is limited and shallow marine environments extensive. On Tikopia (volcanic high island), Hane (volcanic high island), and Lifuka (isolated low raised coral island), the declines in turtles are notable. The declines are most marked in the case of Tikopia, where turtles suffered not only from heavy harvesting pressures

in the initial settlement period, but the island's reef was reduced by 70% over time and nearby refugia were lacking. In contrast, on Fakaofu Atoll in Tokelau turtle populations declined but the process appears to have occurred more slowly—this despite turtle consumption by the population at large. Is the Fakaofu sequence representative of harvesting pressures on atolls generally? Some supportive evidence comes from Utrök Atoll in the Marshall Islands where human settlement dates to ca. AD 300 (Weisler 2001). Although the stratigraphic details relevant to the recovered turtle remains are not presented, Weisler's (2001, Fig. 8.1) summary diagram indicates a relatively even distribution of turtle over time, and elsewhere he notes (p. 104) "turtle was consumed over a thousand-year period during prehistory without completely decimating the stocks." While additional archaeological sequences are clearly needed to fully evaluate these ideas, the preliminary evidence suggests that environmental variability led to differences in the magnitude and rate of turtle loss across Remote Oceania: turtle populations on atolls may have been more resilient than those associated with land rich but reef poor islands, over both millennial (West Polynesia) and centennial (East Polynesia) time frames.

The environmental variables identified above, in concert with the variable long-term effects of intensive human harvesting, may have led to the two contrastive patterns of turtle access seen at western contact. Highly formalised social controls, with turtle capture limited to specialists and consumption to a narrow stratum of the population on a limited number of social occasions appears to have been more common on islands that are large, or have limited shallow marine areas, or both. Whether these regulations were conscious management strategies, or simply the result of increasing turtle rarity, is uncertain but the end result was a powerful conservation tool (see also Balazs 1983, p. 15). While commoners no longer had access to turtle flesh, the "food of the gods" was preserved and the community at large could continue to enjoy, albeit from afar, a special animal which held a unique place in rituals and traditions.

In his classic work on Polynesian social stratification, Sahlins (1958) makes the more general observation that high islands often had complex and hierarchical socio-political systems, while those on atolls were typically more egalitarian, patterns that also were in part a reflection of environmental constraints and opportunities. Sahlins suggests these differences stemmed from the need to buffer environmental variability on atolls, frequently accomplished through re-distribution of resources versus the potential for surplus accumulation on high islands, and efforts to gain its control. Thus, on atolls all resources, not just turtles, were more likely to be widely distributed, whereas on high islands rare resources in particular were often under elite and/or priestly authority; turtles, as a particularly large prey, and one with

unusual, even human-like, characteristics fell into this category.

This analysis also raises questions about the ecological effects of early intensive harvesting practices and the long-term consequences. Human colonists arrived in West Polynesia ca. 2,800 years ago. Intensive turtle harvesting dates from first human settlement and routinely it led to significant declines in turtle populations. The effects of these declines, and possibly local extirpations, on other reef biota are not known. However, recent experiences elsewhere suggest major changes in the structure and ecology of local reefs may have ensued (e.g., Bjorndal and Jackson 2003). Potential flow-on effects include altered predator-prey relations, changes in community structure, declines in reef health, and possibly even the loss of coral cover. Further, if current turtle migration patterns held in the past, with annual movements between western foraging grounds and eastern nesting beaches (Craig et al. 2004), then intensive harvesting from 2800 BP in West Polynesia probably affected turtle abundance and coral reef ecology in East Polynesia *well* before the actual arrival of human settlers, the latter a process that most likely began 1,400 years later (Green and Weisler 2002; Allen 2004). Evaluation of these ideas will require the combined efforts of archaeologists and ecologists, aided by the successful re-establishment of turtle populations to areas where they were once prevalent.

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