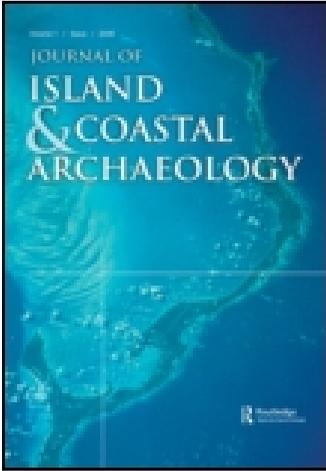


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Shellfish Gathering and Conservation on Low Coral Islands: Kiribati Perspectives

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Shellfish Gathering and Conservation on Low Coral Islands: Kiribati Perspectives

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ABSTRACT

Low coral island societies in the Pacific have always lived in a precarious environment. Consequently, some writers have stated that people living on atolls and table reefs must have devised effective conservation strategies. Predictions from three optimal foraging models in ethnographic contexts (patch choice, patch sampling, and risk) applied to shellfish gathering in Kiribati, Micronesia, do not support the assumption that human foragers are motivated by a desire to conserve resources. While historical ecology data are sparse, there is little to indicate that coral islanders in the past needed to practice conservation of marine resources, including shellfish.

Keywords conservation, historical ecology, Kiribati, optimal foraging, shellfish

INTRODUCTION

Until recently, it was generally assumed that anthropogenic impacts on island ecosystems were the result of Western influence via the introduction of alien crops, ornamentals, and animals, causing considerable damage to the local environment. The last 40 years of research has, however, revealed that indigenous groups have also contributed

in altering their environment to a significant degree prior to the arrival of outsiders. These impacts can sometimes be traced to the early phases of human settlement, at times leading to resource depression, extirpation, and extinction. Most of the evidence comes from terrestrial ecosystems (Steadman 1997). By contrast, the influence of indigenous societies on marine ecosystems is less well documented (Anderson 2008;

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Erlandson and Rick 2010; Morrison and Hunt 2007; Rick and Erlandson 2008), and remains a fruitful topic for research in light of suggestions that coastal dispersal could have been driven in part by the impact of early humans on near-shore and intertidal resources of high value that could be efficiently harvested, such as flightless birds, colony-breeding seabirds, turtles, large reef fish, and invertebrates (Mannino and Thomas 2002; Szabó and Amesbury 2011).

In addition to assessing the degree of environmental change across time and space, environmental scientists are often challenged in their attempts to disentangle the effects of natural processes from those induced by people (e.g., Amesbury 2007; Aswani and Allen 2009; Campbell 2008; Morrison and Addison 2008; Seeto et al. 2012). Coastal zones and small islands present certain difficulties in view of their susceptibility to natural changes linked to sea-level rise, tectonic events, coastal erosion or sedimentation, and storms (Fitzpatrick 2007, 2012).

There is a specific category of island, the atoll, which best exemplifies the close links between marine and terrestrial ecosystems (see Figure 1). As islands formed by biogenic agents (unconsolidated carbonate sediments deposited by waves on reef platforms), atolls and table reefs or low coral islands without lagoons, can be regarded as especially constraining habitats for human societies. The challenges faced by people, both past and present, include low soil fertility, absence of perennial surface fresh water, and extreme vulnerability to flooding by storm surge because of low elevation of the highly fragmented landmass, only a few meters above mean sea level. There are some 300 atolls and low coral islands in the Pacific Islands region and many more individual islets. Several archipelagoes are dominated by these limestone islands, such as the Tuamotu, the Marshall Islands, Tuvalu, and Kiribati.

The islands of modern Kiribati cluster into three island groups: the Gilbert, Phoenix, and Line Islands, consisting of 33 atolls and table reefs spread over an area exceeding 3 million km² of ocean straddling the equator. The total land area, however, only slightly exceeds 800 km² (see Figure 2). Most of the Gilberts, and several of the Phoenix



Figure 1. General view of an atoll (all photos by the author).

and Line Islands, are located in the dry belt of the equatorial oceanic climatic zone. Prolonged drought conditions are common, notably in the Central and Southern Gilberts and many of the Phoenix Islands. The highly alkaline and coarse-textured coral-derived soils are among the poorest in the world, with very little water-holding capacity and little organic matter. Owing to their small size, low elevation, and the porosity of the coral bedrock, there are no surface streams, similar to other atolls. Rainfall soaks through the porous surface soil creating a lens of often slightly brackish water floating on top of the higher density saltwater, often referred to as the Ghyben-Herzberg lens.

Archaeological evidence indicates human activity in the Gilberts about 2,000 years ago when dropping sea level allowed the atolls and table reefs to become emergent and habitable (Dickinson 2003; Di Piazza 1999), while the Phoenix and Line Islands appear to have been settled much later, by about AD 1200 (Anderson et al. 2000; Di Piazza and Pearthree 2004). By the time Europeans rediscovered the latter two island groups, no indigenous communities were encountered, having died out or migrated. The range of food crops that could sustain people on low coral islands was limited compared to what could be grown on the more fertile volcanic islands. Nevertheless, coral island societies devised various strategies that took full advantage of edible wild

Shellfish Gathering and Conservation in Kiribati

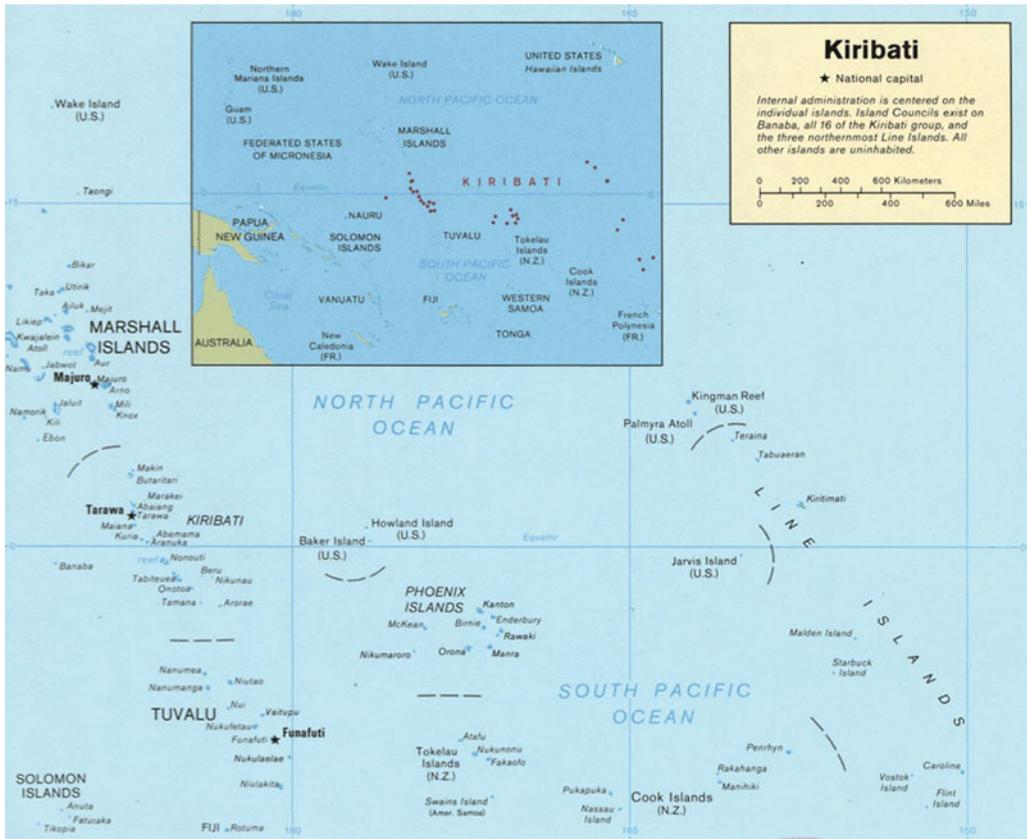


Figure 2. Map of Kiribati (source: Wikipedia).

resources, including abundant marine life, in addition to foods that were successfully introduced.

Using optimal foraging theory (Stephens et al. 2007) and the testing of predictions from three models (patch choice, patch sampling, and risk) applied to shellfish gathering, I argue that human foragers are not motivated by a desire to conserve resources. Likewise, historical ecology data do not support the idea that conservation needed to be practiced.

As Johannes (1993) cautioned, labeling indigenous groups as “ecologically noble” or “ignoble” obscures potential variation that comes from the study of individual behavior and contributes to the maintenance of stereotypes. We should avoid “essentialist” thinking because of the serious implications for the development of policy toward

indigenous groups and their relationship to the environment (Sponsel 1992). Foraging models, however, provide a way to rigorously evaluate individual actions and thus contribute to a better understanding of the context of subsistence activities. Moreover, they provide useful background on the rights and needs of indigenous communities as they strive to maintain a degree of stewardship over their traditional domains, while becoming active participants in decisions involving the management of resources (Alcorn 1993; Winter 1997).

BACKGROUND

One of the shortcomings of research, which portrays indigenous societies as conservationists, stems from an imprecise

definition of conservation that emphasizes effects rather than behavior (McDonald 1977; Taylor 1988; Wodzicki 1981). In the absence of an operational definition for conservation, it is often difficult to make sense of certain practices. For example, atoll societies are depicted as possessing intimate knowledge of their surroundings and were consequently able to live in harmony with their environment (Liew 1990). This knowledge of the environment, also referred to as “traditional ecological knowledge” may have more to do with a utilitarian view of resources than a concern for conserving them.

Optimal foraging theory (OFT) is one of the most active areas of research in the field of human behavioral ecology. Its focus on subsistence strategies has made it particularly appealing to ethnographic and archaeological studies. In line with evolutionary theory, biologists have proposed that animals will forage in a manner that maximizes fitness at the individual level (Stephens et al. 2007). In a similar way, a number of anthropologists have suggested that people will readily adopt those behaviors that contribute to their survival and reproductive success. Despite criticism, it may be said that foraging models could be more relevant to human foragers than to other species because of the ability among humans to process vast amounts of information about their environment to guide them toward the optimal choice, thereby maximizing fitness (Smith 1983 and references therein). It should be emphasized that organisms are unlikely to achieve an optimum level of resource acquisition. Predictions from foraging models attempt to specify the optimum state under given environmental conditions, which are then tested against the behavior exhibited by particular organisms to determine the fit between observation and prediction (Kormondy and Brown 1998:).

Models derived from OFT lead to some predictions about how organisms, including humans, should act under specific circumstances. It is predicted that they choose food or prey types that maximize their short-term harvesting rate. An increased availability of food is assumed to increase fertility and survivorship, and minimizing the amount

of time spent foraging enables the forager to pursue other fitness-enhancing activities. Thus, natural selection would favor organisms that forage more efficiently. The optimal diet is usually determined by considering the amount of energy acquired to energy expended, as well as the time required to search and handle each prey type (handling includes time spent pursuing, capturing, harvesting, and processing a prey type into an edible form).

When decisions are costly in terms of short-term harvest rate maximization, but increase the sustainability of the harvest, there is the possibility that conservation replaces optimal foraging as the strategic goal (Alvard 1993). While “genuine” conservation is opposed to short-term efficiency, it may be compatible with long-term foraging strategies (De Boer and Prins 1989). Conservation for the sake of use (“resourcism” as defined by Oelschlaeger [1991:286]) should not be confused with other wilderness philosophies grounded in non-use or moral principles (Ratcliffe 1976; Redford 1996; Sponsel 2012).

CONTEMPORARY SHELLFISH GATHERING IN KIRIBATI

The *I-Kiribati* (people of Kiribati who were the original inhabitants of Gilbert Islands in eastern Micronesia) were horticulturalists/fishers like most other societies in Remote Oceania. Extensive marine resource exploitation, including shellfish gathering, was remarked upon in early ethnographic descriptions (Wilkes 1845). Today’s visitor is equally struck by the high densities of discarded shells distributed across the landscape (see Figure 3). A significant rise in shellfish consumption was noted on the main atoll, Tarawa, in recent decades, a phenomenon linked to changes in water circulation when causeways were built in the 1960s, encouraging the establishment of certain species and increased fertilization by sewage-driven nutrients (Paulay 2001). At certain times, combined shellfish catches could exceed 40% (by weight) of marine



Figure 3. *Anadara uropigimelana* midden.



Figure 4. *Tridacna maxima* harvesting.

resource landings, with up to 11% of households dependent on shellfish as the main source of protein. The total harvest for the bivalve *Anadara uropigimelana* has been estimated at close to 1500 t per annum. At the same time, local shellfish gatherers noticed declines in size and abundance of this particular species, compelling them to forage in deeper lagoon waters. Prior to European contact, giant clams provided the raw material for adz blades (Koch 1986). These were quickly replaced by metal. Empty valves of the giant clam *Tridacna gigas* are still widely utilized as feeding and drinking troughs for pigs. Other species continue to serve a variety of functions, notably for the manufacture of ornaments.

OPTIMAL FORAGING

Moving beyond the confines of the heavily urbanized/commercialized and crowded atoll setting of South Tarawa, I argue that “traditional” patterns of shellfish gathering on some of the outer islands of Kiribati conform to the predictions of OFT. The research draws on several years of ethnographic and ethnoarchaeological observations, supplemented by more recent archaeological and ecological work (Thomas 2009), relevant to the wider question of conservation behavior anecdotally associated with small island societies faced with limited resources.

A description of materials and methods can be found in Thomas (2007a, 2007b).

Patch Choice

The *I-Kiribati* recognize three main patches in the intertidal to shallow subtidal regions of the lagoon: (1) near-shore; (2) sand flat; and (3) seagrass. The near-shore patch includes all features intersecting the shoreline, occasionally extending to within 100 m of shore where conglomerate tongues and/or gravelly sand spits occur. The sand flat is a wide, gently sloping expanse occupying most of the intertidal, but also comprises areas of mangrove. Seagrass beds are highly productive grounds for a variety of shellfish and are also important in fishing because of the high concentration of nutrients. A fourth patch, “offshore”, is also recognized in the deep section of the lagoon of South Tarawa where intensive harvesting of *A. uropigimelana* was carried out in the 1990s. On other atolls, intensive harvesting of a small species of giant clam, *Tridacna maxima*, took place along the leeward reef platform (see Figure 4).

The ocean side of all atolls is less frequently exploited than the lagoon, but includes three patch types: (1) near-shore; (2) reef flat; and (3) reef crest. The near-shore is similar to the lagoon side. The wide reef flat consists of a hard coralline surface interspersed by sandy pockets and some mangroves. The reef crest is seldom exploited compared to the other patches because of

Table 1. Shellfish return rates by patch type (6 years aggregate).

Patch type	Overall returns (kcal/min)
Seagrass	5.3 (<i>SD</i> = 3.5)
Sandflat	3.6 (<i>SD</i> = 3)
Near-shore (lagoon and ocean)	0.6 (<i>SD</i> = 0.5)
Offshore (South Tarawa)	15.4 (<i>SD</i> = 9.6)
Leeward reef (diving)	16.3 (<i>SD</i> = 11.5)
Leeward reef (walking)	7.7 (<i>SD</i> = 3.5)
Reef flat	1.2 (<i>SD</i> = 1.2)
Reef crest	0.2 (<i>SD</i> = 0.1)

the limited time foragers can collect offshore during low spring tides, and low overall returns. Table 1 shows return rates in the various patches.

Shellfish gathering is focused separately in the patches, each defined as “fine-grained environments” (MacArthur and Pianka 1966:603), although on occasion foragers will visit and gather from more than one patch. The locations of patches are generally well known. Foragers venturing beyond traditional village boundaries can rapidly collect information from kin groups about patch location and quality. Seagrass beds are the focus of the most intensive harvesting insofar as tide conditions permit (Paulay 2001). It is not clear, however, to what extent foragers are willing to travel to reach these productive beds. Observations of foraging behavior, interviews, together with examination of contemporary shell midden, suggest that overland travel usually takes place in the direction of patches roughly facing settlements, although once inside the patch, considerable movement may occur parallel to the shore.

Predictably, near-shore patches (on both lagoon and ocean sides) are significantly less productive than either seagrass or sand flats (seagrass vs. near-shore, two-tailed *t*-test, $t = 4.42$, $df = 19$, $p < .001$; sand flat vs. near-shore, $t = 3.44$, $DF = 37$, $p = .001$). With the exception of one foraging bout, near-shore

foraging took place only when the more productive patches were not easily accessible. The low overall returns from ocean reef flats in comparison to seagrass and sand flats are significant ($t = 3.14$, $df = 16$, $p = .006$; $t = 2.27$, $df = 34$, $p = .030$). Yet, reef flat foraging may demonstrate patch sampling and thus violate the assumption of constancy in patch quality.

The wide distribution of many shellfish prey types across extensive patches would probably not result in step function depletion (Kaplan and Hill 1992), where the energy gain per unit time remains constant until the last prey item is harvested, although for certain prey types that can be easily seen and distributed within relatively small patches, foragers may remain in a given patch until the energy gain drops to zero. For example, several giant clams of the species, *T. maxima*, occurring on microatolls may provide a context for this foraging strategy. In most cases, however, foragers appear to leave patches when faced with diminishing returns.

The marginal value theorem addresses the issue of optimal time allocation to each patch (Charnov 1976). It assumes that foraging gradually depletes resources, resulting in a decline in the net return rate from each patch as a consequence of “exploitation depression”. Heavy predation may also lead to “behavioral depression” (Charnov et al. 1976), when prey alter their behavior in ways that make them more difficult to be harvested; for example by changes in flocking behavior, greater alertness, or deduction of certain activities such as feeding and courting. Diminishing returns can also result from changes in the foraging environment, without affecting patch productivity. In the context of shellfish gathering, tidal movements may act as constraints on decisions to either continue searching in a high-ranking patch and face diminishing returns, because of increasing difficulty in visually locating prey with the incoming tide, or to move to a less productive patch closer to shore.

A predator should leave a patch when the marginal capture rate (i.e., the instantaneous capture rate at the end of a foraging bout within that patch) drops to the average capture rate for the entire set of

patches utilized (including travel time between patches). As the overall productivity of a habitat (set of patches) increases, less time should be spent in any one patch, whereas declining productivity should lead to an increase in optimal patch-stay times. Testing predictions from the marginal value theorem is made difficult by the need to collect detailed information on patterns of movement, time budgets, and return rates, none of which have been satisfactorily recorded in either this or other studies (Kaplan and Hill 1992; Smith 1983).

A correlate of the theorem referred to as the “differential time allocation” hypothesis (Smith 1991:258), has been cited as a reasonable, albeit indirect, test of the question of diminishing returns assumed in the theorem. According to this hypothesis, foragers ought to focus on the highest ranking patch while ignoring or dropping all others, given equal access. Because the most productive patch is expected to provide a higher gain than a lower ranking patch, then it should receive a greater allocation of foraging time. A switch to a lower ranking patch may be interpreted as a sign of decelerating gain in the high-ranking patch. Conditions similar to those described above were noted when foragers shifted their activities from the low- to mid-intertidal sand flat to gather the small bivalve, *Gafrarium pectinatum*, and then into the upper intertidal gravelly sands to search for the larger, but more widely dispersed bivalve, *Asaphis violascens*, when the incoming tide limited foragers’ ability to locate prey in deeper, more productive areas (see Figure 5).

More than any behavior associated with conservation, patch switching has been cited as a possible indication that people are conserving resources. But as prey become less common as a result of predation, or as they become more cryptic in light of exploitative pressure, an efficient forager may decide that it no longer pays to stay in a patch and search for increasingly elusive prey. Provided that travel time to the next best patch is not too costly, a patch type can be temporarily abandoned. Depending on the biological attributes of prey within that patch and the time lapse between visits, prey types may



Figure 5. Foraging for *Asaphis violascens* in upper tidal gravelly sands.

be able to recover from intensive harvesting. Foragers are not paying short-term costs by leaving a patch because they can do better in another one. Alvard’s (1993) distinction between conservation behavior *per se* from its effects (“epiphenomenal” conservation), is pertinent in this context in that conservation may incidentally follow optimal foraging decisions, as illustrated by patch switching.

Among all documented instances of patch switching (or movements within a patch perpendicular to the shoreline), there was little to support the idea that foragers were motivated by a desire to conserve resources. Rather, the motivation always appeared to be tied to diminishing returns and the need to move to other patches. When tide conditions changed, foragers either moved from low-ranked patches to high-ranked patches or vice-versa. This behavior is consistent with short-term maximization.

Patch Sampling

Foragers entering a patch may gain knowledge of patch quality by joining groups already engaged in harvesting. A distinction needs to be made between foraging group size, which refers to the number of individuals who participate together in a specific activity and are expected to pool their catch, and clustering of individuals, including those from different groups, while foraging. The degree of clustering is a function of

resource predictability and distribution. The more a prey type is unpredictably clumped, the greater the advantage of flocking (Smith 1981), because this reduces the time each forager spends searching.

Patch depletion and subsequent high spatio-temporal variation in prey recruitment often lead to situations where shellfish become unpredictable resources, with some marked differences in clumping. The gastropod *Strombus lubuanus* and the bivalve *G. pectinatum* exhibit some of the highest degrees of clumping (the former primarily through behavioral attributes; the latter by virtue of its overall density). However, while both could be defined as “patches”, their specific distribution (i.e., epifaunal vs. infaunal) determines whether synchronous foraging by more than one forager will increase or reduce individual efficiency. For the highly conspicuous *S. lubuanus*, it does not pay for even a small party of two to scan a relatively restricted area. Depending on tide conditions, foragers may be separated from each other by several tens of meters. By contrast, the cryptic habits of dense *G. pectinatum* permit tighter clustering of individual foragers, sometimes on the order of less than a meter, with little interference and competition. On the other hand, foragers are widely separated (often in excess of 100 m) while foraging on the ocean reef flat. This is consistent with the low density of high-ranked prey such as the giant clam *Hippopus hippopus*. Unlike other infaunal prey, such as *G. pectinatum*, foragers rarely excavate more than one *A. violascens* in a single digging motion (which usually involves digging straight down into the hard, gravelly matrix compared to the shallower, scraping motions which characterize *G. pectinatum* in the sand flats).

Knowledge of patch quality based on environmental cues and the sharing of information with other foragers contrasts with information while foraging (Stephens and Krebs 1986:28). Models of information use (Stephens 2007) suggest that foragers do obtain information from conspecifics. Fluctuating resources require this kind of assessment strategy, but given the cost of sampling, under what circumstances would it be

beneficial to sacrifice short-term return rates to acquire information for long-term gains?

Although yields may fluctuate from the dual impact of forager-dependent and forager-independent processes, to be of value, information about change should focus on those attributes of the environment that do not fluctuate too rapidly. For example, if large concentrations of mobile *S. lubuanus* are known to occur, such knowledge would provide little benefit in the long-term because the “patches” are likely to shift. However, the discovery of sedentary bivalves may be more valuable in planning for future gathering, bearing in mind competition from other foragers or marine organisms that feed on shellfish.

Together with the rate of change, there should be large enough differences in return rates between patches or even between sections of patches to justify expanding effort in information acquisition. Patch depletion and the vagaries of successful prey recruitment (e.g., *A. uropigimelana* in the Bonriki-Temaiku seagrass area South Tarawa; see Thomas 2007a) are important factors that determine the usefulness of an assessment strategy. The implication of a sampling strategy is the patch residence time, which differs from the marginal value theorem: foragers either stay longer or leave sooner than predicted by the theorem (Stephens and Krebs 1986:91). It is possible that the shift from the sand flat to seagrass at Bonriki-Temaiku began as a sampling strategy. Near Tebanga Village, Maiana Atoll, people focused almost exclusively on *G. pectinatum*. Foragers commonly limited their activities to the mid-intertidal, but in two observed cases, appeared to be sampling the low intertidal to assess the state of resources away from shore. Interviews suggested that a few years previously, *A. uropigimelana* had been abundant in the area, but then steadily declined, which resulted in foragers switching to *G. pectinatum*. Some foragers, however, had the opportunity to come into contact with high-ranked prey types while travelling to their small seaweed plots in the low intertidal. Reports on the status of shellfish occurring in the area filtered back to the community and sometimes encouraged people to search



Figure 6. Patch sampling (giant clams).

for *A. uropigmelana* in places they would normally ignore.

Another example of sampling strategy is illustrated by observations and interviews on the ocean reef flat. Foragers were monitoring giant clam distribution (see Figure 6). Areas surveyed were carefully selected to avoid spending time in previously searched sections. Up to three months passed before a specific patch section was revisited, presumably to allow for the recovery of heavily depleted resources. However, “patch recovery time” (Bennett 1991) in one instance resulted in less than 20% of the initial caloric intake derived from *H. hippopus*. It was suspected that other foraging groups had exploited some of the recovered biomass in the interim.

Patch sampling may lead to deviations from short-term rate maximization assumed in the marginal value theorem. Because predictions from the latter model could not be properly tested, however, statements about patch sampling where foragers may either stay longer or leave sooner than predicted by the theorem, remain speculative. But, if patch sampling determines an early patch departure time, then OFT provides an explanation as to why certain prey types may be given time to recover in ways not anticipated by the theorem. Natural selection specifies the conditions that may benefit from a sampling strategy, thus sacrificing short-term gains to acquire information for long-term gains, but unless *intent* to conserve can be established,

patch sampling cannot be considered a conservation strategy.

While a distinction between intent and behavior should be kept, and predictions from foraging models are tested against behavior, the criterion of intent remains important in deciding whether a strategy such as patch sampling is synonymous with genuine conservation (see Whitaker 2008 in the context of intentional cultivation of intertidal resources). Although the question of motivation is problematic from evolutionary and archaeological perspectives, this type of information is available ethnographically. A brief note to that effect relates to the absence of clear reference to resource conservation by shellfish gatherers despite assertions that Kiribati society still possesses a deeply rooted conservation ethic (Wilson 1994; Zann 1985).

Risk

Risk is closely related to sampling (Sosis 2002; Winterhalder et al. 1999). Two strategies to reduce risk include resource sharing/reciprocal territorial access and storage (Colson 1979; Smith and Boyd 1990). Both entail costs to the individual, yet the costs for not employing them in appropriate contexts may be even higher.

Several hypotheses for food sharing have been proposed (Winterhalder 1997). In the present context, there is evidence that large package size and asynchrony in the daily success rates of foragers are good predictors of the kinds of resources shared beyond the household. Eels, sharks, and large species of giant clams are shared among all foragers who cooperated, as well as individuals who did not participate in foraging efforts. Often, they included non-kin of neighboring households and anyone who happened to be visiting at the time (kin or non-kin). Admittedly, sharing of this sort does not in itself constitute evidence of risk reduction reciprocity. For example, “tolerated theft” (Blurton-Jones 1984) or the social benefits that may accrue from consistent one-way flows between distributors and recipients, notably at ceremonial gatherings where the above-mentioned prey types are likely to be presented,



Figure 7. Fishtrap.

provides an alternative explanation. By acquiring large packages, it might be argued that men expect to gain the attention and support of scroungers, most notably women.

Traditionally, repeated boiling, drying, and salting helped preserve various resources. Sharing and hoarding are contrasting strategies to reduce risk, and the kinds of resources that are widely shared and those that are stored are quite different. Because traditional land tenure is still recognized, terrestrial production and food preservation belong to extended families. Most marine resources are no longer culturally regulated, which explains why a successful fisherman sometimes relinquishes part of his catch to distantly related kin or non-kin. Remnants of a more extensive tenure system, such as fish traps and “gardens” for the live storage of giant clams (further discussed below), are increasingly at odds with the open access policy governing lagoon and ocean habitats (see Figures 7 and 8).

Risk-aversion strategies are important in determining whether genuine conservation has been selected for. Although sharing of certain marine resources does take place, there is no unequivocal evidence to suggest that the *I-Kiribati* share to prevent over-exploitation. While sharing and hoarding are often depicted as contrasting strategies to reduce risk, they need not be mutually exclusive. For example, some households might hoard pandanus fruit or dried fish in times



Figure 8. Giant clam “garden.”

of abundance for possible sharing in times of scarcity.

A form of giant clam aquaculture has been reported in Kiribati and other Pacific Island communities (Bliege Bird et al. 1995; Foster and Poggie 1993; Hviding 1993; MacLean 1978; Moir 1989), representing the live storage of animal meat. But, does this require an initial cost in consumption, which would make it a good candidate for conservation?

Storage is an effective risk-reduction strategy, and by definition it involves delayed consumption. Although there are costs to storing foods (they may deteriorate rapidly or may be scavenged or stolen), the live storage of giant clams does not appear synonymous with conservation (even though conservation may be a byproduct of live storage—for instance, Alvard and Kuznar’s (2001) idea of animal husbandry as conservation) because costs are minimal in evolutionary terms relative to costs involved in not harvesting a high-ranked prey on-encounter for immediate consumption. Only when there is an excess are giant clams stored (live or salted). Return rates for *T. gigas* and *H. hippopus* are variable because of the wide range in size of individual prey items. It may be that small prey items (<40 cm) actually fall outside the optimal diet. Nevertheless, giant may be regarded as high-ranking prey, but still inferior to most other marine resources. The fact that both taxa are harvested incidentally is in itself revealing. Cases where live specimens

were kept correlated with large fish catches, so that transplanting them does not involve a short-term cost. It would be possible to identify giant clam “gardens” archaeologically by the concentrated distribution of valves in shallow water, particularly since *T. gigas* is not naturally found in near-shore, shallow water environments prone to turbid conditions.

HISTORICAL ECOLOGY

In recent years, historical ecology has emerged as one of the most useful and comprehensive approaches to understanding how environments and landscapes were affected by climate change, early human settlement, historical interactions, and modern development and industrialization (Balée 2006; Fitzpatrick and Keegan 2007; Rick and Erlandson 2008; Russel 1997). This approach, which combines the natural and social sciences using paleoecology, archaeology, land-use history, and long-term ecological research, has great potential for examining natural and cultural phenomena behind changes to island ecosystems (Fitzpatrick and Intoh 2009; Kirch and Hunt 1997).

Compared to “high” volcanic islands, atolls and table reefs have received scant attention from archaeologists focusing on historical ecology. More specifically, little is known about paleoclimatology, the introduction of exotic fauna, the extent of human-induced environmental impacts, and social transformations on low coral islands prior to Western contact (Allen 2006; Anderson 2006; Pregill and Weisler 2007; Sachs et al. 2009). Given the unique environmental challenges posed by coral islands, it is all the more surprising that pre-European ecological research has been largely neglected. By contrast, the last two decades have witnessed a host of environmental studies, from sea-level rise to contemporary human impact on terrestrial and marine ecosystems (Thomas 2003).

A number of studies have examined the long-term effects of human exploitation and environmental change on fish, invertebrate,

and sea mammal populations resulting in declines in species diversity and reduction in average age and size. But as Allen (2003) noted, there is a need to understand how these collective impacts might have fundamentally altered marine ecosystems.

As noted above, it has been suggested that people living on coral islands were more acutely aware of environmental constraints than communities on larger continental or volcanic islands and thus realized at an early stage the need to conserve resources. The testing of predictions from the foraging models described in this study, together with attributes of selected shellfish taxa to account for prey resilience, and zooarchaeological analyses comparing species composition and size with length of human settlement (Catterall and Poiner 1987; Poiner and Catterall 1988; Thomas 2001; Weisler 2001b), indicate that the apparent balance between people and their resources in terms of deliberate conservation strategies may not stand scrutiny.

While faunal losses have not been widely reported from coral islands, with their chronologies often remaining uncertain (Drew et al. 2013; Steadman 1989; Thomas 2004), the very high ratio of reef to land, typical of most atolls, would have ensured abundant protein resources, with little noticeable impact by human communities that remained generally small. Weisler (2001a) presented evidence for the extirpation of the Bullmouth helmet shell (*Cypraecassis rufa*) from Utrök Atoll in the Marshall Islands. However, the presence or absence of marine organisms in a particular habitat is largely determined by chaotic or unpredictable recruiting events that shape the structure of reef assemblages over time (Paulay 2001). This is not to deny that some species, by virtue of biological, ecological, and behavioral attributes, display different levels of resilience to human exploitation. The disappearance of *T. gigas* in the Marianas, New Caledonia, and Fiji is a case in point (Munro 1989). Along with other large members of the *Tridacna* family, this species of giant clam is considered vulnerable to gathering pressure.

DISCUSSION AND CONCLUSION

Predictions from optimal foraging models provide a means to test the hypothesis of short-term costs and gains in food acquisition. They are therefore relevant to discussions related to the value of traditional ecological knowledge for conservation (Alvard 2002; Smith and Wishnie 2000) and for understanding likely foraging strategies in the past. Testing these predictions archaeologically remains problematic, as the archaeological record often cannot capture the variability proposed in even the simplest foraging model (Broughton and Grayson 1993; Madsen and Schmitt 1998; O'Day 2004; Thomas 2002).

Low coral islands, regarded among the most fragile and challenging environments for human existence, present cases of both sustainable living over centuries as well as possible instances of resource depression or where societies did not endure (Di Piazza and Pearthree 2001; Weisler 2003). The paucity of anthropogenic impacts noted by Anderson (2002) in the Line and Phoenix Islands does not necessarily imply that coral islanders were actively managing their environment and resources. Relatively low population densities and abundant reef resources may have ensured sustainable living, while the question as to why these islands were abandoned prior to Western contact remains. Although work continues in building up coral island chronologies throughout the Pacific, there is a need to address broader patterns and processes similar to those proposed for the "high" islands (Kirch 2000:302–325). Results have been partially achieved for the atolls and table reefs in the Marshall Islands (Weisler 2001c) and Kiribati (Thomas and Horrocks in prep).

The interlinked topics of "sustainability" archaeology, historical ecology, and conservation biology (Hardesty 2007; Kirch 2005; Lyman and Cannon 2004; Thomas 2012; van der Leeuw and Redman 2002) highlight the many challenges faced by contemporary Pacific Island communities as they attempt to cope with changing environments, economies, and social values, which now

more than ever pose a threat to sustainable livelihoods.

In a general sense, it can be asserted that islands, and especially atolls and table reefs, are microcosms of larger, but equally fragile environments. While debate continues regarding the role of people versus climatic factors as the leading cause for environmental change, it is reasonable to assume that human impact can exacerbate the effects of natural perturbation, leading at times to major social disruption. More data are required to evaluate the degree and main causative agent of past environmental change on coral islands in the Pacific.

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