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# Patterns of marine harvest effort in southwestern New Georgia, Solomon Islands: resource management or optimal foraging?

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## Abstract

Numerous researchers in the field of maritime anthropology have accepted the notion that marine tenure institutions are cultural systems designed to conserve marine resources. This idea has attained wide acceptance without the development of an ecological model to account for the occurrence of conservation and/or depletion of resources. In this study, foraging theory is offered as an alternative theoretical framework to examine the diversity of human resource exploitation strategies in coastal ecosystems. The results generated by the foraging models are considered here in relation to their significance in linking ecological evolutionary approaches in anthropology with coastal resource management. © 1998 Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

In this paper, I present an approach to the study of customary marine tenure in anthropology that departs from recent studies in the field. Models drawn from evolutionary ecology, specifically from optimal foraging theory, are offered as an alternative theoretical framework for studying indigenous resource management strategies. The utility of foraging models to analyze coastal foragers is assessed by applying two related models: the patch choice [1] and the marginal value theorem [2] patch time allocation models. These are employed to generate predictions on the daily and seasonal movement of marine foragers in the Roviana Lagoon, southwestern New Georgia, Solomon Islands (Fig. 1) and to assess their possible impact on the marine environment. The results yielded are then considered with regard to their significance in linking ecological evolutionary approaches in anthropology and the management of coastal aquatic resources.

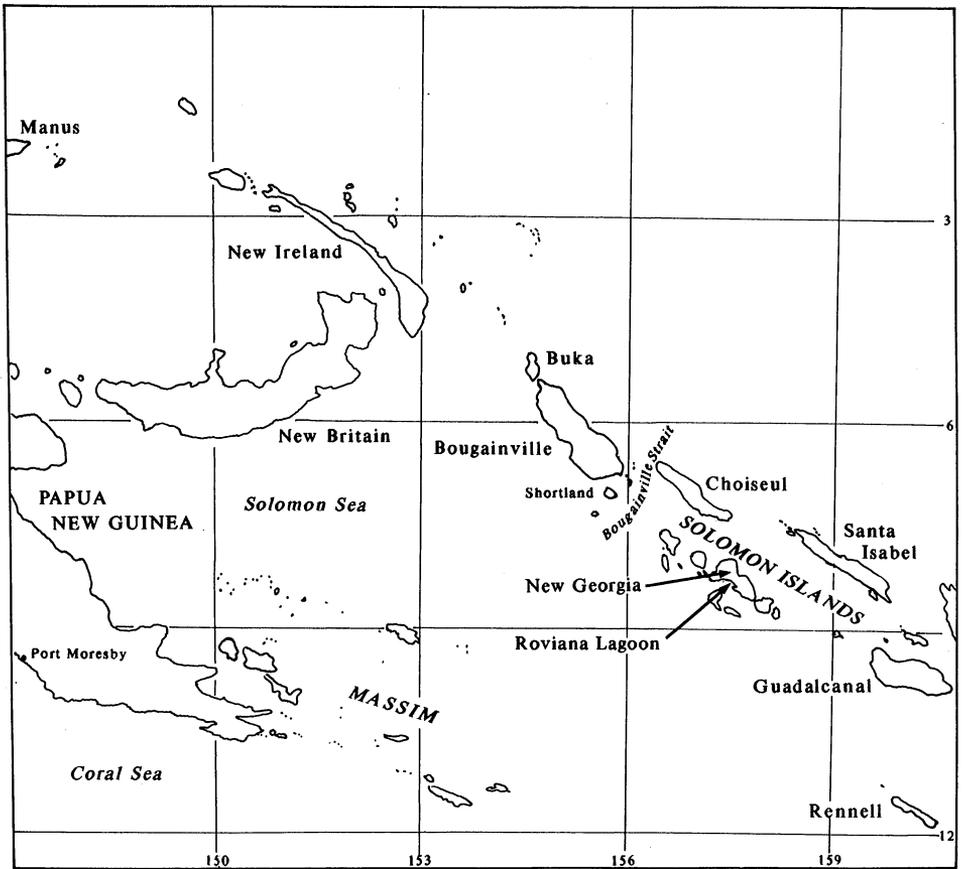


Fig. 1. The Solomon Islands.

The purpose of foraging models is to formulate testable predictions that can account for the decisions (*choices*) that foragers make in the types and abundance of food they consume (*diet breadth*), the areas utilized (*patch choice*), and the time spent foraging in them (*patch use*). Foraging theory models are based on the simple assumption that foragers' decisions are formulated to maximize short-term energy return rates while foraging [3]. Foraging theory is an evolutionary approach because if foragers are successful in maximizing food returns and minimizing resource harvest time their Darwinian fitness may be enhanced. The patch choice model predicts a foragers' selection of where to forage, and the marginal value theorem complements it by forecasting the time that a forager will spend harvesting prey in a patch.<sup>1</sup>

<sup>1</sup> The term "patch" is used here synonymously with the terms "fishing ground" or "ground".

The use of these models here demonstrates that a fisher's<sup>2</sup> selection of habitats<sup>3</sup> across seasonal variation and the foraging times spent in them are subject to the expected rates of return for foraging in those areas. If fishers' behavior conforms to the models' predictions, fishers are not expected to refrain from overexploiting the resource and assure the future sustainability of the local marine environment but, rather, to attempt to exploit their environment as efficiently as possible. The foraging hypothesis does not reject the possibility that resource conservation may occur as a *side effect* of a resource maximization strategy, but specifies the conditions under which optimal foraging strategies should take place. If conservation occurs, it does so under conditions where a fisher's movement between patches (i.e. fishing grounds) to increase short-term foraging efficiency results in the abandonment of remaining prey. The alternative hypothesis, from the standpoint of evolutionary ecology, suggests that fishers can mitigate resource scarcity by way of controlling their short-term intake rates (i.e. cease to exploit resources) to increase long-term sustainable harvests [4]. That is, foragers will actively restrain their effort, consciously or unconsciously, to reduce pressure from habitats experiencing a perceived or absolute decline in productivity. Analysis of empirical data collected during fieldwork from May 1994 to December 1995 suggests that the decisions made by fishers in the Roviana Lagoon are consistent with the predictions of the foraging theory models presented here.

## 2. The anthropological context

It is now almost two decades since McCay [5] cautioned researchers in maritime anthropology about using a systems ecology approach to analyze resource management in coastal fisheries. Systems ecology, as applied in anthropology, examines the major biotic and abiotic components that regulate the functional constituents of social and ecological systems [6]. McCay emphasized the need to focus on the individual actor as the locus of analysis, rather than trying to assess the complete characteristics of fisheries institutions [5]. Yet, most researchers in customary marine tenure [7], (see footnote 4) have not heeded this warning. Despite efforts to document indigenous corporate institutions of sea tenure [8–16] little has been done to understand the micro-ecology of human actors' interaction with the marine environment.

Numerous researchers [10, 11, 13] in the field of maritime anthropology have accepted, without empirical support, the notion that marine tenure institutions are cultural systems designed to conserve marine resources, and have ignored the daily behavior of the actors whose cultural systems they seek to analyze. This line of

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<sup>2</sup> The term "fisher" and "forager" are used synonymously here. In the Roviana vernacular the term *tie habu* is used to refer to a "person that fishes" regardless of their sex. Similarly the term forager or fisher is used in this paper to refer to individuals of either sex.

<sup>3</sup> The term "habitat" is used here to refer to an ecosystem type such as "shallow reefs" or "lagoon passage". It also refers to an *assemblage* of fishing grounds sharing similar environmental characteristics.

<sup>4</sup> The terms "customary marine tenure" [7] is used synonymously with "corporate marine tenure", "sea tenure" "indigenous corporate institutions" and "indigenous institutions of resource management".

reasoning ensues from a general reaction by anthropologists to Hardin's "tragedy of the commons" [17]. Investigators have argued that Hardin's thesis, which states that unregulated access to common property resources leads to unchecked exploitation and environmental degradation, fails to distinguish between "common" tenure and "open" or "free" access [18, 19]. Maritime anthropologists have shown that littoral waters are usually controlled by identifiable groups of people and that access to "common" resources is not "open" to everyone, as presumed by Hardin [6, 11, 20]. This disclaimer of Hardin's postulate, in turn, has led to the widespread belief that corporate (i.e. "common") systems of resource management can lead to fisheries regulation (i.e. conservation).

Acheson and Wilson have recently argued [21] that "folk societies" having customary entitlement to their sea territories can properly manage their biotic resources by means of various cultural practices. Referring to Oceania, the authors argue that "conservation efforts were rooted in the reef and lagoon tenure system" [21, p. 582]. Similarly, Foster and Poggie [12, p. 6] contend that "customary marine tenure practices evolved over the centuries to ensure that marine resources were conserved for sustained use." This parallels the reasoning of many cultural ecologists who maintain that hunter-gatherers have institutions and practices designed to maintain harmony with the natural environment [22, 23]. The absence of apparent resource degradation in areas occupied by indigenous people invites this kind of speculation [24]. This view of indigenous resource management has been employed without the development of a rigorous ecological model to account for the occurrence of conservation and/or depletion of resources within corporate institutions of marine tenure.

The systems ecology approach to sea tenure research is problematic in three respects:

- it lumps existing variation in human foraging strategies into simple typologies such as "conservationist" versus "non-conservationist";
- it does not articulate a set of middle range methodologies to link observed phenomena (e.g. conservation) and theory; and
- researchers rely on functional explanations to justify ecological causation (i.e. marine tenure and conservation) but fail to specify the mechanisms producing the behavior with the beneficial consequences [25, 26].

Researchers in the field of marine tenure have tended to polarize into two camps. One argues that indigenous environmental knowledge, cultural practices, and marine tenure are responsible for the conservation of marine resources [10–13]. Conversely, several authors [27, 28] have argued that marine tenure systems are not intended for resource management purposes and thus cannot be expected to conserve resources. For instance, Polunin's research in Papua New Guinea and Indonesia raises doubts about the dependability and utility of traditional methods of sea tenure in relation to modern managerial practices, since, according to him, traditional institutions were created to "gain and not restrain" [28, p. 267].

In his recent monograph on Marovo fishing communities, Hviding [29, p. 63] argues that the polarization of indigenous practices into conjectural categories, such as "conservationist" versus "non-conservationists" distracts from the real pressing issue of indigenous rights to manage and control resources. Hviding also rejects the

imposition of “western ontological schemes” to the study of ecological relations between people and their environment [29, p. 26]. However meritorious, Hviding’s focus on indigenous rights ignores the empirical and theoretical validity of ecological approaches in anthropology that seek to understand human resource exploitation practices and their possible impact on the environment.

Although I do not concur with Hviding’s judgment of ecological anthropology, I do agree that compressing existing variation in human resource exploitation practices into simple typologies such as “conservationist” or “non-conservationist” is misleading and erroneous. The range in variability and possible outcomes of human behavior cannot be easily simplified by being placed into reified categories. In this sense, foraging theory may offer an adequate alternative theoretical framework to examine the diversity of human resource use strategies. Resource conservation and depletion, as viewed under the rubric of foraging theory, are contingent on varying environmental conditions (e.g. patch productivity) and the effect of these in the structuring of human foraging practices.

Some anthropologists have opposed using optimal foraging theory because they question its applicability to the study of human culture [30]. The main charges against foraging models are that they are reductionistic and cannot account for the historical and socio-cultural factors that structure human societies. Although foraging models cannot account for all of human behavior, their purpose is not to examine every component of socio-cultural systems, but to explain the existence of specific human behavioral traits [31]. The models presented here are not designed to replace detailed qualitative ethnographic fieldwork. Rather they are to present a set of heuristic models that can aid researchers in the formulation of hypotheses to account for patterns of human interaction with the marine environment.

Foraging theory models are commonly used to interpret hunter-gatherer foraging behavior [26, 32, 33]. Despite this interest, the application of optimal foraging theory has been generally limited to hunter-gatherers in terrestrial habitats. Most studies have concentrated on hunting in terrestrial habitats in the Amazon basin. Beckerman’s [34] focus on the fishing practices of the Bari of Colombia, while an exception, is still geographically confined to South America. Other studies that touch on the subject of aquatic resource exploitation strategies include Smith’s [31] Inujjamiut study, Begossi’s [35] study of patch choice among Brazilian fishers, and the study by Bird and Bird [36] on Torres Strait Islanders food sharing practices. Difficulties in defining the spatial characteristics of marine habitats coupled with a research bias towards terrestrial habitats encourage this neglect. Prey mobility in aquatic environments presents a further challenge.

### **3. The foraging models**

All foraging models share four common elements that need to be specified. These are the

- participating actors,
- set of choices made by foragers that are analyzed (e.g. patch choice),

- unit of maximization (or minimization), and
- set of intrinsic and extrinsic constraints faced by the forager.

Roviana fishers are the actors, and the decisions evaluated here, as presented earlier, are patch choice and patch residence time.<sup>5</sup> The third issue needing clarification is the unit of maximization.

Anthropologists using foraging theory in the study of hunters and gatherers have generally used energy as a measurement of optimization [31, 33–37]. Most fishing effort in the Roviana Lagoon is directed toward subsistence, hence energy is used in this research as the currency maximized. Foraging efficiency is best expressed as the “net return rate” per capita [31]. This rate is equivalent to the energy gained during fishing (the kcal value of the catch) minus the labor input<sup>6</sup> (labor costs incurred during foraging including travel, search and handling times) divided by the total residence time at a patch.<sup>7</sup> The intrinsic constraints that limit Roviana fishers include such biological limitations as the ability to tolerate extraneous forces like temperature.<sup>8</sup> Extrinsic factors that may limit a fisher’s ability include such constraints as knowledge of the environment, changing patch productivity according to shifts in the tidal and lunar cycles, and other environmental elements.

The patch choice model predicts that patches (or habitats) will be selected by a forager according to the mean return rate of that patch [1, 38, 39]. Patch types (e.g. habitats) are ranked from highest to lowest yielding, and are added to the foraging range until savings in travel time are outweighed by a lowering in mean return rate for the set of utilized patches [37]. There are some pressing limitations in the application of this model. In particular, the model does not predict time allocation nor does it specify the degree of resource depletion in a patch. That is, it assumes that energy gained during harvesting remains constant until a sudden drop to zero gain (all resources are exhausted) when a forager moves on. This is unlikely for most natural situations where hunting or fishing grounds can either undergo seasonal foraging-unrelated changes in mean productivity, or display diminishing returns as foraging pressure increases [3, 40].

The marginal value theorem predicts that:

- the optimal strategy (in terms of energy maximization) for a subject foraging in any given group of patches is to abandon a given patch when the marginal rate of return is equal to the mean return for the entire habitat or set of patches (including travel time);
- if the overall environmental productivity decreases without affecting the gain function of a patch, then foragers should spend more time in that patch type, and conversely if productivity increases, the optimal strategy is to decrease residence time; and

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<sup>5</sup> Patch residence time is interchangeably used in this article with “foraging time per bout”, “residence time”, and “foraging time”.

<sup>6</sup> Labor cost is attained by multiplying minutes spent in a certain activity (e.g., paddling a canoe or hand lining) by standardized measures from published sources (Indirect calorimetry measurement for various activities adjusted to age, weight, and sex).

<sup>7</sup> Further divided by the number of participating fishers in the bout.

<sup>8</sup> These are not discussed in this paper. For more information see Ref. [3].

- a patch should not be used, unless it can provide a marginal rate of return equal to or greater than the mean productivity for the set of patches utilized [2, 3, 38].

In addition, McNamara [41] has shown that an increase in travel time between patches results in an increase in patch residence time and a decline in mean return rate. As a consequence, the longer it takes to find an alternative patch, it pays an optimal forager to stay longer in a patch even under conditions of declining yields. Likewise, Charnov and Parker [42] have shown that organisms display phenotypic variation in their foraging adaptive strategies and that expected harvesting practices are not uniform. “Good” foragers are expected to lower travel time and achieve a higher return rate, whereas “bad” foragers are likely to have higher traveling times and lower returns.

The marginal value theorem predicts patch residence time and thus corrects for the temporal insufficiency of the patch choice model. Further, the model assumes that patches exploited exhibit diminishing returns as foraging time increases [3, 40]. In the case of lagoon ecosystems, patch depletion generally occurs from sustained predation on sedentary species, such as coral reef fish, molluscs and certain crustaceans. A possible exception is the lagoon passage habitat, that has large numbers of pelagic species passing through on a daily and seasonal basis, and where patch productivity may be unrelated to subsistence foraging activities. Under conditions of prey mobility it is more difficult for fishers to assess patch productivity changes, and so they must constantly adjust their harvest strategies [43]. Nevertheless, it is still safe to assume that lagoon passage micro-habitats, such as reef flats and drops with predominant coral reef fish assemblages, experience patch depression as foraging times increase.

Prey mobility in aquatic environments presents a challenge in the conceptual enclosure of marine habitats as patches. The circumscription of a patch is relative to the organism that utilizes it and the set of exploitative strategies that the organism uses. That is, patchiness in the environment can exist in any spatio-temporal scale. In the case of human beings, resources targeted tend to be scattered through the landscape and found in many habitat types. This variation poses some methodological difficulties in ascribing a patch or set of patches. To overcome this problem the first step is to specify the environmental characteristics of the area. Environments can either be heterogeneous or homogeneous in nature. The variegation and discontinuity of its resource distribution determine heterogeneity of a habitat. Conversely, homogeneous environments are characterized by having uniform and evenly distributed resources. Once the environmental characteristics of an area and the distribution of resources are mapped, conceptual enclosure of exploited patches can take place.

The foraging models presented here were conceived to predict an organism's behavior in a heterogeneous environment [44]. New Georgia lagoons are appropriate ecosystems to test foraging models because local habitats are extremely mosaic, with recognizable microenvironments that are cognized by local informants as physically bounded resource patches.

In addition to the prerequisite that habitats, or set of patches, exhibit diminishing returns, the marginal value theorem also assumes that foragers encounter patches in a sequential and random fashion. Evolutionary ecologists suggest that predators

encounter prey or patches stochastically, and proceed to intake energy until experiencing patch depression, or recognizing the patch as inferior [3, 45]. For humans, this assumption is often violated because they purposively chose prey and patches to pursue. Kaplan and Hill [40] assert that it is inappropriate to use the marginal value theorem when foragers do not sequentially and randomly encounter patches, and that employing the model under these circumstances can lead to inaccurate conclusions. In the Roviana case, the stochastic encounter rule is partially met. Although true that fishers do not generally select habitat types randomly, movement within a chosen habitat tends to be more haphazard. For instance, when trolling for bonito fishers follow moving schools of fish as they surface, and when angling, micro-patches are successively and randomly encountered as fishers move through a reef complex.

Smith [31] has identified three major implications of the marginal value theorem (MVT) that deserve special consideration. First, determining the optimal time allocation to a patch cannot take place without the previous consideration of the opportunity cost of foraging elsewhere. For instance, if fishers chose to fish in shallow inner lagoon reefs during the low tide season, they are forfeiting the opportunity of fishing elsewhere. Foragers must be able to measure the cost–benefit ratio of their choices in the light of alternative opportunities. Second, the MVT explains hunter-gatherer mobility without relying on the assumption that foragers depart a patch when all resources are exhausted. The MVT suggests that if a habitat's productivity increases, a forager's optimal choice is to shift to alternative patches within the habitat before any undergoes patch depression. This prediction is counterintuitive to the widespread notion that fishers will increase residence time in a fishing ground if habitat productivity increases, and the inverse. The model suggests that as habitat productivity increases and accessible productive patches become available, per bout residence time will decrease, and as habitat productivity decreases per bout residence time will increase. Patch residence time declines when productivity increases, because foragers can do better by shifting between highly productive patches before any of them experience within-patch resource depletion (as long as travel costs do not increase). High mobility between accessible patches (within a productive habitat) allows a fisher to maintain a high return rate without experiencing a dramatic drop in the mean intake rate during foraging. On the other hand, if alternative patches within that habitat have low productivity rates it does not pay the fisher to travel to them, hence leading to an increase in patch residence time. Alternatively fishers can move to a more productive habitat type if travel costs are not too high.

Finally, Smith suggests that foragers' patch switching behavior provides a rationale to explain human resource conservation and management without having to rely on the notion that hunter-gatherers, or fishers, exert intentional resource conservation strategies. Because the MVT explains resource conservation as a possible side effect of optimal foraging, accounting for a resource conservation strategy from the standpoint of evolutionary ecology requires an alternative hypothesis [4, 46].

From the patch choice and marginal value theorems, the following hypotheses are operationalized to show how fishers at Baraulu Village, Roviana Lagoon select habitat types and the times spent foraging in them in the course of seasonal variation:

**Hypothesis 1.** Overall time allocation to a habitat type increases when seasonal productivity for that habitat increases and is higher than that of other habitats. Conversely, overall time allocation to a habitat type decreases when seasonal productivity for that habitat declines and is lower than that of other habitats.

**Hypothesis 2.** Fishers will spend less time at a fishing ground while foraging when the mean return rate of that habitat type increases. Conversely, fishers will spend more time at a fishing ground while foraging when the mean return rate of that habitat type decreases.

It is important to note that Hypothesis 1 refers to overall total hours of fishing allocated to a habitat type when habitat productivity increases or decreases in a given season. Hypothesis 2 refers to the lengthening or shortening of per bout patch residence time in relation to changing habitat productivity. For instance, if seasonal habitat productivity decreases, the habitat as a whole will be visited less often (fewer overall hours allocated). However, any time the habitat is visited patch residence time will be lengthened and fewer fishing grounds within that habitat type will be visited. Fishers will drop poorer grounds from the rank list of preferred spots *within* that habitat type and, therefore, intensively exploit fewer patches. The inverse is also true.

From this discussion a crucial distinction deserves special consideration. Fishers' diminishing pressure on habitats experiencing declining productivity can be attributed to *either* a resource management strategy or to an optimization one, making it difficult to distinguish the actual strategy. To overcome this ambiguity, the analysis of time utilization *during foraging* is of paramount significance to distinguish between a foraging strategy designed to maximize foraging efficiency from one designed to manage resources.

#### 4. Study site and the fishing community

The Roviana Lagoon lies between the Marovo and Vonavona Lagoons in the Island of New Georgia, Western Solomon Islands. It extends for over 52 km southward from Munda to Kalena Bay (Fig. 2). The lagoon is protected by a series of offshore raised reef islands between 20 and 40 m high. The lagoon, which has a maximum depth of 40 m, comprises numerous habitats. Human settlements are located both in the islets and the New Georgia mainland. From Kalena Bay, at the southeastern end of the lagoon, to Munda and beyond, rain forest covers both the New Georgia mainland and the raised coral islands that enclose the lagoon.

Several main tribal groups (*butubutu*) inhabit the Roviana Lagoon. The largest are the Saikile and Kalikoqu chiefly districts, followed by the smaller districts of Nusa Roviana (Kokorapa), Dunde, Kekehe, Lodu Maho, and Kindu. Although each of these groups has independent control of its land and sea estates (*pepeso*) they all share kinship ties. These ties have originated from a long history of tribal inter-marriage between the inland groups of Kazukuru, Taghosaghe, Lio Zuzuloqo, and Hoava with the coastal groups of Vuragare and Koloï. In addition, kinship relations extend interregionally to include bonds with Rendova, Marovo, Simbo, Isabel, Ranongga,

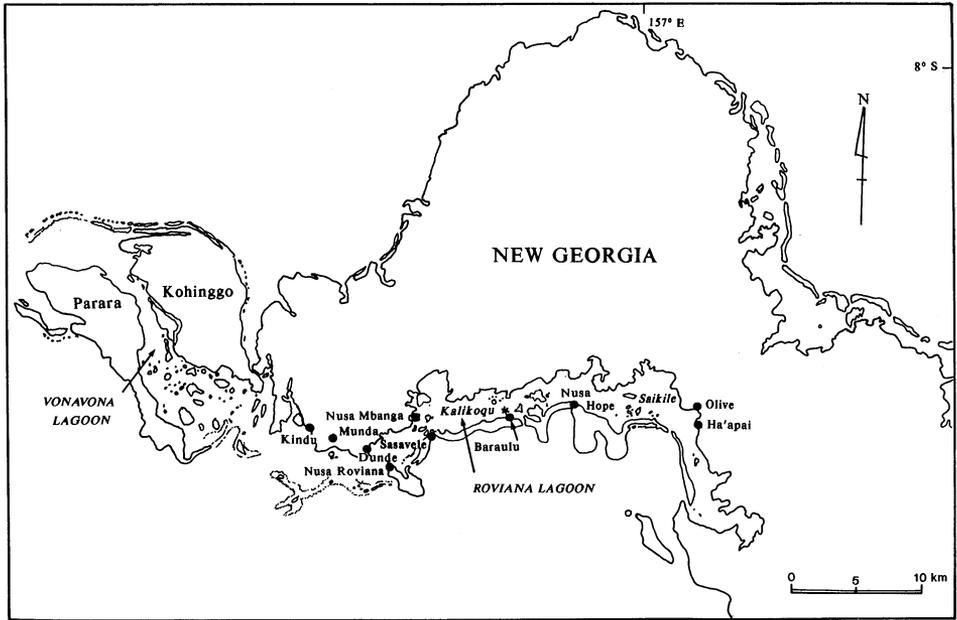


Fig. 2. Roviana and Vanavona Lagoons.

Choiseul, Vella Lavella, and other parts of the Western Solomons, and, in recent years, increasingly with the Eastern Solomon Islands. The most prominent tribal groups in the Roviana Lagoon are the Saikile and Kalikoqu chiefly districts (which are further subdivided into smaller polities). The main human settlements at the Saikile district are at, Hapa'i, Olive, Nusa Hope, and Baraulu Village. On the other hand, the Kalikoqu district consists of the Nusa Bana, Sasabele, and Baraulu villages. Although people in Saikile consider Baraulu within their jurisdiction, this view is not shared by many people at Baraulu who share kinship ties with both chiefly districts. Baraulu, therefore, can be included in both areas.

In the Roviana Lagoon control of resource use and access to tribal territories (*pepeso*) is exercised by the chief (*banara*) and elders (*palabatu*) of each community. A *pepeso* in Roviana, as a *puava* in Marovo [28] (see footnote 4) is a property domain which extends from the top of mountains of South New Georgia (*tutupeka*) to the barrier islands (*toba*), which form the Roviana Lagoon, and beyond to the open sea (*lamana*) midway in the channel separating South New Georgia and Rendova Island. Conceptually, entitlement to land (*pepeso*, soil) and sea (*kolo hokara*, or salt water, also referred to as *kolo*, or *idere*) exist as one, but the jurisdictional control of these two domains are exercised differently.

Rights to access and tenure of land vary according to descent line (*tututi*), residence (*koa vasina*), and affiliation (e.g. through marriage-*roroto*). Land rights range from usufructuary (*ilaka*) to individual tenure (*hinia*). All land in Saikile and Kalikoqu is

under the jurisdictional umbrella of the respective chiefs. In spite of the chiefs' control, land is jealously guarded by individual families (*tatamana*), specific kin-based groups (*butubutu*), and tribal polities (*butubutu*-although all the aforementioned can be referred to as a *butubutu*) within each of the chiefly districts.

In contrast, the exercise of tenure rights to sea space is quite distinct. As a result of a long history of intermarriage among the polities forming each of the main chiefly district of Saikile and Kalikoqu (also between them) tenure rights to passages, reefs and other marine habitats that were held by specific descent groups in the past have been pooled into the larger collection of land and sea entitlements held by all members of the two main socio-political enclaves forming the lagoon. As there are no claims to sea tenure by any specific descent group within each of the chiefly districts, jurisdictional power over the sea (*kinopu*) is entrusted to the chief (*banara*). This causes a problem of internal regulation of the fishery, as people do not feel responsible for either limiting their own catch rates or enforcing their property rights against interlopers. Like citizens of nation-states who do not generally take part in coastal protection, for which the state is responsible, Roviana inhabitants do not take an active role in managing the fishery because chiefs are entrusted with that task. Notwithstanding the internal regulatory problems, marine tenure institutions have been successful in fending off the threat of large-scale fishery development in the inner lagoon (only at Saikile and Kalikoqu, in the Munda area, have chiefs and elders opened their reefs to baitfishing) [47].

The Roviana Lagoon is characterized by a highly mosaic ecosystem, consisting of grass beds, mangroves, shallow reefs, deep lagoon, outer reef-drops, and estuaries. Fishing grounds are clearly definable micro-environments that include isolated reefs (or reefs surrounded by deep water), channels, bays, grass beds, inland pools, coastal pools, mud flats, and sections of the outside reefs (reef slopes). Local informants recognize grounds as productive depending on daily, lunar, and seasonal events. Other grounds are recognized as productive only when certain migratory species pass through the area. In areas with no human settlements, fishing grounds are identified as productive at any time.

Several environmental factors deserve special attention, because they structure the way marine resources are exploited. The daily variation in tidal cycles determines the times at which fishers go fishing. Generally, catches are better during incoming and outgoing tides. As water rushes in or out of the passages connecting the Roviana Lagoon with the open sea, numerous species pass through as they move in and out of the lagoon for feeding. Over the year, seasonal tidal variation predetermines the times, methods and species exploited by fishers in Roviana.

During the *odu rane-masa boni* (day high/night low) tidal season, from the beginning of October to the end of January, tides remain high during the day and drop during the night. At this time fishers employ the drop line method (*dakudaku* or *goregore*) to target pelagic species in the lagoon passages and along the outer lagoon reef drops. Simultaneously, fishing in the inner lagoon reefs is greatly reduced. Most inner lagoon reef fishing is carried out during the late evenings, as the tide ebbs. It is generally accepted that fishing in the lagoon is usually better during low tide, regardless of the time of day. Low tide at night is good for night spearing (*zuke boni*), as many fish

concentrate in reefs and grass beds. Other nocturnal activities include women's collection of shells and chitons (*sapora*) in the outer-lagoon reef edge intertidal zone.

Starting at the beginning of February and lasting until mid-April, tidal cycles change again. This tidal season, or *vekoa kolo*,<sup>9</sup> is a transitional time from one tidal cycle to the next. Tides ebb and flood four times in a 24-h period, and waters remain relatively high during the night and day. Frequent changes in the flow of water in and out of the lagoon bring concentrations of large schools of a baitfish called *katukatu* (*Herklotsichthys quadrimaculatus*). Trolling (*karukarumae*) and angling (*vekovekoe*) in the lagoon passages intensify as large pelagic species come to feed on the baitfish. This season is also the best time to troll for skipjack tuna (*karumae makasi*) from motorized canoes in the open ocean.

The *masa rane-odu boni* (day low/night high) tidal season, lasting from May to September, brings a series of changes in the manner of resource exploitation. Daytime ebbing tides allow for a whole series of activities in the inner lagoon reefs. With the intensification of the inner lagoon fishery, angling becomes the favored method. Fishing improves in the inner lagoon reefs as waters drop and fish move away from grass beds and mangroves into reefs. Diurnal low tides also permits the use of other fishing methods, such as organic piscicides (*bunabuna*), netting (*vaqara*) and fish drives (*kuarao*) (only at Nusa Roviana and Munda). During this season women exploit the mangrove and grass bed shells on a daily basis. Most commercial shell-diving takes place during this season.

Other factors within these tidal seasons, such as the lunar cycle and the prevailing winds, also determine the daily choices of fishers. As will be shown, the decisions made by fishers to switch from the inner lagoon reefs grounds to the outer reef drops and lagoon passages during *odu rane-masa boni*, the concentration of effort in the lagoon passages during *vekoa kolo*, and the return to the inner lagoon reefs during the *masa rane-odu boni* season, are consistent with the predictions of the foraging models presented here.

## 5. Field methods

This study is based on 20 months of uninterrupted research conducted at Roviana and Vonavona Lagoons in southwest New Georgia, Solomon Islands from April 1994 through December 1995. The data presented here form part of a larger project that included research in 13 communities throughout both lagoons. Data were obtained through a combination of ethnographic field methods. Field research objectives included:

- the documentation of indigenous ecological knowledge;
- the study of marine tenure and its social and historical context;

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<sup>9</sup>Note that not all native informants recognize this time as a specific season and continue to refer to this time as *odu rane*. The term *vekoa kolo* (or "staying water") refers to small fluctuation in tidal levels with a 24-h persistence of mid and high tides. Nevertheless, the term *vekoa kolo* is used here to refer to a period when there is a clear change in water levels and fishing activities.

- understanding the vulnerability of marine tenure institutions to the encroachment of the market economy; and, most importantly
- to study the relationship between human foraging and conservation or depletion of marine resources.

The methodology was tailored to examine the micro-ecology of Roviana and Vonavona fishers' interactions with their marine environment. Although the research design focused on marine foraging, the objectives were to address broader issues of human impact on the marine environment.

Data presented here were collected through direct observation of fishing forays and by the diary method in the Roviana Lagoon. Hired assistants and I directly observed over 450 fishing events. Further, more than 70 fishers in both lagoons were recruited to complete fishing diaries. These fishers were given a watch and scale to monitor their fishing activities. A total of 2203 fishing trips encompassing 5920.7 h of fishing in 4445 visits to fishing grounds were collected. The data for only Baraulu Village, in Roviana Lagoon, are analyzed here. Data collected at Baraulu include focal and diary data on 1125 fishing trips, including 2892.6 h of foraging in 2425 visits to grounds.

## 6. The evidence: Roviana patch choice and patch time allocation

In the ensuing sections a detailed analysis is presented to show intra-habitat productive variability and its influence on foraging strategies. A qualification is in order before proceeding. The use of “return rates”, similar to the fisheries science concept of catch per unit effort (CPUE) to estimate relative abundance, is warranted in this research as it would have been methodologically infeasible to determine the absolute environmental productivity of surveyed habitats. Appeldoorn [48] has argued that to successfully use relative abundance measurements to determine local productivity, differences among gears employed need to be sorted out and specific gears be selected as calibration standards. In this study, seasonal fluctuations in habitat productivity are only relative to the recorded catches. Varying yields do not necessarily reflect changes in the environment in any absolute sense. Hence, any allusion made here to “habitat productivity” is in reference to measures of relative abundance only.

The habitats of *inner lagoon shallow reef*, *lagoon passage* and *outer reef drop*, have been selected to illustrate how fishers seasonally shift between habitats for the following reasons:

- they are the most important and widely exploited habitats in the lagoon;
- most data collected during this project pertains to these habitats; and
- the methods employed in these habitats are mostly hand-lining.

The use of similar fishing methods in each habitat permits calibration for technological differences and their effect on catches and time allocation. If fishing bouts where methods such as nocturnal “net setting” were included in the analysis, residence times and returns would be disproportionately skewed. In testing Hypothesis 1, the seasonal mean return rate for each habitat type and the proportionate allotment of time to each are measured. Hypothesis 2 is tested by taking the major fishing grounds *within* each

habitat type and calculating their mean net return rate<sup>10</sup> and mean residence times per fishing event.<sup>11</sup> Rather than factoring single figures for each ground, each area is broken into the three main seasonal events outlined in this article. This allows identification of significant seasonal variation in return rates and their corresponding effects on time allocation.

## 7. Baraulu village

Baraulu village is located in the mid-Roviana Lagoon, in the inward face of the Honiavasa barrier island (Fig. 3). The village is relatively close to the major habitats exploited, saving fishers from having to travel long distances. Baraulu fishers are locally reckoned among the best in the region, particularly for their skillfulness in drop lining for barracuda. This section of the lagoon is narrower and the passage linking the lagoon with the open ocean is smaller and shallower than the other passages. Movement of fish across this section of the lagoon is not as notable as in other areas, and yields are lower than other villages.

### 7.1. Patch choice

The three main habitat types are presented here to show how fishers seasonally rank habitats. The expectation is that fishers will increase *overall* time allocation to the highest-yielding habitat and decrease *overall* time to the lowest yielding habitats. Table 1 shows that during the 1994 *odu rane* tidal season, kcal returns for fishing at the lagoon passage habitat were higher than all other habitats. From a total of 474 recorded foraging hours, 66% of all time was directed toward the lagoon passage habitat, 18% to the outer reef drop, and 16% to the inner lagoon reef habitats. Although the outer reef drop habitat shows low returns, a mere 994 kcal per hour, and low overall time, it is visited more often than illustrated in Table 1. Outer reef drops are potentially productive habitats, particularly during the barracuda season from late-August to the end of December. The figure for lagoon passage includes fishers bottom lining for barracuda at the outer section of the passage, the interface between the passage habitat and outer reef drops. Accordingly, the higher figure for the passage also reflects time allocation and return rates for adjacent outer reef drop fishing spots. The figure for the outer reef drop habitat in Table 1 is for grounds not adjacent to the passage.

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<sup>10</sup> Traveling to a patch is factored as a labor cost and it is subtracted from within-patch yields. Therefore, the mean net return rate for each fishing ground and habitat includes all traveling costs. Also, hereafter, the word mean net return rate will be interchangeably used with “yields” “habitat productivity”, and so forth.

<sup>11</sup> Table 1 shows mean returns and overall time allocation to 108 fishing grounds spread in the three major habitats outlined in this paper. The fishing grounds of each habitat type illustrated in Tables 2–4 are a selection of the major grounds in each of the three habitats. All grounds were not included because I did not have enough data to evaluate seasonal changes for each. Mean yields in grounds in Tables 2–4 may differ from those of the habitat in Table 1 due to inter-ground variability in yields.

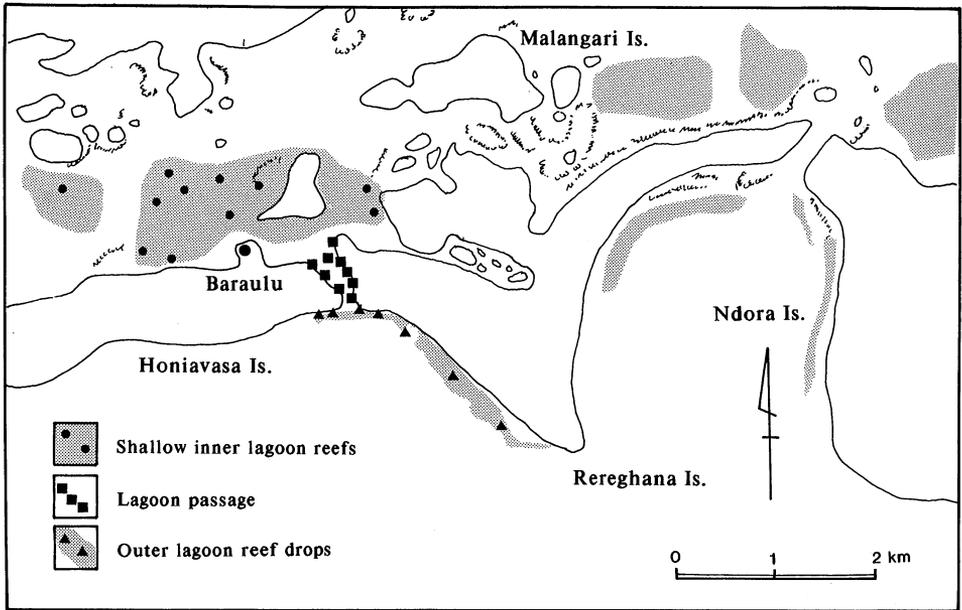


Fig. 3. Major habitats and fishing grounds at Baraulu Village.

Table 1

Seasonal overall time allocation and return rates for major habitats at Baraulu Village

Tidal season	Habitat	Total hours of foraging	Seasonal mean return rate (kcal per hour)	Percentage of overall hours	<i>r</i>
Odu rane 1994	Inner shallow reef	77	1106	16	0.97
	Lagoon passage	313	1501 <sup>a</sup>	66	
	Outer reef drops	84.2	994	18	
Vekoa kolo 1995	Inner shallow reef	165.4	1038	25	0.98
	Lagoon passage	419.6	1899	64	
	Outer reef drops	67	942	10	
Masa rane 1995	Inner shallow reef	305.7	1411	47	0.99
	Lagoon passage	294.3	1452	45	
	Outer reef drops	53.2	965	8	
Odu rane 1995	Inner shallow reef	106.5	1096	18	0.78
	Lagoon passage	330.3	1352 <sup>a</sup>	57	
	Outer reef drops	144.7	1295	25	

<sup>a</sup> Also includes bordering outer drops at the mouth of the passage.

With the advent of the *vekoa kolo* tidal season, in late-January, the lagoon passage fishery intensifies. Large schools of baitfish concentrate in the passages, attracting numerous pelagic species into the area. The return rate for the lagoon passage habitat at this time is 1899 kcal per hour, which differs substantially from the 1038 kcal per hour attained at the inner lagoon reefs, and a low 942 kcal in the adjacent outer reef drops. From a total 652 documented hours allocated to foraging during the *vekoa kolo* tidal season, 64% of total fishing time was assigned to the highest yielding lagoon passage habitat whereas the lower yielding habitats of inner lagoon reef and outer reefs drops received 25% and 10% of effort, respectively. But in some years schools of herring do not visit Baraulu. Fishers are flexible, and respond by adjusting their strategies to exploit the most accessible and abundant resources.

Local informants reckon that inner lagoon reefs are more productive during the *masa rane* tidal season. As the tide ebbs in the early morning, fish move away from grass beds and mangroves and concentrate in shallow to mid-depth reefs and pools. The mean return rate for foraging in this habitat during this period is of 1411 kcal per hour. From a total of 653 recorded hours allocated to fishing during the *masa rane* tidal season, 47% of all time was allotted to the inner lagoon reef habitat, 45% was directed to the lagoon passage, which also have high returns, and only 8% was designated to the outer reef drops. The overall times allotted to inner reef and lagoon passage habitats concur with their seasonal higher return rates.

With the return of *odu rane*, fishers again shift from the inner lagoon reefs to the more productive lagoon passage and outer reef drop habitats. Table 1 shows that the return rates for passages and outer reef drops during *odu rane* 1995 are higher than the inner reefs, and so they receive greater attention. The data show that Baraulu fishers rank habitat types according to their return rates as the three major tidal cycles progress. The *odu rane* tidal season brings a switch away from the inner lagoon shallow reefs to the outer reef drop and lagoon passage habitats.<sup>12</sup> With the advent of the *vekoa kolo* season most fishing effort concentrates in the lagoon passage, as the other two habitat types are less productive. But visits to habitat types are not monolithic. Fishers might visit a less productive habitat to “test” an area. If the probing is not satisfactory, and travel costs elsewhere are not too high, fishers have the option to turn to the seasonally productive habitats. During the *masa rane* tidal season fishers visit inner lagoon reefs more often, as these are more accessible and productive. But the lagoon passage remains productive throughout the year, and receives the highest overall effort. The choices made by Baraulu fishers are consistent with hypothesis one.

## 7.2. Patch time allocation

The next major and complementary question is whether fishers spend less foraging time *per bout* at a fishing ground when habitat productivity increases, and, conversely, if a fisher spends more time *per bout* when the habitat productivity decreases. To

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<sup>12</sup> It should be noted that most women continue to fish in the inner reefs.

examine this, a set of fishing grounds representing the three habitat types is presented in Tables 2–4.<sup>13</sup> The grounds shown are among those most frequented by Baraulu fishers (see Fig. 3). Data in this section include over 1800 visits to 35 fishing grounds, encompassing 2483 h of fishing.

### 7.3. Outer reef drops

Results for grounds in this habitat are fairly consistent with hypothesis two. The *odu rane* tidal season is a period when the outer reef drops and lagoon passage fishery intensifies. Low tides at night and calm weather make these habitats ideal for fishing and gleaning. Table 2 shows that in *odu rane* 1994 return rates were higher in the outer grounds than in the other tidal seasons, although the mean residence time per bout remained fairly low. Figures for the subsequent *vekoa kolo* season show lower returns, and residence time synchronically decreases because fishers are probing these grounds as they move between the more productive lagoon passage grounds and the open ocean for bonito trolling. With the advent of the *masa rane* season, the only ground sampled (Kurihokata) shows a low rate of 530 kcal per hour, and a considerable increase in time, to 179 minutes per bout. Residence time is high because during *masa rane* foragers pay a high travel cost to access these grounds and are unwilling to paddle elsewhere.<sup>14</sup>

Like the previous year, the advent of *odu rane* 1995 brings an increase in return rates and a decrease in residence time. Residence time figures for outer reef drops are generally high because travel times to these grounds are higher than to other habitats. This does not contradict the foraging models, as the optimal solution to an increase in travel costs is to increase patch residence time even under circumstances of diminishing returns [41, 45]. Fishers may decrease residence time to the outer drops if they can access alternative productive habitats without paying a high travel cost. This occurs only during the *vekoa kolo*, season when schools of bonito surface in the open ocean near the drops and fishers abandon them to forage in the open sea (see lower time figures in Table 2 for *vekoa kolo* season). On the other hand, during the *masa rane* schools of bonito rarely surface. As a result, fishers who paddle out to probe the outer reefs have no other alternative than to stay in the same patch, thus increasing residence time.

### 7.4. Lagoon passage

The figures for *odu rane* in Table 3 show high residence times and fair returns for the passage grounds. With the advent of *vekoa kolo* residence times per bout decrease and

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<sup>13</sup> The rate and time for each ground in Tables 2–4 are a mean of all visits carried out in each of the named grounds during each of the tidal seasons.

<sup>14</sup> It should be noted that the outer reef drops visited during *masa rane* are not the same ones as those visited during the *odu rane* tidal season. The more distant outer drop grounds visited during *masa rane* are to check for possible aggregations of *heheoku* (*Lutjanus gibbus*) as well as other snappers, while the outer drops visited during *odu rane* are adjacent to the passage and are visited for barracuda fishing.

Table 2  
Seasonal mean within-patch residence time ( $T$ ) and mean net return rate ( $R$ ) for the most prominent outer reef drop fishing grounds at Baraulu Village

Fishing ground name	Odu rane (94)		Vekoa kolo		Masa rane		Odu rane (95)		Yearly mean		Travel time	Total hours	$r$
	$T$ (min)	$R$	$T$ (min)	$R$	$T$ (min)	$R$	$T$ (min)	$R$	$T$ (min)	$R$			
Gurana	76	700	59	853	—	—	—	—	63	809	45	30.3	
Miho Rava	98	1194	61	715	—	—	—	—	59	1000	65	32	
Kurihokata	131	885	70	992	179	530	135	973	134	890	45	214	
Bae Siri	56	2870	87	952	—	—	83	1732	77	1739	25	38	
Kopi Basioto	54	1932	86	960	—	—	—	—	65	1326	30	22	
Totals	83	1516	73	894	179	530	109	1352	80	1153	42	336.2	-0.67*

\* Statistical significance at  $p < 0.10$ .

Table 3  
Seasonal mean within-patch residence time ( $T$ ) and mean net return rate ( $R$ ) for the most prominent lagoon passage fishing grounds at Baraulu Village

Fishing round name	Odu rane (94)		Vekoa kolo		Masa rane		Odu rane (95)		Yearly mean		Travel time	Total hours	$r$
	$T$ (min)	$R$	$T$ (min)	$R$	$T$ (min)	$R$	$T$ (min)	$R$	$T$ (min)	$R$			
Herapa	59	1972	55	1408	66	712	63	853	59	1268	8	104	
Tiro Ughele	108	1240	58	2005	83	743	74	1207	91	1149	14	77.5	
Miho Zela	64	981	62	2322	58	731	70	954	60	1276	10	115	
Masa Moku	111	790	79	2297	75	1500	109	1723	86	1703	16	263	
Patu Kiso	83	1672	79	2010	51	1125	—	—	70	1580	15	62.5	
Miho Podala	150	840	42	2886	151	528	—	—	115	1428	20	28.7	
Sanava	153	1418	60	1436	63	2362	174	1074	117	1571	18	626	
Totals	104	1273	62	2052	78	1100	98	1162	85	1054	14	1277	-0.72*

\* Statistical significance at  $p < 0.05$ .

Table 4  
Seasonal mean within-patch residence time (*T*) and mean net return rate (*R*) for the most prominent inner lagoon shallow reef fishing grounds at Baraulu Village

Fishing ground name	<i>Odu rane</i> (94)		<i>Vekoa kolo</i>		<i>Masa rane</i>		<i>Odu rane</i> (95)		<i>Yearly mean</i>		Travel time	Total hours	<i>r</i>
	<i>T</i> (min)	<i>R</i>	<i>T</i> (min)	<i>R</i>	<i>T</i> (min)	<i>R</i>	<i>T</i> (min)	<i>R</i>	<i>T</i> (min)	<i>R</i>			
Vorinae	—	—	55	818	29	1418	38	1262	40	1298	24	29	
Kolekolo	—	—	63	108	46	811	—	—	48	690	38	35	
Masiqe	—	—	81	1695	66	2352	62	1542	66	2056	47	37.3	
Sagauru Zare	—	—	64	1326	61	1602	77	1345	71	1402	44	29.5	
Suluwana	64	743	83	526	50	880	—	—	61	769	38	24.2	
Vugasa	—	—	63	757	61	1043	47	1110	58	1000	25	26.6	
Kamoana/Avavisi	—	—	—	—	33	1692	47	715	35	1417	20	16.7	
Sagauru Tape	45	1128	—	—	39	1286	50	1191	44	1229	22	12	
Avanui	50	1152	96	1428	55	2520	—	—	64	1686	21	22	
Sagauru Mudala	—	—	63	942	48	1815	—	—	55	1337	15	25	
Miho Kokodovi	—	—	43	375	29	1114	—	—	35	785	3	18.3	
Kaisoto	97	476	—	—	64	943	50	960	64	834	25	107	
Uma Boni	—	—	53	2711	61	1182	—	—	59	1606	17	87	
Sagauru	—	—	—	—	—	—	—	—	—	—	—	—	
Tototu	102	900	83	1680	83	1980	—	—	86	1782	45	68	
Nusa Pakopako	—	—	91	1763	55	2632	—	—	67	2322	45	19	
Sagauru Onone	—	—	62	729	45	1490	—	—	52	1065	16	35	
Nusa Vaqura	—	—	64	361	44	1170	—	—	50	1023	23	13.5	
Kokoqana	—	—	72	412	44	709	—	—	48	667	20	30.5	
Totals	72	880	69	1042	51	1480	53	1161	56	1273	27	636	-0.89

returns increase. The mean return for the sampled fishing grounds during *vekoa kolo* is of 2052 kcal per hour, with a mean residence time of 62 min per bout. The most important ground is Sanava, with a lower mean return rate of 1436 kcal per h and a mean residence time of 63 min. This ground is an interface between the lagoon passage, the passage outer reef drops, and the open sea. Fishers are moving from Sanava to adjacent open sea grounds in pursuit of surfacing schools of bonito. If open sea bouts are included as part of passage foraging, as the foraging strategy during *vekoa kolo* is to alternate between habitats, the mean return rate increases to 1924 kcal per h and time further decreases to 49 min per bout.

The next tidal shift, to *masa rane*, brings a decline in productivity and, consequently, an increase in mean residence time. With the advent of the 1995 *odu rane* tidal season the return rate slightly drops and mean residence time further increases. Although the marginal value theorem does not predict the optimal number of patches that a forager should visit, it is worth pointing out that in the Roviana case number of bouts per foraging event are contingent on habitat productivity. The average number of grounds visited per event (day of fishing) during the productive *vekoa kolo* season is 2.5, whereas during the poorer *odu rane* season the number of patches visited drops to 1.8. The coefficient correlation in Table 3 shows an inverse relationship between patch residence times and seasonal habitat return rates. This is consistent with hypothesis two.

### 7.5. Inner lagoon shallow reefs

Table 4 shows a negative correlation between habitat seasonal return rates and time spent in a patch. Beginning with *odu rane* 1994, yields are at a yearly low, with a mean of 880 kcal and a residence time of 72 min per bout. As the year advances productivity progressively increases and time synchronically decreases. During the *masa rane* tidal season the mean net return rate for inner reef fishing grounds reaches 1480 kcal per h and the mean residence time drops to the yearly low of 51 min per bout. The average number of grounds visited for each fishing trip during *masa rane* is 2.5. By contrast, during the *odu rane* when inner lagoon reef fishing grounds have lower returns and higher mean residence times, the mean number of grounds visited decreases to 1.7 per fishing event.

### 7.6. Baraulu synopsis

Fig. 4 combines the total results for Tables 2–4 to illustrate seasonal mean times and mean return rates for the habitats outlined in this section. At both ends of the graph, during *odu rane* 1994 and 1995, the outer reef grounds and passage have the highest per bout residence time, notwithstanding increasing or declining changes in mean returns.<sup>15</sup> This occurs because the grounds visited during this time have

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<sup>15</sup> The *masa rane* results also indicate a very high time allocation to the single illustrated ground (see Table 2).

Seasonal mean residence times and mean net return rates for illustrated fishing grounds of each habitat type at Baraulu Village

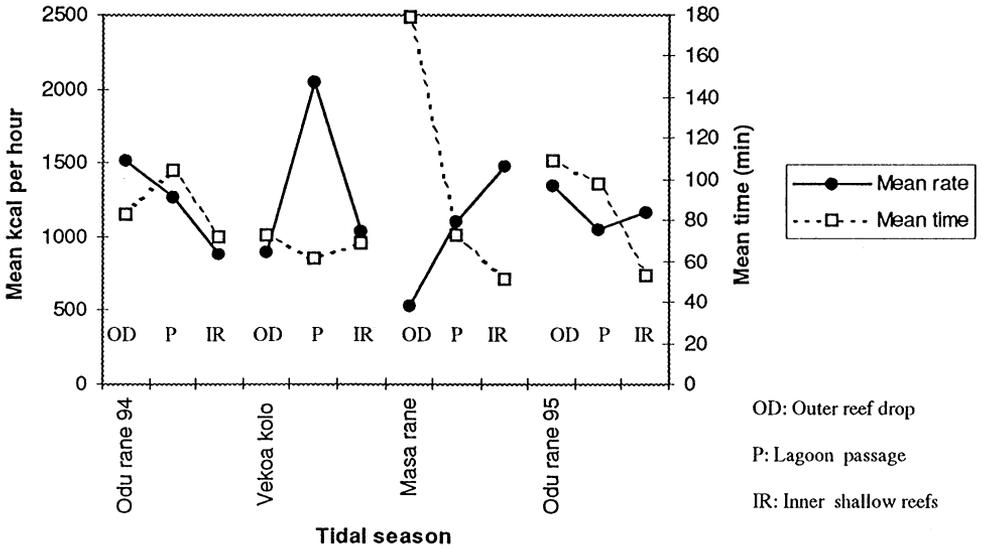


Fig. 4. Total mean residence times and rates of return for grounds in Tables 2–4 showing the inverse relation between time and return rates for each habitat type.

a considerable traveling cost. As mentioned, this does not contradict the foraging models because the outer reef grounds, and drops at the mouth of the passage, are more distant than inner reefs, paying foragers to increase residence time. Seasonal overall time allocation in Table 1 indicates that during *odu rane* the outer drop habitat has the lowest rates and the lagoon passage the highest. The lagoon passage results obscure the fact that outer drop grounds adjacent to the passage are part of lagoon passage foraging. Fig. 4 shows that mean results for the *vekoa kolo* and *masa rane* seasons conform to expectations. The highest yielding patches of a habitat type have the lowest per bout residence time.

### 8. Discussion

The patch choice model offers a very intuitive prediction. For each of the three tidal seasons more efforts are directed to the habitats with the highest yields, whereas habitats with lower returns are not visited as often. Generally, inner lagoon reefs and lagoon passage habitats have more stable seasonal return rates and are more accessible than the outer reef drop habitat, so more overall effort is directed to them.

The patch time allocation patterns indicate that as habitat productivity increases less time per bout is spent in each ground unless the forager incurs a high travel cost

getting to the habitat. Further, more fishing grounds within the habitat type are added to the rank list (i.e. more are visited) during seasonal periods of high returns. Residence time decreases and the number of patches increases because foragers can find numerous alternative productive patches at a close range. This shifting strategy permits fishers to avoid a dramatic drop in their mean energy intake during foraging. On the other hand, when the habitat productivity decreases the optimal strategy is to increase per bout patch residence time. It is too costly for a forager to travel elsewhere if he or she cannot do better. This pattern is counterintuitive to the common notion that fishers stay longer in fishing grounds when productivity increases and, conversely, decrease patch residence time as productivity declines. The results presented here counter this assumption and support the foraging hypothesis.

These results indicate that Roviana fishers behave to maximize their foraging efficiency. In his study of the Piro in the Peruvian Amazon, Alvard [4, 46] argued that hunters harvest prey independently of the possible consequences to the population structure of it. He suggests that Piro prey choice is consistent with the foragers short-term goals of energy maximization, and not with the long-term objectives of resource conservation. Similarly, Roviana fishers' decisions to stay or leave a habitat or set of patches are formulated separately from the possible consequences to the long-term sustainability of the marine environment.

If fishers followed a resource management strategy, foraging time per bout within fishing grounds experiencing declining productivity should decrease. On the other hand, if fishers want to forage as efficiently as possible when productivity declines they will increase their foraging time per bout as resources are depleted or they will shift attention to more productive habitats. It should be noted that although residence time per bout increases when a habitats' productivity declines, overall seasonal time allocation to that habitat is reduced as fishers search for alternative productive habitats. This strategy suggests that poorer habitats are relieved of some foraging pressure, possibly allowing for habitat recovery time. Decline in overall time allocation to a habitat experiencing lowering productivity, however, should not be confused with an effort to regulate the fishery. Fishers are attempting to offset decreasing return rates by switching to more productive habitats. The general behavioral patterns of fishers and their daily micro-ecological interaction with the marine ecosystem are consistent with the foraging model predictions. Resource conservation and/or depletion is situational and conditional to the shifting strategies of Roviana fishers.

## **9. Implications for modern fisheries: linking ecological theory and coastal resource management**

The use of an evolutionary ecology approach to the study of human resource utilization practices sets the stage for the development of a human ecology that can be applied to establish management policies. Before examining the utility of foraging theory and its research design to contemporary problems in littoral fisheries management, an important consideration is in order. This article does not question the rights of indigenous peoples to control and use their resources as they see fit. The objectives

here are to understand human resource utilization strategies so that any collaborative efforts between indigenous peoples and government and non-government organizations may result in the sustainable use of marine resources.

Elucidating anthropogenic patterns of resource utilization is not a mere academic exercise. Neither is it to doubt that an effort to conserve resources is practiced by Roviana fishers. Portraying indigenous tenure and fishing practices as conservationist is as misleading as saying that indigenous peoples are destroyers of nature. Recognizing that the range in variability and possible outcomes of human behavior are conditional and dynamic is the soundest foundation on which to build a co-managerial partnership between governments and indigenous peoples.

Co-management as understood in this paper is a joint effort between local peoples and government and non-government organizations to establish rules and regulations capable of managing inshore fisheries. A “middle-down–middle-up” approach is propounded here. Statutory measures should be modeled after local patterns of resource utilization and existing social institutions. It is imperative, however, that any regulatory steps are first understood and accepted by local peoples. Once endorsed, the implementation and enforcement of rules are carried out conjointly between local peoples and government agencies. The primary governmental role is to facilitate the legal means for indigenous peoples to formally hold tenure to their land and sea space.

There has been an increasing realization in recent years that community-based management of coastal resources is amongst the most effective ways to manage reef fisheries [13, 49–51] Acheson and Wilson [21] have argued that, as fisheries models fail to predict the outcome of human predation on fish populations, the safest way to prevent over-exploitation is by mimicking non-Western institutions of resource management. They call this approach “parametric management”. Their basic idea is that non-Western systems of resource management do not focus on numbers harvested (i.e. catch quotas) but manage access to resources through various cultural controls. These controls, they argue, are more in congruity with the chaotic nature of fish populations and, therefore, can better deal with stochastic fluctuations in fish numbers.

The parametric model as well as other measures that emphasize a bottom-up approach to Third World littoral fisheries management requires closer and more critical scrutiny. The internal dynamics of non-Western institutions of resource management have to be assessed through the examination of participating actors and their potential impact on the marine ecosystem. From the standpoint of human ecology the inclusion of foraging theory to issues of coastal resource management in artisanal fisheries is a promising approach. Foraging models are adequate heuristic devices, as they can forecast the decisions that fishers make in the types and abundance of fish that they prey on, the use frequency of marine habitats, and the fluctuating intensity of fishing effort. Further, the research design provided by this approach aids in the collection of other data sets relevant to resource management objectives (e.g. ecological zone mapping).

The results presented here indicate that fishers behave to optimize their short-term self interests by way of exploiting resources as efficiently as possible. Fishers select habitat types and the fishing times within them according to their seasonal productivity. Above it has been demonstrated that during the *odu rane* tidal season, from the

beginning of October to the end of January, tides remain high during the day and drop at night. Diurnal high waters allow numerous fish species to move away from coral reefs into mangroves and grass beds. As a result, the inner lagoon reef fishery declines and fishers move to the lagoon passage and outer reefs drops. With the arrival of the *vekoa kolo* tidal season, foraging pressure is relieved from the outer reef drops and concentrates in the lagoon passages and nearby reefs. On the other hand, when diurnal tides are low during the *masa rane* from May to September, fishers move away from the outer reef drops and the lagoon passage and exploit the inner lagoon reefs.

These patterns of behavior can be incorporated with managerial measures that *mimic* the seasonal movement of fishers. As frequency of visits to an habitat type or set of patches decreases, the temporary closure of that area may be encouraged. For instance, seasonal closures could be established in the outer and inner lagoon coral reef habitats, as these are more vulnerable to fishing pressure than other habitats. Reef fish tend to be sedentary and spend most of their life-cycle in a delimited area, making them more susceptible to fishing pressures [52]. Limiting access to certain reefs during periods of declining fishing activity may allow for patch recovery time. But no limitations should be established for lagoon passages, except for specific periods of spawning activity. Most species caught in the passages are pelagic, and therefore are less susceptible to pressures from a subsistence fishery.

Numerous marine scientists [53–55] have supported the idea of periodic closures, among other measures, to regulate coral reef fisheries. In the Roviana case, access restrictions to particular inner and outer lagoon reefs can have beneficial consequences. Although the long-term benefits of temporal closure of lagoon habitats is uncertain, it is argued here that seasonal limitations on access to fishing grounds is among the soundest policy measures to prevent resource overexploitation. For example, anecdotal evidence collected during my research suggests that various species of Balistidae, Lethrinidae, Serranidae, and Lutjanidae spawn in shallow inner lagoon reefs (and also in the lagoon passages) during the *odu rane* tidal season. Limitations on reef exploitation at this time, which coincides with declining frequency of inner reef habitat use, can aid in relieving pressure at crucial periods of spawning activity.

Habitat closure is not an alien concept to Roviana fishers. Tabooing of reefs was regularly practiced by chiefs (*banara*) and traditional priests (*hiama*) in the recent past. Even today, prior to any large religious feast, church leaders occasionally place shell beds off-limits. Information generated by the foraging models can be used to find habitats and specific grounds that are vulnerable to seasonal overexploitation. This information must be coupled with current biological data and indigenous environmental knowledge to improve any managerial plans. Results can then be discussed with traditional authorities and participating fishers, to formulate regulatory measures that would not be disruptive and that probably would be well accepted by local communities. Further, other issues, such as gear utilized, size or species restrictions, and monitoring access to the fishery, can be discussed. These fisheries management strategies are not foreign concepts to Pacific Island fishers [13].

Besides elucidating frequencies of visits and use, the application of a foraging research design is useful in collecting data that can be relevant to resource management objectives. For instance, to test the foraging hypotheses, all utilized fishing

grounds and their characteristics have to be identified. Other data collected include frequencies of methods utilized, daily and seasonal events that structure a fisher's decisions, and various other data sets. This information, coupled with seasonal productivity rates for major grounds utilized can, for instance, be integrated into a Geographical Information System (GIS) data base to enhance any ecological planning [13, 21, 51, 54, 56].

The notion that indigenous sea tenure institutions can aid modern fisheries management, as propounded by many social and marine scientists [13, 21, 51, 54] is supported here. The results of the research reported here suggest that regulatory collective action to maintain the sustainability of marine habitats is not regularly practiced by Roviana fishers. Notwithstanding that folk fishers are not environmental altruists, the existence of institutionalized communal tenure provides a framework in which co-managerial goals to control littoral fisheries can be accomplished. However, researchers must be cautious before describing indigenous practices of resource management as a panacea for all coastal fisheries ills. Under pressure from both exploding populations and increasing commercialization of subsistence economies, Pacific Island marine habitats are bound for further ecological degradation. Researchers must pay closer attention to the daily ecological and social behaviors of the actors whose cultural systems they seek to analyze, for it is the fishers, and not the indigenous institutions of marine tenure, that ultimately affect the sustainability of any fishery. By integrating case specific research results with existing indigenous practices of resource use, a partnership between local peoples and exogenous forces may be forged to achieve the common goal of resource use sustainability.

## **10. Conclusion**

Two important issues have emerged from this research: the relevance of evolutionary ecology to the study of coastal foragers, and the significance of its results in linking evolutionary approaches with the management of coastal aquatic resources. A number of anthropological studies have used optimal foraging theory to predict hunter-gatherer foraging behavior, and these have shown the usefulness of such models. The integration of optimization models to the study of indigenous coastal management strategies can lead to a better understanding of human foraging choices and their effect on the marine environment. The rigorous research framework provided by evolutionary ecology equips researchers with a coherent set of theoretical guidelines with which to carry out field research. In addition, the use of an actor-based methodology overcomes some of the shortcomings of functionalist human ecology in marine tenure studies.

Maritime anthropologists can make a significant impact on coastal policy if they include in their research agenda a theoretical base and a set of quantitative methodologies to account for the varied levels of human resource exploitation. Results generated by foraging models can be integrated with coastal resource management policies. The data presented here indicate that foraging pressure in the inner lagoon coral reefs, as well as other habitats, shifts according to varying environmental

conditions and their effect on foraging decisions. This information can be used to integrate indigenous patterns of resource utilization into co-management. Any form of regulatory measure, however, should include the participation and approval of traditional authorities and local people. It is within this context that ecological theory in anthropology and the pressing issue of coastal resource management can be linked.

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## References

- [1] MacArthur RH, Pianka ER. On optimal use of a patchy environment. *American Nature* 1966;100:603–9.
- [2] Charnov EL. Optimal foraging, the marginal value theorem. *Theoretical Population Biology* 1976;9:129–36.
- [3] Stephens DW, Krebs JR. *Foraging theory*. Princeton: Princeton University Press, 1986.
- [4] Alvard M. Intraspecific prey choice by Amazonian hunters. *Current Anthropology* 1995;36(5):789–818.
- [5] McCay B. Systems ecology, people ecology and the anthropology of fishing communities. *Human Ecology* 1995;6:397–422.
- [6] Moran EF, editor. *The ecosystems approach in anthropology: from concept to practice*. Ann Arbor: The University of Michigan Press, 1990.
- [7] Hviding E. All things in our sea: the dynamics of customary marine tenure, Marovo Lagoon, Solomon Islands. Port Moresby: IASER Special Publication 13, 1989.
- [8] Akimichi T. Territorial regulation in small fisheries. In: Ruddle K, Akimichi T, editors. *Maritime Institutions in the Western Pacific*. Senri Ethnological Studies, vol. 17. Osaka: National Museum of Ethnology, 1984.
- [9] Baines GB. A traditional base for inshore fisheries development in the Solomon Islands. In: Ruddle K, Johannes RE, editors. *The Traditional knowledge and management of coastal systems in Asia and the Pacific*. Jakarta: UNESCO.
- [10] Dahl C. Traditional marine tenure: a basis for artisanal fisheries management. *Marine Policy* 1988;12(1):40–8.
- [11] Cordell J. Sea tenure: In: Cordell J, editor. *A sea of small boats*. Cambridge, MA: Cultural Survival Report 26, 1989:1–21.
- [12] Foster K, Poggie J. Customary marine tenure and mariculture management in outlying communities of Pohnpie State, Federated States of Micronesia. *Ocean and Coastal Management* 1993;20:1–21.
- [13] Johannes RS. Traditional marine conservation in Oceania and their demise. *Annual Review of Ecology and Systematics* 1978;9:349–64.

- [14] Johannes RE, MacFarlane JW. Traditional fishing in the Torres Strait Islands. Hobart: CSIRO Division of Fisheries, 1991.
- [15] Mathew S. Study of territoriality use rights in small-scale fisheries: traditional systems of fisheries management in Pulicat Lake. Tamil Nadu, India. FAO Fisheries Circular 839, 1991.
- [16] Pollnac RB. Investigating territorial use rights among fishermen. In: Ruddle K, Akimichi T, editors. Maritime institutions in the Western Pacific. *Senri Ethnological Studies* 17. Osaka: National Museum of Ethnology, 1984.
- [17] Hardin G. The tragedy of the commons. *Science* 1968;162:1243–48.
- [18] Berkes F. Common property resources: ecology and community-based sustainable development. London: Belhaven Press, 1989.
- [19] Ciriacy-Wantrup SV, Bishop RC. "Common property" as a concept in natural resource policy. *Natural Resources Journal* 1975;15(4):713–27.
- [20] Acheson JW. The lobster fiefs: Economic and ecological effects of territoriality in the Maine lobster industry. *Human Ecology* 1975;3(3):186–207.
- [21] Acheson JM, Wilson JA. Order out of chaos: the case for parametric fisheries management. *American Anthropologist* 1996;98(3):579–94.
- [22] Reichel-Dolmatoff G. Cosmology as ecological analysis: a view from the rain forest. *Man* 1976;307–18.
- [23] Ross EB. Food taboos, diet, and hunting strategy: The adaptation to animals in Amazon cultural ecology. *Current Anthropology* 1978;19:1–36.
- [24] Hames R. Game conservation or efficient hunting?. In: McCay BJ, Acheson J, editors. The question of the commons: the culture and ecology of communal resources. Tucson: The University of Arizona Press, 1987.
- [25] Elster J. Explaining technical change: a case study in the philosophy of science. Cambridge: Cambridge University Press, (Chapter 2). 1983.
- [26] Smith EA. Anthropology, evolutionary ecology and the explanatory limitations of the ecosystem concept. In: Moran E, editor. The ecosystem concept in anthropology. MI: Michigan Press, 1984.
- [27] Carrier J, Carrier H. Profitless property: marine ownership and access to wealth on Ponam Island, Manus Province. *Ethnology* 1983;22(2):133–51.
- [28] Polunin N. Do traditional reserves conserve? A view of Indonesia and New Guinea evidence. In: Ruddle K, Akimichi T, editors. Maritime institutions in the Western Pacific. *Senri Ethnological Studies* vol. 17. Osaka: National Museum of Ethnology, 1984.
- [29] Hviding E. Guardians of Marovo Lagoon: practice, place, and politics in Maritime Melanesia. Honolulu: University of Hawaii Press, 1996.
- [30] Dwyer PD. A hunt in New Guinea: some difficulties for optimal foraging. *Man* 1985;20:243–53.
- [31] Smith EA. Inujjuamiut foraging strategies: evolutionary ecology of an arctic hunting economy. New York: Aldine de Gruyter, 1991.
- [32] Hill K, Hawkes K. Neotropical hunting among the Ache of eastern Paraguay. In: Hames R, Vickers W, editors. Adaptive responses of Native Amazonian. New York: Academic Press, 1983:223–67.
- [33] Hames R, Vickers WT. Optimal diet breadth theory as a model to explain variability in Amazonian hunting. *American Ethnologist* 1982;9:258–78.
- [34] Beckerman S. Optimal foraging group size for a human population: the case of Bari fishing. *American Zoologist* 1983;23:283–90.
- [35] Begossi A. The use of optimal foraging theory in the understanding of fishing strategies: a case from Sepetiba Bay. *Human Ecology* 1992;20(4):462–73.
- [36] Bird RB, Bird DW. Delayed reciprocity and tolerated theft: the behavioral ecology of food sharing strategies. *Current Anthropology* 1997;38(2):49–78.
- [37] Winterhalder B. Optimal foraging strategies and hunter-gatherer research in Anthropology: Theory and models. In: Winterhalder B, Smith EA, editors. Hunter-gatherer foraging strategies: ethnographic and archaeological analysis. Chicago: University of Chicago Press, 1981:13–35.
- [38] Charnov EL, Orians GH. Optimal foraging: some theoretical explorations. Mimeograph, Department of Biology, University of Utah, Salt Lake City, 1973.

- [39] Pyke GH, Pulliam HR, Charnov EL. Optimal foraging: a selective review of theory and test. *Quarterly Review of Biology* 1977;52:137–54.
- [40] Kaplan H, Hill K. The evolutionary ecology of food acquisition. In: Smith EA, Winterhalder B, editors. *Evolutionary ecology and human behavior*. New York: Aldine de Gruyter, 1992:167–202.
- [41] McNamara JM. Optimal patch use in a stochastic environment. *Theoretical Population Biology* 1982;131:307–32.
- [42] Charnov EL, Parker GA. Dimensionless invariants from foraging theory's marginal value theorem. *Proceedings of the National Academy of Sciences* 1995;95(5):1446.
- [43] Clark CW. *Bioeconomic modeling and fisheries management*. New York: Wiley, 1985.
- [44] Smith EA, Winterhalder B. New perspectives on hunter-gatherer Socioecology. In: Winterhalder B, Smith EA, editors. *Hunter-gatherer foraging strategies: ethnographic and archaeological analysis*. Chicago: University of Chicago Press, 1981:1–12.
- [45] McNair JN. Optimal giving-up times and the marginal value theorem. *American Naturalist* 1982;119:511–29.
- [46] Alvard M. A test of the ecologically noble savage hypothesis: interspecific prey choice by neotropical hunters. *Human Ecology* 1993;21:355–87.
- [47] Aswani S. Troubled water in south-western New Georgia, Solomon Islands: Is codification of the commons a viable avenue for resource use regularization? *Traditional Marine Resource Management and Knowledge Information Bulletin* 1997;9:2–16.
- [48] Appeldoorn RS. Model and method in reef fishery assessment. In: Polunin NVC, Roberts CM, editors. *Reef fisheries*. London: Chapman & Hall, 1996:219–48.
- [49] Polunin NVC. Delimiting nature: regulated area management in the coastal zone of Malaysia. In: West PC, Brechin SR, editors. *Resident peoples and natural parks*. Tucson: University of Arizona Press, 1991:107–13.
- [50] Ruddle K. Traditional management of reef fishing. In: Polunin NVC, Roberts CM, editors. *Reef fisheries*. London: Chapman & Hall, 1996:315–35.
- [51] Ruddle K, Hviding E, Johannes RE. Marine resource management in the context of customary marine tenure. *Marine Resource Economics* 1992;7:249–73.
- [52] Sale PF. Assemblages of fish on patch reefs- predictable or unpredictable? *Environmental Biology of Fish* 1980;5:243–9.
- [53] Alcalá AC. Effects of marine reserves on coral fish abundance and yields of Philippines coral reefs. *Ambio* 1988;17:194–9.
- [54] Munro JL. The scope of tropical reef fisheries and their management. In: Polunin NVC, Roberts CM, editors. *Reef fisheries*. London: Chapman & Hall, 1996:1–14.
- [55] Russ G. The use of refugia for fisheries resource management in coral reefs. In: Munro JL, Munro PE, editors. *The management of coral reef resource systems*. Manila, 1994:72–4.
- [56] Calamia MA. Traditional ecological knowledge and geographic information systems in the use and management of Hawaii's coastal reefs and fishponds. *High Plains Applied Anthropology* 1996;2(16):144–64.