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Lagoon Ecology and Social Strategies: Habitat Diversity and Ethnobiology

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Abstract This study describes the seascape ecology of the Roviana Lagoon in the Western Solomon Islands. Using a combination of ecological and ethnographic data, we analyze the dominant characteristics of the habitats represented in the area, the prevalent environmental phenomena, and the productive practices exerted in these habitats by the local inhabitants. The lagoon offers an ecological structure characterized by micro-patchiness and a productive system in which the members have a detailed knowledge of an extremely complex environment and a set of extractive practices that take advantage of this intimate knowledge to selectively use most of the niches provided by the ecological heterogeneity of the lagoon. The correlation of ecological structure and social use of a landscape is not just a descriptive endeavor. It is a fundamental step toward understanding human–environmental relations and developing integrative base resource maps for planning marine and terrestrial conservation in the Roviana Lagoon and elsewhere. More generally, the socioecological analysis of seascapes is of key importance for formulating ecosystem-based management plans.

Keywords Land- and seascape ecology · Human ecology · Indigenous ecological knowledge · Marine Conservation · Solomon Islands

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Introduction

Marine ecosystems are complex interacting habitats with different abiotic and biotic characteristics. Understanding the marine and human ecologies of seascapes and landscapes requires a full assessment of their ecological structure as well as the social uses and values inscribed on them by their inhabitants and managers. This central role of ecological structure and human use situates local inhabitants in a privileged position to provide highly accurate ecological descriptions of their land- and seascapes. The invocation of local ecological knowledge has often resulted in fragmentary accounts or unsubstantiated claims about the potential of indigenous ecological knowledge to inform modern natural resources management. However, the correlation of ethnoecological knowledge with the analytical concepts of landscape ecology can provide a venue to establish the effectiveness of indigenous ecological knowledge in resource management decisions. A "thick" locally generated seascape description, combined with the analytical potential of landscape ecology, can succeed in generating a nuanced description of a seascape's structure, its ecological interactions, and the human uses and impacts on its resources.

For marine scientists, one of the initial steps for analyzing a given seascape is habitat mapping, which serves to identify the existence, size, and location of abiotic and biotic resources at local, regional, or continental scales. Researchers have used a number of methods (or a combination of them) for mapping benthic environments, including conventional quadrat and line-intercept field dive surveys, aerial photography (Sheppard *et al.* 1995), space-borne remote sensors (e.g., Landsat ETM+, SPOT, and IKONOS) (Purkis and Pasterkamp 2004), remote videography (Stevens 2005), and multibeam acoustic seabed mapping (Pickrill and Todd 2003) among others. Habitat mapping, then, serves to improve marine habitat representation, increase efficiency in managing fish stocks, and conserve marine biodiversity (Jordan *et al.* 2005) when fisheries management and conservation programs are designed.

Given the absence of reliable biological data in many developing nations, Johannes (1998) argued that incorporating local knowledge into marine resource management planning is an effective and low-cost strategy for understanding local habitats and ecological processes. Yet, other marine scientists have generally ignored indigenous ecological knowledge when mapping the seascape for creating base resource maps. In this respect, social scientists have been more forthcoming and have shown the usefulness of local knowledge for mapping marine habitats and for applying this knowledge to fisheries management and biodiversity conservation (e.g., Anuchiracheeva *et al.* 2003; Aswani and Hamilton 2004). While the significance of indigenous ecological knowledge for marine resource management is well established (e.g., Johannes 2002), methods for systematizing local knowledge with Western modes of biodiversity conservation more comprehensively and equitably are still being developed (Aswani and Lauer 2006a; Fazey *et al.* 2006). The essential idea behind these efforts is that a systematic articulation of local cultural knowledge and ecological values with marine science can create reliable and cost-effective scientific information while enhancing local participation in community-based conservation efforts.

In this paper we explore the seascape ecology of the Roviana Lagoon in the Western Solomon Islands (Fig. 1) by integrating indigenous ecological knowledge with ecological science. More specifically, we (1) describe the habitat structure of the Roviana Lagoon, with emphasis on the salience of its micro-patchiness; (2) illustrate the local knowledge of this fragmented habitat structure; (3) explain the specific extractive uses associated with each habitat as well as the ethnoecological knowledge that informs and limits such practices; and (4) provide a case of the articulation of ecological and ethnographic data. More generally, we argue that the integration of ecological

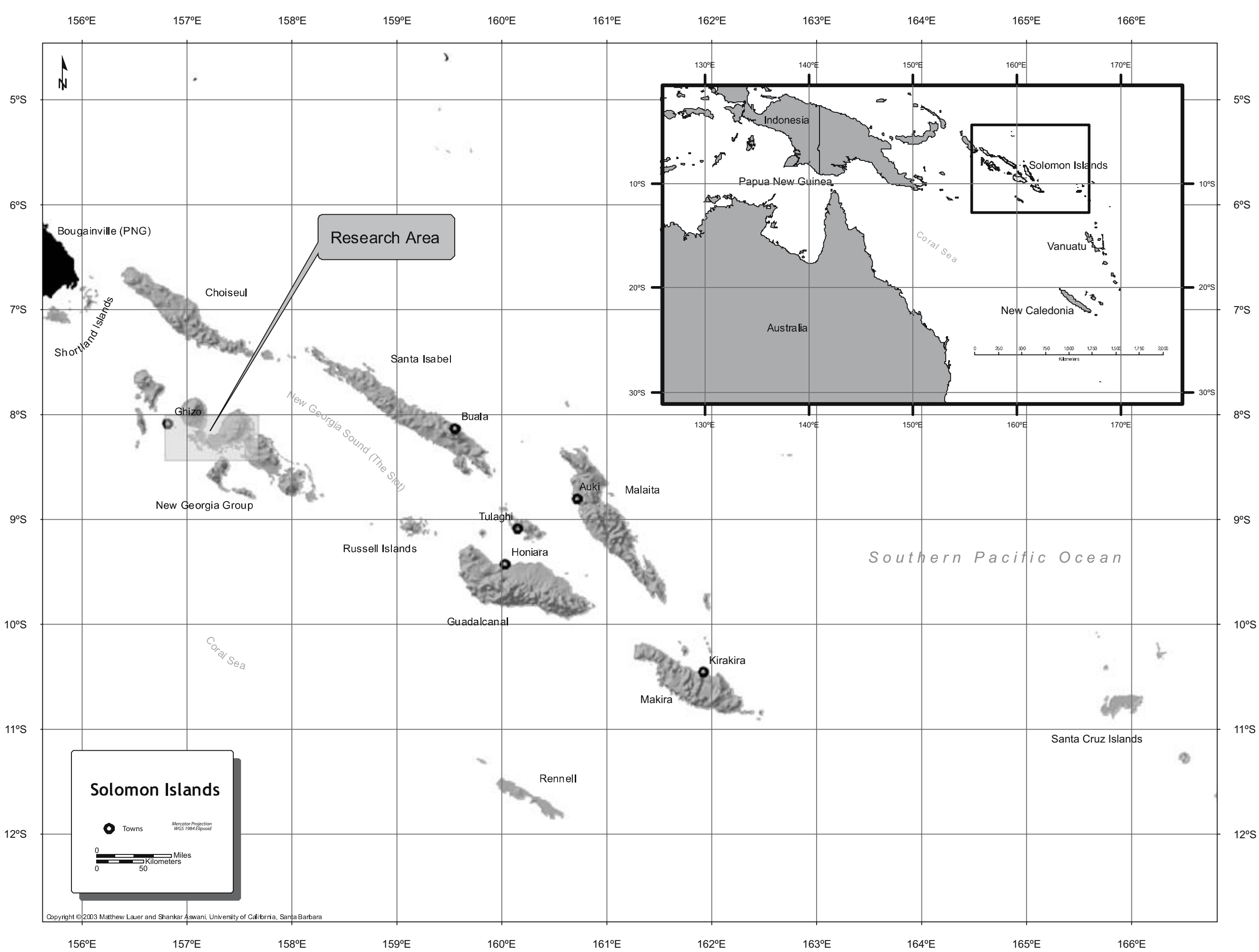


Fig. 1 The Solomon Islands

structure and social use of a sea- or landscape is not just a descriptive endeavor. It is a fundamental step toward developing hypotheses about human–environmental dynamics, base resource maps, and culturally contextualized ecosystem-based conservation. The latter is particularly relevant because in recent years a paradigm shift toward ecosystem-based management (EBM) (e.g., Botsford *et al.* 1997)—an approach that integrates management across ecological systems and incorporates human resource use and knowledge—has been championed as a distinctive way of tackling management challenges in coastal interface ecosystems.

Methods

Study Area

The New Georgia Group lies between longitude 156° 30′E and 158° 20′E and between latitude 7° 30′S and 9° 10′S with the larger island of New Georgia occupying the central position in the chain (Fig. 1). The group's geomorphic structure originates from the geological processes of faulting, volcanic cone fusion, volcanic sedimentation, and reef uplifting. The Roviana Lagoon is formed by fringing barrier islands that developed during the Pleistocene from sea level changes and accretion of coral limestone, organic debris, and volcanic detritus (Brookfield and Hart 1971; Stanton and Bell 1969). The marine ecosystem displays a mix of habitats characteristic of both coastal and coral atoll lagoons, including mangrove forests, river mouths, mudflats, grassbeds, coral atolls, barrier reefs, and marine lakes, among other habitats.

Rural communities are found on both the New Georgia mainland and the islands enclosing the lagoon and have populations ranging between several dozen to over a thousand individuals (Fig. 2). Tribal estates extend from the interior of New Georgia to the barrier islands and beyond to the open sea, and inhabitants access land and sea resources by virtue of their birthright, spousal affiliation, and location of residence (Aswani 1999). Chiefs and elders control each district and exercise control of resource use

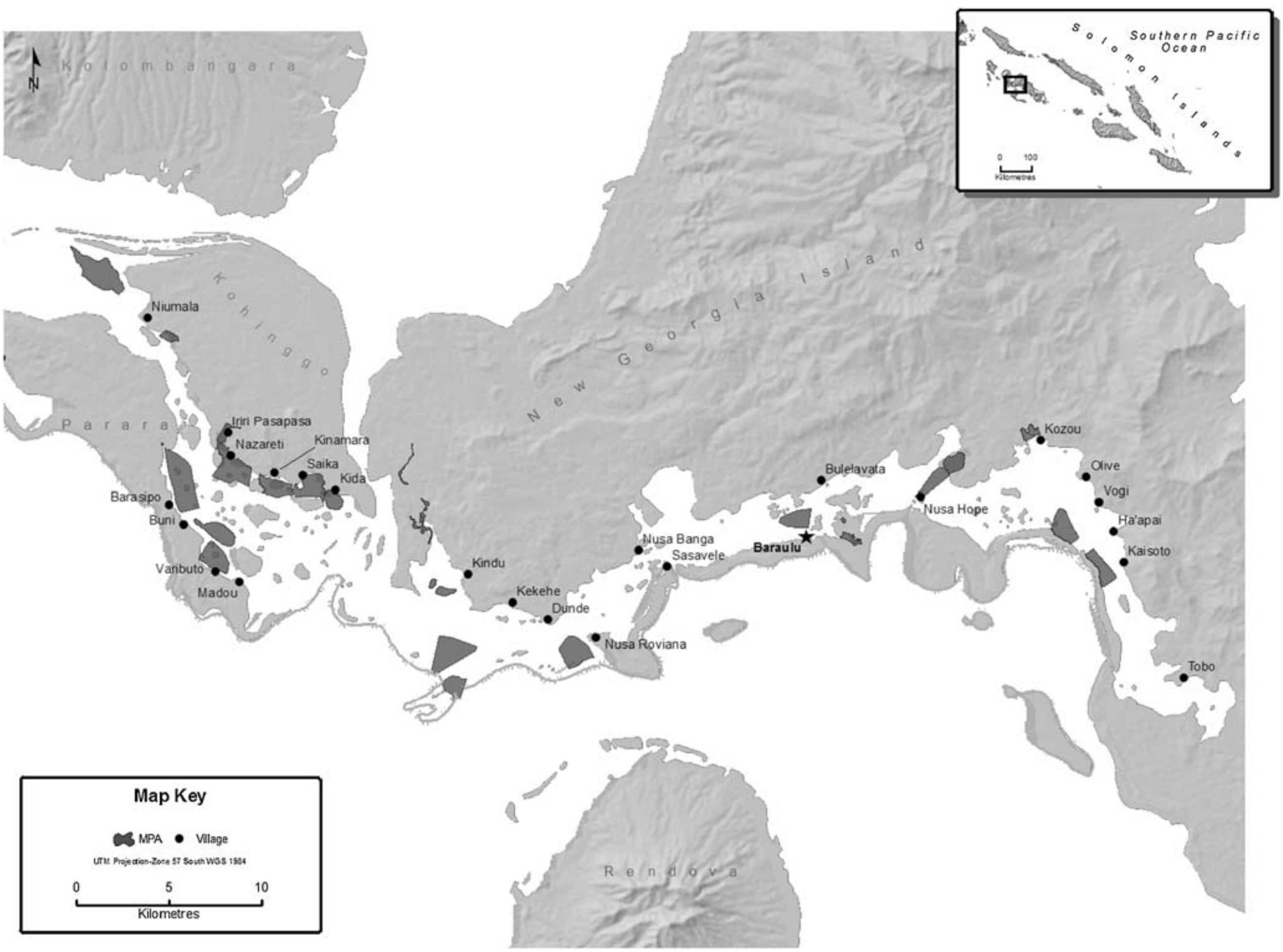


Fig. 2 The Roviana (right) and Vonavona (left) Lagoons, New Georgia, Solomon Islands (MPA sites established under our research and conservation program shown in *gray*)

and access. Today the people not only live off the land and sea but also generate cash by shell diving, marketing of local produce, the selling of handicrafts, copra production, and the operation of small stores, among other types of activities.

Data Collection

Indigenous ecological knowledge (IEK) was documented through extensive participation in fishing expeditions and interviews with fishermen. Participant observation consisted of focal follows, which involved keeping in situ time–motion records of over a hundred fishermen's behavior and measuring their catches. Open-ended and structured interviews with more than two hundred young, middle-aged, and elderly men and women from Roviana and Vonavona Lagoons were conducted over a period of 14 years (1992–2006). Marine habitats and associated species were identified by asking about (1) the name and ecological composition of each habitat; (2) the species of fish, mollusks, and crustaceans found in each habitat; (3) seasonal variations in the availability of different taxa; (4) the existence of particular seasonal events such as spawning aggregations; (5) varying weather, tidal, and lunar conditions and their impacts on the habitat and fauna; and (6) human uses for each habitat and its associated species. Indigenous environmental categories as the focal point were matched with corresponding Western ones to describe climatic phenomena, habitat composition, and biotic taxonomies. The Latin binomial nomenclatures for identifying corals follow Vernon (1993); for shells, Cernohorsky (1978) and Hinton (1972); for fish, Masuda *et al.* (1984), Munro (1967), and Randall *et al.* (1990); for echinoderms and algae, Morton and Challis (1969); and for sea grasses, Waycott *et al.* (2004). All organisms were identified through photographs and specimen collections (particularly shells).

Lagoon Ecology

Roviana people do not cognitively disjoin land and sea spheres, although they exercise their respective entitlement rights independently (see Aswani 1999). The word *pepeso* literally means "ground," but it is employed as an inclusive property domain that includes all habitats in the New Georgia mainland, the inner lagoon, the barrier islands, and beyond to the open sea mid-way between the channel separating New Georgia and Rendova Island. A *pepeso* is divided into four major zones: the mainland (*tutupeka*), the lagoon (*poana* or *koqu*), the outer barrier islands (*toba*) and their adjacent sea-facing habitats (*vuragarena*), and the open sea or deep (*lamana*) (Fig. 3). Roviana people then divide each of the above marine domains into named sites that represent biophysical resource exploitation areas, geomorphologic features that allow or bar people from navigating, and cultural and historical markers that define the seascape. Next, fishermen identify fishing grounds (*habuhabuana*) that are nested within the larger indigenously named and demarcated biophysical sites. Fishing

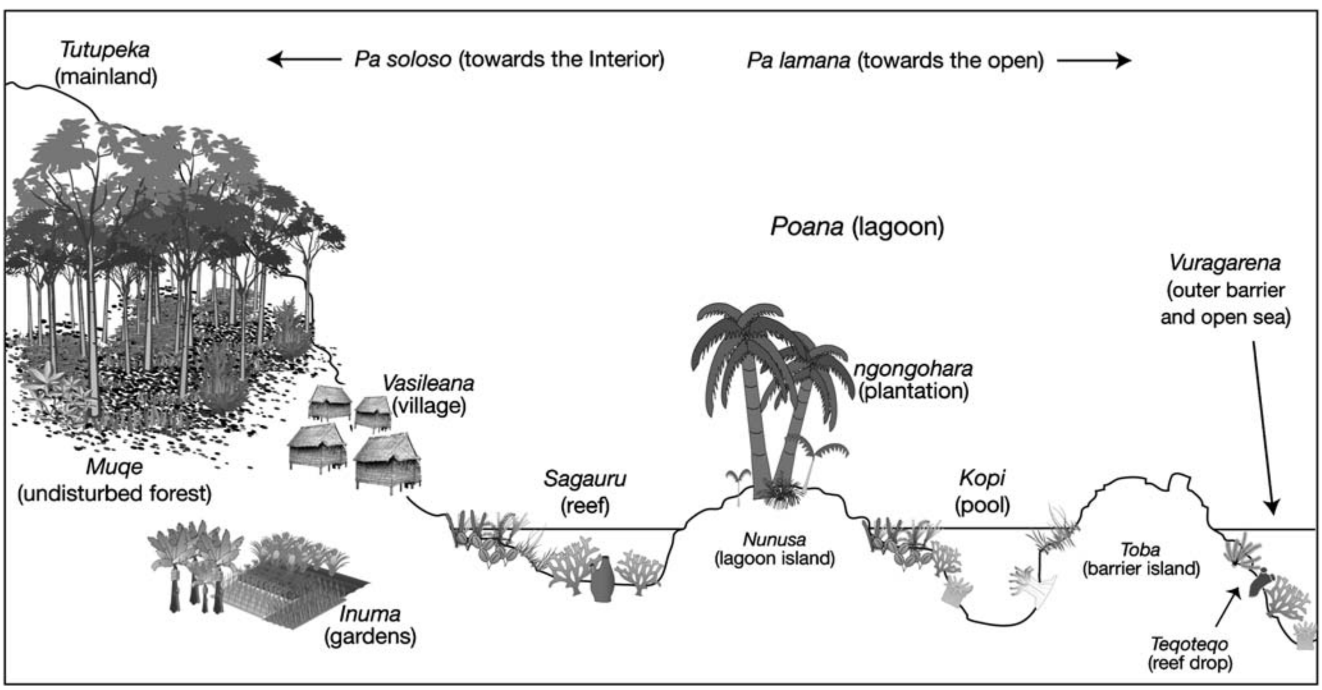


Fig. 3 Roviana zoning of land and sea domains or *pepeso*

grounds, in turn, are composed of one or more areas or floating spots (*alealeana*), in which people actually fish (for example a reef channel). Local fishermen recognize these fishing sites as productive depending on daily, lunar, and seasonal variation. Beneath this cultural construction of the seascape, informants identify biological events of significance (e.g., spawning aggregations) and major and minor marine habitats. Each locally defined habitat, in turn, is identified by its composite benthic substrates (see Aswani and Lauer 2006a, b). In general, major and minor habitats are distinguished according to their biological complexity and general productivity, but not necessarily by spatial scale. Fishermen tend to distinguish between major and minor habitats by associating the latter as part of the former.

Major Habitats

Mangroves (Petupetuana)

Mangrove ecosystems are well established in the region and are extremely important as nurseries for juvenile fish, as spawning grounds for numerous species, and as major feeding zones for reef and pelagic species alike. The term *petupetu* is a generic term for mangroves, although more than 20 species are present and locally recognized. The most prevalent species found in Roviana and adjacent Vonavona are *Rhizophora* species in the low mangrove forests and *Rhizophora* mixed with *Dolichandrone* and *Bruguiera* species in taller stands (Directorate of Overseas Surveys 1974). As in nearby Marovo Lagoon, species distribution is contingent upon lagoon areas with, for instance, *Acanthus*, *Ceriops*, and *Lumnitzera* mangroves, among others, growing on the lagoon islands and *Aegiceras*, *Excoecaria*, and *Pemphis* growing on the barrier islands (Albert *el al.* 2006). In the mainland mangrove-dominated habitat, the substrate of adjacent waters is fine silt and clay with large colonies of *Enhalus acoroides* and other sea grasses. Scattered dead and living *Porites* coral colonies dot these areas and provide productive spots for angling small reef and pelagic species. Mainland mangrove habitats are regularly used by women and children for several activities, including collecting mud clams (*Geloina* spp.) and ark shells (*Anadara granosa*), spearing fish, collecting crabs, and, principally, harvesting hermit crabs and *Terebralia* shells for bait. Dead mangrove trees lying in the water are excellent fishing spots for trolling for juvenile barracuda (*Sphyraena* spp.) and Carangids, which congregate under them.

River Mouths (Sada Ovuku)

Numerous rivers flow into Roviana discharging organic and inorganic sediments into the lagoon. Ordinarily, river mouths are shallow mud-beds dominated by various sea grasses such as *Enhalus acoroides* with scattered dead *Porites* corals and stones. River mouths are not considered productive fishing habitats except for particular times when certain species visit these areas. Schools of mullet concentrate at the river mouths during high tide before entering them in search of food. In former times, some river mouths were dammed (*tukutuku leana* or *hukuhukata*) preceding ebbing tides to trap exiting schools of blue-tail mullet (*Valamugil seheli*). Rainy days are excellent for trolling for trevally near river mouths, as these become rapacious feeders, particularly at the time of a new moon. Also, mangrove jacks (*Lutjanus argentimaculatus*) are caught on full moon nights. Common fishing methods employed in river mouths include trolling, night spearing, netting, and angling. Old fishermen indicate that tiger sharks (*Galeocerdo cuvier*) often enter rivers during high tide in search for mullet.

River Banks (Taqele Leana)

River banks are of rocky substrate and heavily vegetated habitats. Sago palm, (*Metroxylon salomonense*), betel nut (*Areca catechu*), and small gardens are usually planted near river banks. While these areas are not used commonly for fishing and gleaning, men occasionally spear river eels at night. Women sometimes come to river banks to find River Nerites shells (*Nerita pulligera*), which are collected to feed sick people because they are considered less "greasy" than saltwater Neritidae species. A fish locally identified as *maqiu* (spp.?) can be captured along some river banks if fishing lines are baited with grasshoppers. In Roviana, but mostly in the Kusaghe region of north New Georgia, an anchovy locally recognized as *tanginae* (possibly *Stolephorus indicus* or *S. waitei*) enters the rivers in the early mornings and evenings during the months of August through November. These are either netted or scooped with traditional hand nets known as *sipele*.

Sea Grassbeds (Kulikuliana)

Sea grassbeds are among the most widespread habitats in the Roviana Lagoon and are characterized by very shallow waters ranging from 0.5 to 2 m in depth. Locals recognize two sea grass categories—*kuli*, or *Enhalus acoroides*, and *kuli ngongoto*, which is actually a generic category that includes a number of Cymodoceaceae and Hydrocharitaceae sea grass species. *Halimeda* spp. and other macroalgae (locally known as *tatalo*, *kakoto*, *omomo*, and *garagara*) are also common in this habitat. The benthos is of fine silt mixed with sand and coral rubble, with some dead and living *Porites* coral colonies scattered throughout. Sea grassbeds are not frequently used for line fishing because fish hooks easily become caught in the grasses. Nonetheless, they can be productive for fishing and netting during evening ebbing or flooding tides and during new and full moons. Shallower patches are better during flooding tides because fish return with the rising waters.

Hawksbill (*Eretmochelys imbricata*) and Green (*Chelonia mydas*) turtles are commonly speared during nocturnal high tides while feeding on sea grasses, and occasionally dugong (*Dugong dugon*) is also captured this way. Close to shore, fish shore drives are conducted to catch rabbit fishes (*Siganus spinus* and *S. vermiculatus*). As the fish are frightened and seek refuge in the sea grass, they are speared. Spearing is also used to capture barred garfish (*Hemiramphus far*) and blue-tail mullet as they float on the grassbeds at night, and yellow-margin (*Pseudobalistes flavimarginatus*) and titan (*Balistoides viridescens*) triggerfishes as they dig for benthic organisms. Also, thumbprint emperors (*Lethrinus harak*) are either speared or captured by hand as they earth themselves on the sand. Finally, diverse commercial and subsistence shells are collected in grass habitats.

Inner Lagoon Shallow Reefs (Sagauru Masa)

Shallow reefs usually range between 1 and 4 m in depth and are characterized by dead and live coral species belonging to the Poritidae, Acroporidae, Agariciidae, Pocilloporidae, and Fungiidae families, among others. A number of species of Hydrocharitaceae sea grass (e.g., *Thalassia hemprichii* and *Halophila ovalis*) and *Halimeda* spp. macroalgae are spread over the dominant sand and coral rubble substrate. Shallow reefs are heavily exploited by everyone for fishing and collecting crustaceans and shells, particularly during the day low-tide season from May to September. Fishing in shallow reefs is productive during early mornings and evenings, especially during ebbing and low tides when reef and pelagic species concentrate in certain areas. The best lunar phases for fishing in shallow reefs are the new, first quarter, and full moons. The most important income-generating shell species are gathered from shallow reefs, including cardita clams (*Beguina semiorbiculata*) and Nassarius shells (*Nassarius camelus*). Shells taken for subsistence purposes in shallow reefs include Venus (*Gafrarium tumidum*) and ark (*Anadara antiquata*) shells. With the shift in tidal seasons in September, nocturnal low tides allow divers access to multiple reefs where sea cucumbers (bêche-de-mer) are found. These are sold to Chinese traders in Honiara, who export them to Asian markets.

Inner Lagoon Mid-depth Reefs (Sagauru Lamana)

Mid-depth reefs range between 5 and 15 m in depth and are of similar ecological characteristics as shallow reefs, although sea grasses and macroalgae are not as abundant. The substrate is a mix of coral rubble and fine silt blended with sand. Mid-depth reefs occur throughout the lagoon and are prevalent around lagoon pools and channels. Large coral formations of *Porites cylindrica* are associated with this habitat type. These sites are considered productive fishing spots because various Lutjanidae species such as hussar (*Lutjanus adetii*), paddle-tail (*Lutjanus gibbus*), and yellow-margined (*Lutjanus fulvus*) snappers aggregate here during full moons. Yet these reefs are not as heavily visited as shallow reefs, and men do most of the fishing in them because women and children prefer shallower waters. Fishing is favored during low tide because larger fish concentrate in these areas away from shallow reefs, grassbeds, and sand banks. Common fishing methods used in this habitat include drop-line, angling, trolling, and diving.

Cape Reefs (Miho Sagauru)

The Roviana people recognize cape reefs as different from other lagoon reefs because they usually form around promontories or peninsulas that extend out from lagoon islands and present different opportunities for fishing. In general, they are shallow and are ecologically similar to other reefs, except that soft corals such as *Sarcophytum*, *Sinularia*, and some gorgonians are more common in the sloping edges of these reefs. Prevalent fishing methods include trolling, angling, day and night spearing, netting, diving, and gleaning for invertebrates. Numerous species of fish such as bluefin trevally (*Caranx melampygus*) aggregate in large schools in these capes. Skilled fishermen know that the fish forage up and down the fringing drops and wait for them to aggregate at the reef's edge. For instance, between September and December during the mornings and evenings of the last quarter moon, fishermen angle and drop-line for yellow-margin and titan triggerfish, scribbled snapper (*Lutjanus rivulatus*), and speckled-fin rockcod (*Epinephelus ongus*) as these species aggregate in these sites (for spawning or other reasons).

Lagoon Pools (Kopi)

The Roviana and Vonavona Lagoon system is an intricate puzzle of channels, reefs, and pools, some large and others small. Pools, or *kopi*, are very numerous, and their deeper waters provide refuge for schools of fish seeking shelter from seasonal low tides, which dry up some shallow lagoon reefs. Pools can be of sandy coral rubble and silt substrate, and can be bordered by reef drops or slopes of various sediment compositions. Lagoon pools are not considered particularly good spots for fishing except when targeting specific species, most commonly carangids and juvenile barracudas. Pools are also areas to find hawksbill and green turtles, and fishermen stalking turtles wait for them to surface at the edge of a pool, as a fleeing turtle will seek shelter in them. Common fishing methods used in these areas are sink-line, slow troll with bait, and diving. The latter is generally conducted at night and in pools bordered by reef drops.

Tidal Sand Banks (Bolebole)

Tidal sand banks are constituted of sandy and coral rubble substrates that are not encroached by reefs and are exposed during low tides. Fishing in sand banks is especially good for targeting of species of the Lethrinidae family (emperors). Prevalent Lethrinidae caught here are longnosed (*Lethrinus elongatus*), yellowlip (*Lethrinus xanthochilus*), and thumbprint (*Lethrinus harak*) emperors. Large schools of mullet are also known to concentrate in sand banks during full moons, particularly in the Munda and Rarumana areas. Common fishing methods include angling, netting, and "grab" fishing, the latter consisting of grabbing or spearing thumbprint emperors when they camouflage themselves in the sandy substrate. Men and women come to this habitat to dive for bêche-de-mer and to collect spider (*Lambis* spp.) and stromb (*Strombus* spp.) shells.

Lagoon Passages (Holapana or Sangava)

The Roviana Lagoon has five main passages through which medium-sized ships can pass. The channels are generally deep and are bordered by shallow reef flats dropping at the edges. These are excellent areas for fishing because they are transient zones for fish moving in and out of the lagoon and for certain events of biological significance (e.g., spawning aggregations). During the *odu rane* or day-high/night-low tidal season from the end of September to mid-January (which can sometimes stretch until April), water flushes into the lagoon in the early morning, and at about 5:00 A.M. fishermen begin to gather at the margins of passages to wait for the incoming schools of goldspot herring (*Herklotsichthys quadrimaculatus*) and bigeye scads (*Selar crumenophthalmus*) entering to feed in the lagoon. These are followed by large pelagic predators such as giant trevally (*Caranx ignobilis*), barracudas, bigeye trevally (*Caranx sexfaciatus*), and Spanish mackerel (*Scomberomorus commerson*) that voraciously feed on the smaller fish. As water flushes out in the evenings, the same events are replicated. During this same period, various species of barracuda (e.g., *Sphyraena jello*, *S. putnamiae* and *S. barracuda*) aggregate at the mouth of the passages throughout the lunar cycle but with greater intensity during the full moon. Methods used in this habitat include trolling, angling, drift troll with bait, vertical trolling,[1] bottom lining, and jigging.

[1] Vertical trolling was introduced from Papua New Guinea. This method is referred to as *kura niugini*, the name being borrowed from the traditional "fish trapping," or *kura*, fishing method.

Outer Lagoon Intertidal Zone (Raratana Vuragarena)

The outer lagoon intertidal zone of the barrier islands encompasses various biotopes. This area is recognized as the area opposite to *koqu* (inside the lagoon), where the weathered limestone surfaces of the barrier islands become steep reef slopes subsiding into the open ocean. The shore is formed of notched and elevated tidal terraces of reef rock (Stoddart 1969), and the rocky substrate near the eulittoral zone is covered by sea lichens (e.g., *Verrucaria*) and various macro-algae (e.g., *Porolithon onkodes* and *Halimeda* spp.) developing to variable densities in the intertidal zone. Common organisms found in this area include cowry shells (e.g., *Cypraea tigris* and *C. mauritania*), turban shells (*Turbinidae* spp.), Nerites shells (*Nerites* spp.), periwinkles (*Tectarius pagodus*), drupes (*Drupa morum*), and various chiton (e.g., *Acanthozostera gemmata*) and sea urchin (e.g., *Echinometra mathaei*, *Heterocentrotus mammillatus*) species. The intertidal shoreline is usually visited by women and children, and the adjacent reef drops and open ocean are used only by men. In the past, it was a customary prohibition for women to fish here, and women were only allowed to glean for shells during fine weather conditions. Today, most gleaning takes place during nights of the second quarter and full moon and during nocturnal low tide in the months of September through December (an activity known as *sapora*). The harvesting of floating turtles is also common in this habitat. As floating debris flushes out of the lagoon, turtles come to feed on the debris, so fishermen look for mangrove seeds, sea grasses, and small jellyfish as evidence of the presence of turtles.

Reef Drops (Teqoteqo)

The Roviana term *teqoteqo* refers to any reef drop in the inner or outer lagoon (when small they are referred to as *barapatu*). Inner lagoon drops extend from 3 to 40 m in depth and are located at the edge of lagoon channels, pools, and passages. Inner lagoon drops generally consist of coral rubble and rocky substrates mottled with sparse *Porites*, *Acropora*, *Pachyseris*, and *Merulina* colonies, among other hermatypic corals. In areas of sizable water exchange, such as passages, colonies of soft corals such as *Sarcophytum*, *Sinularia*, and gorgonians are common. Fishing here is excellent, and fishermen prefer early mornings and evenings, low tide, and the new and full moons for fishing. In the drops bordering the passages, the last quarter and "no moon" (*koroqana*) are optimum lunar phases to fish for scribbled snapper, triggerfishes, speckled-fin rockcod, and flowery cod (*Epinephelus fuscoguttatus*).

Reef drops in the outer lagoon range between 3 and 200 m in depth and have more diverse coral assemblages than inner lagoon reefs. Fishing in the outer reef drops is excellent and less subject to tidal variation than the inner lagoon reef drops, although weather conditions determine their accessibility. Common methods in this habitat include angling, trolling, bottom lining, spearing, and diving. Inner reef drops are used throughout the year, while outer drops are intensively used from August through December when large schools of barracuda aggregate at certain spots.

Outer Lagoon Deep Water Reefs (Sagauru Ruata)

Deep water reefs are mostly found in the outer lagoon, are generally not visible from the surface, and range from 15 to over 100 m in depth. Dense coral formations, including *Acropora reticulata*, *Echinophyllia* spp., and *Leptoseris*, *Pavona*, as well as *Sinularia* spp. and gorgonians, predominate in the rocky substrate (Morton and Challis 1969). Some deep reefs are near reef drops, while others are hundreds of meters away from the shoreline. The latter are used by men and are only accessible at specific times. The southeast trades and westerlies barricade access to these reefs in most villages. *Sagauru ruata* are considered productive fishing spots, and, unlike the inner reefs, they are productive throughout the lunar cycle. Mid-days and nights are the favored times to fish here. Fishing is optimal on full moon nights as currents are not too strong and certain species like paddletail snappers, big-eye bream (*Monotaxis grandoculis*), and red bass (*Lutjanus bohar*) are abundant. Traditionally, a method called *kura habili*, or the use of traps to capture humphead Maori wrasse (*Cheilinus undulatus*), was practiced during the last quarter of the lunar phase from September to December of every year. Today, the most common fishing methods conducted in deep reefs are drop lining, vertical trolling, and regular trolling if schools of fish are spotted on the surface.

Barrier Island Sandy Lagoon (Avasa)

Avasa refers to a small sand bar within a reef. The term is also used in reference to a small, shallow lagoon within the outer barrier islands or within outer lagoon islands. Regardless of their location, they are generally formed of fine sandy and silty substrates. These sandy lagoons are regularly visited by everyone because they are productive fishing and gleaning areas. Fishermen note that they like to fish here because their hooks do not get caught in stones and because catches are considerable. Optimum fishing times vary according to the depth of the bank. If shallow, high tide is best, and if deep, low tide is better since fish cluster in the deeper ends. Fishermen often visit sandy lagoons from the new moon to the end of the first quarter and again during the full moon and few days thereafter because emperor fishes (Lethrinidae) are more active at these times. Three unusual species are found inside these pools. The six-fingered threadfin (*Polydactylus sexfilis*), locally known as *vulu*, is a fish resembling mullet that is occasionally speared in *avasa* and is not found elsewhere. Milkfish (*Chanos chanos*) or *pogu* are known to aggregate in these pools during December and January waiting to feed on the eggs of a semiterrestrial crab (*Cardisoma carnifex*) or *garumu* that descends in an annual migration from the forest interior to spawn at the shore. Finally, bone fish (*Albula neoguinaica*), a favorite of American sport anglers, is seen only in *avasa* and *bolebole* during the day-low-tide season. Methods conducted here include angling, netting, and diving for commercial species such as Nassarius shells and bêche-de-mer.

The Open Ocean (Kolo Lamana)

Fishing in the open ocean is mainly conducted by men trolling for skip-jack tuna (*Katsuwonus pelamis*) and island bonito (*Euthynnus affinis*) by paddle or motorized canoe. Women do not fish in this habitat because in pre-Christian times it was a customary prohibition for them to fish for tuna. Fishing in this habitat requires certain ecological knowledge because the movement of currents, the sightings of sea birds, and the presence of floating debris tell fishermen the possible locations, size–class, and species of tuna. Once a school of tuna is encountered, a fisherman must be able to recognize surface water conditions to know the appropriate size and color of lure to employ. Most open-ocean fishing in Roviana and Vonavona, particularly in paddle canoes, is conducted between the months of February and April.

Minor Habitats

Roviana people also recognize ecological microhabitats that are distinguishable from the major environmental categories housing them. Fishermen have developed a classification that takes into account the extreme diversity of the environment and the productive possibilities of each patch.

Reef Channel (Karovoana)

A myriad of sandy moats filled with coral rubble ranging between 2 and 5 m in depth bisect many shallow reefs. These passages serve as routes for fish moving in and out of feeding grounds in the adjoining mangroves and grassbeds of the New Georgia mainland. Roviana fishermen know that numerous species follow determined pathways throughout the lagoons as they move from one feeding ground to another, and they know the exact location and times when the fish pass. Thus, at the opportune time, the fishermen simply position themselves according to the direction of the current. For instance, during the day-low-tide season fish pass into accessible feeding grounds during evening surging tides and move out with the morning ebbing tides. Conversely, during the day-high-tide season, fish move into shallow reefs in the early morning away from deeper waters in the main channels. At the right time, large pelagic fish like great barracudas, giant trevally, and Spanish mackerel pass through and can be easily caught.

Small Lagoon Channel (Goreana)

Goreana are small moats in the outer lagoon that link coastal pools or small lagoons with the open ocean. These are usually of rocky substrate and can be covered with corals such as *Pocillopora*, *Montipora*, *Acropora*, *Porites*, *Pavona*, *Echinophyllia*, and *Favia*. Fishing in this micro-environment is only productive at certain times. High tide allows large schools of fish to enter the pools through these channels, but when the tides ebb many are left dry and are only useful for collecting shells such as crocea clams (*Tridacna crocea*). Early morning flooding tide is the optimum time to spear fish in this microhabitat, particularly during the period of September through December.

Small Mangrove Passage (Susuka)

Susuka are shallow, silty channels that connect lagoon waters with the interior of flooding mangrove forests. Rising tides make these channels accessible to fish entering the mangrove's arching roots to feed or spawn. With ebbing tides, most of these channels are left dry, so fishing here is uncommon and is only possible during high tide. Men may occasionally spear passing fish while looking for bait or looking for mud crabs, and women search for mudwhelks (*Terebralia palustris*) shells and mud clams in these small passages. Common fishing methods used include spearing, gleaning, and angling if targeting mangrove jacks on full moon nights.

Burrow (Mavara)

The term *mavara* refers to burrows embedded in dead or living *Porites* coral colonies where musk crabs (e.g., *Thalamita crenata*) or certain types of fish are found. Divers recognize the presence of a musk crab when empty shells such as those of *Cardiidae* spp. are seen outside the burrow, as these are the crabs' favorite foods. Predation on these crabs is periodic because during full moons they are considered inedible. Crabs carrying egg sacs at this time are said to be *poranga*, or watery, and fishermen prefer to wait until the new moon or last quarter before visiting the burrow again. Other species found in burrows include titan and yellow-margin triggerfishes, which night divers spear while they are resting inside their burrows.

Coral Colony (Pede)

Pede is a generic term for colonies of *Turbinaria*, *Pavona*, and *Acropora* corals, which are found in shallow and mid-depth areas of the inner lagoon. These colonies tend to stand apart in sandy bottoms away from coral reefs, areas that are more intensively exploited during the day-low-tide season. The most common fishing methods used here are angling and diving, and all sorts of coral fish species are caught, the most prevalent being paddletail snappers, various groupers, and brown-headed emperor (*Lethrinus hypselopterus*).

Coral Colony (Huquru)

These are *Porites cylindrica* coral colonies, which are found in shallow, but mostly mid-depth, reefs around islands and are considered excellent fishing spots. They are also notorious places to catch turtles resting under the coral formations. Common reef fish found here include hussar snappers, various groupers, black-banded seaperch (*Lutjanus semicinctus*), yellow-margined seaperch, and sweetlips (*Plectorhinchus chaetodonoides*, *P. goldmanni*, and *P. obscurum*). Also, painted rock lobsters (*Panulirus versicolor*) are commonly found in this locally identified microhabitat. The prominent methods practiced are angling and diving with locally made spear throwers.

Coral Head (Patu Voa)

Patu voa are *Porites* coral formations (e.g., *P. lobata*, *P. australiensis*, and *P. lutea*) and are the most widespread hermatypic corals in the lagoons of New Georgia, particularly in Roviana, where they are found throughout the area, including in mangroves and near river mouths. These corals can be massive and grow well in the sediment-laden water of the lagoons (Vernon 1993). Practically all reef fish species that inhabit the lagoon can be caught near these coral heads, the most prominent being several species of groupers (e.g., *Epinephelus ongus*), titan triggerfish, and sabre squirrelfish (*Sargocentron spiniferum*). Groups of surgeonfish and sweetlips aggregate in these coral heads at specific times. The most common fishing activities carried out near these corals are angling, diving, and the use of piscicides during certain times.

Coral Head (Patu Kakarapihi)

Patu kakarapihi are corals of the *Favites* and *Goniastrea* genus and are locally recognized as morphologically similar to *Porites* but much softer and less widespread. *Patu kakarapihi* are found in well-developed coral reefs near reef slopes and outer lagoon reefs, and few are found in the inner shallow reefs of the lagoon. Common reef fish found here include paddletail snapper, yellow-margined seaperch, groupers, and angelfishes (*Pomacanthus* spp.).

Environmental Variability and Foraging Strategies

There are four major interdependent environmental forces that structure the times and places where fishermen exploit marine resources: daily and seasonal tidal fluctuations, lunar phase periodicity, wind patterns, and lagoon hydrology.

Daily and Seasonal Tidal Variation

The ability of fishermen to gain access to particular habitats is regulated by daily and seasonal tidal fluctuations, and in fact all maritime practices, including sea travel, are governed by tidal variation. The islanders organize fishing, gleaning, and commercial diving according to the prevalent tidal stage. For instance, an attempt to collect mud clams in a mangrove forest can completely fail if the water level is even a few inches above the anticipated tidal stage.

Locals classify this tidal variation into three tidal seasons: *odu rane-masa bongi*, *masa rane-odu bongi*, and *vekoa kolo*. During the *odu rane-masa bongi*, or day-high/night-low tidal season from the end of September to mid-January, tides remain relatively high during the day and ebb in the evenings. For fishermen, this is a good time to drop-line for pelagic species in the lagoon passages and outer-lagoon reef drops. Fishing in the inner lagoon habitats is not completely abandoned but is reduced. Nocturnal low tides are also advantageous for night spearing and netting because concentrations of fish are plentiful in mid-depth reefs and grassbeds.

Beginning in February, the tidal cycle changes again. This tidal season, *vekoa kolo*,[2] which lasts until mid-April, is a transitional time from one major tidal cycle to the next. Although islanders recognize a change in tidal oscillation from the previous tidal season, not all local informants recognize this time of the year as a specific season and continue to call it *odu rane*. Frequent change in the flow of water entering and exiting the lagoon concentrates large schools of herring in some passages, and large pelagic species come to feed on the herring. This season is also the best time for open-sea trolling with paddle or motorized canoes for skip-jack tuna.

Finally, the *masa rane-odu bongi* or day-low/night-high tidal season, which lasts from May to September, brings a series of changes in the way resources are exploited. Diurnal ebbing tides allow for a whole array of activities in the inner-lagoon reefs. With the intensification of the inner lagoon fishery, angling becomes the favored method because diurnal ebbing tides force fish to cluster in mid-depth reefs. Diurnal low tides also permit the usage of other fishing methods such as organic piscicides and fish drives, which are not conducted during other seasons. Women gather shells in mangroves and grassbeds on a daily basis, and most commercial shell diving takes place during this season. In recent years, tidal periodicity has changed for reasons unknown to the local population.

Lunar Periodicity

Lunar phase shifts provide fishermen with information regarding the timing of tidal fluctuations; the behavior, location, and vulnerability of certain species; the direction of the currents; and the appropriate methods to be employed (Johannes 1981). In the daily discussions of Roviana fishermen, lunar phases play center stage. Women anticipate the new moon to fish for orange-striped emperors (*Lethrinus obsoletus*), and with the approach of last-quarter dark nights divers sharpen their spears to fish for bumphead parrotfish. The best lunar phases for fishing are the new and full moons, with the last quarter being better if targeting particular species such as titan and yellow-margin trigger-fishes and scribbled snapper. Traditionally, the Roviana people recognize 28 days, with a periodic additional 29th, in their lunar calendar (Fig. 4) and enumerate 13 lunar months in a year. Since the early 1900s, the traditional Roviana yearly calendar has been replaced by the Gregorian one and the enumeration of lunar phases have been combined with Western terminology.

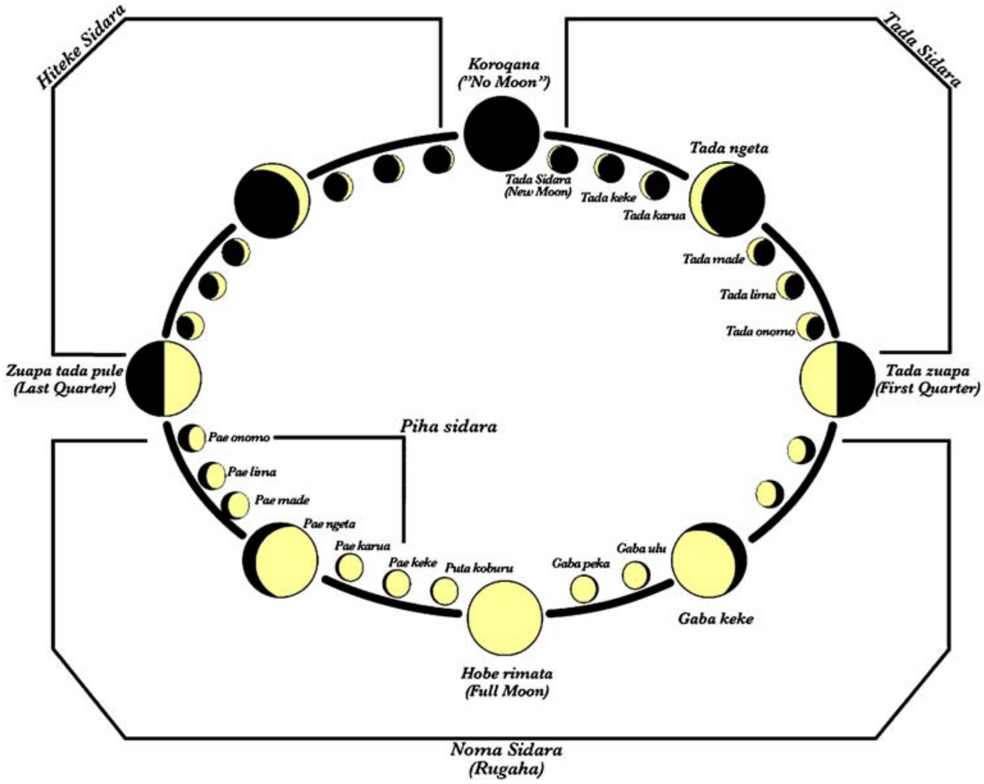
Wind Patterns

Wind patterns are seasonal and predictable phenomena for Roviana Lagoon dwellers. The periodicity of winds, however, has changed in the last two decades, and numerous informants claim that today wind patterns are harder to predict due to global climate change.[3] Five major wind categories are locally recognized: (1) *gevasa* blowing from the southeast, (2) *peza* coming from the west, (3) *zokolo* coming from the northeast, (4) *togarauru* blowing from the northwest, and (5) *givusu hopo* blowing from the southwest. *Gevasa* is the most prevalent wind pattern for the greater part of the year. Commencing in mid-April or May, the southeast trades begin to blow in the early morning, intensify during midday and subside in the late evening. Even after wind patterns change in mid-October,

[2] The term *vekoa kolo*, or "still water," refers to semi-diurnal neap tides with a 24-h persistence of mid- and high tides.

[3] Local people have heard about global climate change through the media (e.g., local newspapers, Voice of America radio, etc.) and through formal education.

Fig. 4 A version of the Roviana lunar calendar



the southeastern trades still regularly sweep the lagoons because New Georgia lies south of the "equatorial perturbation belt" (Brookfield 1969). From a total 2,384 wind samples taken during a 22-month period in 1994–1995, 56% of all counts were *gevasa* wind (Aswani 1997). The southeastern trades hinder access to outer reef drops, passages, and the open sea because high swells make fishing dangerous. The *peza*, or westerly wind, begins to blow in October and lasts through mid-April, when the southeast trades return. This wind is locally considered to be the most dangerous, in that it can hinder inner lagoon travel by creating high waves. On the other hand, Roviana Lagoon passages are sheltered from the westerly gusts, making them ideal spots for fishing at this time.

Hydrology and the Lagoon Routes

While there are no scientific studies of the general water dynamics in the Roviana Lagoon, local people recognize certain patterns. The volume of water exchange between the lagoon and the open ocean varies according to the size of a passage. Some passages, such as those in Nusa Hope and Sasavele, are between 150 and 300 m wide and over 20 m deep, which allows for the movement of large volumes of sea water. Narrower passages, such as that at Baraulu, are between 100 and 150 m wide and not as deep. This is significant because fishing is conditioned by a lagoon's hydrology. Generally, catches are better during incoming and outgoing tides when fish passing through the channels are moving in and out of their feeding grounds. Local informants note that pelagic fish caught in deeper passages are larger and more abundant than those caught in shallow ones, and catch data concur with these observations. For instance, the Baraulu shallow passage has a mean return rate for line fishing of 1,536 kcal/h, whereas the deeper Sasavele and Olive passages have 3,174 and 2,532 kcal/h, respectively (see Aswani 1998).

The movement of water and its influence on fishing is not only limited to passages but also includes numerous habitats in the inner lagoons. Informants maintain that numerous species of pelagic and reef fish migrate through the lagoon following currents and specific paths. For instance, various species of mullet migrate from Kalena Bay at the bottom of Roviana to Rarumana at the tip of the Vonavona Lagoon. Fishermen claim that every full moon huge schools of mullet begin their monthly migration following known paths near the coastline to spawn in the reef channels of Rarumana in Vonavona (Fig. 2). In their spawning migration, mullet stop for several days at Munda area reef flats, sand banks, and lagoon islands, where they can be netted and speared. Another event, known as *ukuka*,[4] occurs in the last quarter

[4] Johannes and Hviding (1987) have recorded an event called *ukuka* in nearby Marovo Lagoon. Their description of this event is different, as it describes the behavior of fish during rainy periods followed by still weather.

of the lunar cycle during the months of September through December. Large schools of mixed species swim into the lagoon in the early morning following incoming tides and move through locally known paths. These schools include species of surgeonfish (*Acanthurus* spp.), parrotfish (*Scarus* spp.), goatfish (Mullidae spp., particularly *Parupeneus barberinus*), black-spot snappers (*Lutjanus fulviflamma*), long-faced emperors, and sometimes various species of Carangids. Elders report that this phenomenon has not taken place since the early 1960s.

Marine Extractive Practices

Roviana fishermen distinguish approximately 52 extant and extinct major fishing methods, with innumerable local variants. Each method is adapted to particular ecological circumstances and is designed to target general fish populations or specific species. Today, most traditional methods have either been transformed by the introduction of new technologies or have been abandoned altogether. The most predominant methods currently employed are hook-and-line fishing, netting, diving, spearing, and gleaning. Less frequently used techniques include fish drives, piscicides, fish trapping, hand fishing, and, rarely, dynamite fishing (Table 1).

Line Fishing

The most conventional gear type employed in the region is hook-and-line, which includes angling (*vekovekoe*), sink lining (*lolodu*), bottom lining (*goregore*), motion bottom lining (*dakudaku*), trolling (*karumae*), drift line with bait (*tatadara*), vertical trolling (*kura niugini*), jigging with multiple hooks (*rakapa*), surface troll with pole line (*sasasa*), and pole lining (*valusa*), among others. The most common methods are angling, trolling, sink lining, and bottom lining. Angling enjoys wider use among women and children, while trolling and bottom lining for big game are practiced mainly by men, who can earn great prestige through their skillfulness. In broad terms, angling intensifies during the day-low tidal season, bottom lining increases during the day-high season, and slow, open-sea, and vertical trolling augment during the "still water" season. As with other fishing methods, the optimum times for hook-and-line fishing are during ebbing or low tides, in the early mornings and evenings, and at new and full moons, although the best times for targeted species vary.

Netting

Traditionally the most prominent methods were conventional netting (*vaqara*), turtle netting with giant barrier nets (*morumoru*), mounted bait nets (*zapu*), and hand-scoop nets (*sipesipele*). Nets were manufactured from the bark of trees, certain kinds of buoyant woods were used as floaters, and cowry shells were employed as sinkers. Today, monofilament nylon nets are prevalent. Two strategies are followed when netting—stationary netting (*vaqara aqa vekoa*) and drive netting (*vaqara piqo*). The former can be carried out by a single fisherman and involves anchoring a net between two points, while the latter requires at least two fishermen and consists of driving schools of fish into a net. The appropriate times for netting are contingent upon the chosen strategy. If using stationary nets, night-time ebbing tides and full moons are the most appropriate times. Some people claim that dark nights are better because during full moons fish can detect the nets. On the other hand, experienced fishermen contend that if the night is too dark fish can see the bioluminescence of plankton as it is pushed by currents through the net. Netting is carried out in grassbeds, shallow reefs, sand banks, and river mouths. Species generally targeted in the inner lagoon include mullets, trevallies, hairback herring, striped mackerel (*Rastrelliger kanagurta*), biddies (*Gerres* spp.), and juvenile queenfish (*Scomberoides* spp.). Outer lagoon and barrier reef netted species are more varied and include such species as surgeonfishes, parrotfishes, unicorn fishes, and juvenile wrasses.

Spearing

Spearing is a culturally significant fishing method that requires great ability and patience. Roviana people contend that skillfulness with spears (*tie hopere* or "spearman") is a heritable customary trait that is passed from a father to one or more of his sons. Several types of spears are used to target different species. Small, light spears (*panga*) with multiple prongs are utilized to catch baitfish as well as small reef fish. Larger spears (*soloro*) are employed to target large fish, turtles, and occasionally dugongs. Spearing is among the most productive fishing methods, particularly when practiced at night with flashlights or portable kerosene lamps. The major species targeted during torch night spearing (*zuke bongi*) are lagoon species such as mullet and mud crabs, and turtles are also stalked at night. When detected, turtles are deliberately frightened so that they leave a luminescent trail as they flee, which facilitates their spearing. Spearing is also conducted in shallow lagoon reefs and in the outer lagoon barrier reefs. All types of fish are stalked, but the prized catch is larger-size bumphead parrotfish. Other methods involve the release of objects, such as the tossing of flattened iron tins (*divedive*) at small fish, and in the past bows (*bokala*) were used to target mullet and other estuarine-associated species.

Table 1 Major Contemporary Roviana Fishing Methods

Major fishing methods	Technology employed	Major habitats targeted	Principal prey species	Principal season/s
Netting (*vaqara*)	Mono-filament gill nets and paddle or motorized canoes	Shallow reefs, grassbeds, and mangroves	Mullet, Carangids, surgeonfishes, milkfish, goatfishes, and biddies	Full year, but more intense during *masa rane*
Paddle canoe trolling (*karukarumae*)	Hook and nylon lines (40–90 lb test), lures, paddle canoe	Lagoon passages, channels, reef drops, and river mouths	Carangids, kingfish, rainbow runner, barracudas, and tunas	Full year, but more intense during *odu rane* and *vekoa kolo*
Open sea troll (*karumae makasi*)	Hook and nylon lines (30–60 lb test), motorized canoe	Open sea	Skip-jack, yellowfin, and bigeye tunas island bonito, and blue marlin	Full year, but more intense during *vekoa kolo*
Drift-line (bait) (*tatadara*)	Hook and nylon lines (70–100 lb test), paddle canoe	Lagoon passages and reef drops	Barracudas, kingfish, and Carangids	Full year, but more intense during *vekoa kolo*
Vertical-trolling (*kura niugini*)	Hook and nylon lines (50–80 lb test), lures, stones, coconut leaf, and paddle canoe	Mouth of passage and reef drops	Snappers, rainbow runner, groupers, and Carangids	Full year, but more intense during *vekoa kolo*
Bottom-lining (*dakudaku/goregore*)	Hook and nylon lines (90–150 lb test), sinker, and paddle canoe	Mouth of passage and reef drops	Barracudas, kingfish, and snappers	Mostly during *odu rane*
Sink-line (*lolodu*)	Hook and nylon lines (50–100 lb test), sinker, and paddle canoe	Lagoon deep pools and channels and mid-depth reefs	Groupers, snappers, Carangids, triggerfishes, and juvenile barracudas	Full year
Angling (*vekovekoe*)	Hook and nylon lines (10–30 lb test) and paddle canoe	Shallow and mid-depth reefs, reef drops, grassbeds, passages, and river mouths	Snappers, grouper, triggerfishes, wrasses, goatfishes, emperors, breams, and Carangids	Full year intensifying during *masa rane*
Diving (*suvu*)	Homemade spear-guns, iron wires, rubber, and paddle or motorized canoes	Shallow and mid-depth reefs, reef drops, and passages	Groupers, wrasses, parrotfishes, surgeonfishes, sweetlips, and rabbitfishes	Full year intensifying during *masa rane*
Spearing (*hopehopere*)	Hand spears and paddle canoe	Mangroves, grassbeds, river mouth, shallow reefs, and reef drops	Mullet, parrotfishes, sweetlips, triggerfishes, and rabbitfishes	Full year
Piscicides (*bunabuna*)	*Derris* spp. leaves, sand, and paddle canoe	Shallow reefs	Snappers, groupers, soldierfishes, and wrasses	*Masa rane* only
Fish drives (*kuarao*)	*Arara* vines, *Derris* spp., spears, gill net, and motorized canoes	Shallow barrier reef flats	Parrotfishes, wrasses, triggerfishes, emperors, and surgeonfishes	*Masa rane* only
Collecting crabs (*hata garumu*, etc.)	Bare hands and bag	Mangroves, shallow reefs, and outer barrier island intertidal zones	Mud crab, coconut crab, mangrove crabs, and land crabs	Mostly during *odu rane*
Collecting shells (*hata riki*, etc.)	Bare hands, bush knife, and bag	Mangroves, grassbeds, sand-banks, shallow reefs, and outer barrier island intertidal zones	Clams, oysters, Turbinids, Nerites, chitons, Tridacna shells, and others	*Masa rane* for estuarine species and *odu rane* for outer barrier island ones

Diving

Coastal New Georgia populations have traditionally used a non-buoyant wood spear called *dumi* to spear fish while free-diving in shallow and mid-depth reef drops. Commencing in the 1960s, wood *dumi* were replaced by metal spears, spear guns (*paka loko*), and rubber-propelled wire spears (*bugiri*). With the introduction of diving goggles, diving has become more popular because fishermen can now clearly see their prey. Diving can produce large yields, particularly when practiced during moonless nights, and parrotfishes, wrasses, surgeonfishes, and sweetlips are particularly vulnerable to this type of fishing. In a single night, a pair of skilled divers can take hundreds of kilograms of fish and crustaceans. Some communities around Roviana and Vonavona have locally forbidden this activity to avoid depleting their reef stocks, but these prohibitions are not respected everywhere and some traditional authorities have been unable to stop divers from decimating parrotfish populations in inner and outer lagoon shallow reefs (Aswani and Hamilton 2004). Additional underwater activities include diving for crabs, triggerfish eggs, seaweed, and shells.

Fish Drives

Fish drives using leaf sweeps are common in the Pacific and are prevalent throughout Solomon Island coastal communities. In Roviana, four local drive methods utilizing leaf sweeps or sticks to herd fish are practiced (locally known as *kuarao*, *balubalu*, *hake sinoku*, and *butu petu*). The most important is *kuarao*, which is conducted in shallow reef flats by large groups of individuals (up to 100) in the early morning from May to early July. Strands of a coastal vine called *arara* (*Flagellaria* spp.) are held by people advancing in a circle and enclosing fish into a net or weir. Coral rock weirs were traditionally built, but this practice has been discontinued and only nets are used today. Johannes (1981:12) has noted that although fish can physically swim under the sweep prior to their netting, the leaf barrier forms "an effective psychological barrier for most species." Once herded, the fish are first stunned with a stupefacient and then speared and hand collected. This method is only practiced in Munda and Vonavona because habitats in Eastern Roviana are not appropriate for *kuarao* (Fig. 1). A similar method, also practiced exclusively in Munda, is the *hake sinoku* fish drive, a technique that requires fewer people and consists of herding parrotfishes into small pools surrounded by a rock fence. As in *kuarao*, once the fish are inside the fence they are stunned and speared. Some roughly similar techniques are used in the inner Roviana, but they are less labor intensive and target assemblages of different fish species. A fish drive method called *balubalu*, which was last employed in the 1950s, consisted of herding fishes with coconut leaves, and another technique that is still in use today, *butu petu*, involves driving rabbitfish toward shallow mangrove mudflats for their subsequent capture.

Piscicides

Organic stupefacients are used in shallow inner lagoon reef flats during the day-low-tide season. *Derris* spp. leaves mixed with sand are pounded into a crush and then placed into reef crevices harboring fish. As stunned fish surface, they are grabbed or speared. Frequently caught reef fish species include speckled-fin rockcod, anchor tuskfish (*Choerodon anchorago*), and hussar snappers. Today, poison fishing (*bunabuna*) is seldom employed, and there is a growing local and governmental move to outlaw this practice, albeit with some local resistance to a full ban. Some fishermen note that this method is environmentally harmful because it can seriously damage a whole coral colony and kill all of its inhabitants.

Trapping Fish

Fish-trapping methods have almost disappeared as a result of the introduction of new technologies, although there are a few villages such as Nusa Hope Village (Fig. 2) where a few old men still carry on the fish-trapping tradition. A *kura*, or a v-shaped trap made of cane is baited with crabs and submerged to about 10 m to catch titan and yellow-margin triggerfishes. In former times, a larger basket was made to catch humphead wrasse, but today very few people even remember the existence of this method. Similarly, a large, round bamboo trap (*ezi*) was placed in shallow and mid-depth reefs to catch all types of reef fish. Finally, in the Munda and southern Vonavona areas, stone weirs called *hidi* were used to trap fish in open barrier reefs during receding tides. Today, *hidi* remain as markers of the coastal-dwelling peoples who built them, but their significance is more than nostalgic in that they embody important implications in the establishment of rightful tenure to the outer barrier reefs.

Gleaning and Collecting

Gleaning for shells and crabs is the domain of women and children, who exploit numerous habitats based on their accessibility and resource availability. Women have an intricate knowledge of the fauna with which they interact, including knowledge about spawning seasonality, feeding habits, and the temporal periodicity of many invertebrates (Aswani and Weiant 2004). Women glean predominantly in two habitats—estuarine and outer barrier island intertidal flats. The lagoon bivalves collected include blood cockles, mud clams, oysters (e.g., *Crassostrea rhizophorae*), Venus shells, and mudwhelks, among others. The primary season for collecting these organisms is during the months of May through August, when diurnal low tides allow women to enter mangrove forests. With the advent of the day-high tidal season in mid to late September, tidal periodicity reverses, and the women move into other habitats. The most sought-after invertebrates in the region are the mangrove *Anadara granosa*, or blood cockle, and the Polymesoda (Geloina) spp., or mud clam, although in Munda and south Vonavona species that are characteristic of open reef flat, coral rubble, and sand banks are harvested more frequently.

Discussion

Landscape ecology, broadly defined, is an attempt to refine ecology's explanatory potential by emphasizing the impact of scale and structure on environmental processes (Ingegnoli and Forman 2002). This analytical strategy focuses on understanding environmental heterogeneity (Sanderson and Harris 2000), which explains the landscape as a mosaic of interacting patches that represent dominant species and biophysical features. The landscape is described in its structural complexity through concepts such as boundary, edge, corridor, and flows (Forman 1995). Central to landscape ecology is the integration of human agency into the study of the environment and its anthropogenic features. In this respect, landscape ecology has become critical for designing conservation policies (Ingegnoli and Forman 2002; Liu and Taylor 2002) because it provides a theoretical context for understanding patterns of interaction between biological and cultural communities (Scoones 1999).

This case study provides an indigenous description of a seascape that is characterized by the same explanatory parameters that inform landscape ecology. The data offered are structured around three main categories: major and minor habitats, environmental variability, and marine extractive practices. This configuration connects ecological structure to seasonality and use (Forman 1995), and the outcome, even using indigenous knowledge as a dominant narrative, unfolds in terms of complex assemblages of habitats and species. The Roviana people describe the lagoon as a mosaic characterized by interdependent micro-patchiness. In addition, every patch is carefully delineated

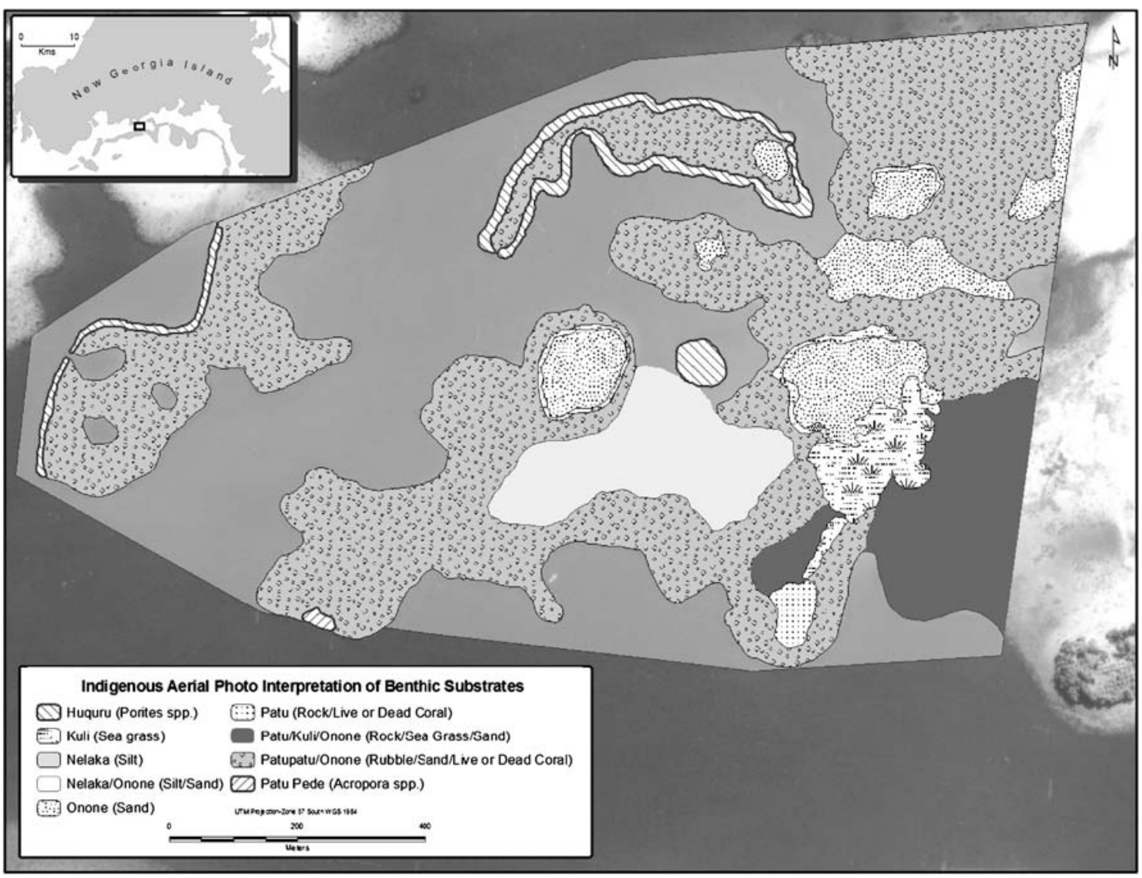


Fig. 5 Indigenous demarcation of predominant abiotic and biotic substrates in Central Roviana (Baraulu MPA). Categories reflect benthic components of indigenously defined habitats (Aswani and Lauer 2006a)

in terms of size, species distribution and relative abundance, trophic ecology, and abiotic structure (Hansson *et al.* 1995).

The value of local knowledge and practices for marine resource management is not only hypothetical, as we have shown how marine protected areas that integrate IEK into their design can be successful biologically and socially (see Aswani *et al*. 2007; Aswani and Furusawa 2007). This success is not limited to the Western Solomon Islands. McClanahan *et al.* (2006) have found that areas under customary management in Papua New Guinea and Indonesia have significantly higher biomass of target fish compared to areas outside of this management regime. In our participatory conservation efforts, then, socioecological data has been fundamental, especially when delimiting the fragmentation and distribution of locally identified habitats across the lagoon (see Aswani and Lauer 2006a, b). This emphasis on micro-patchiness has resulted in careful definitions of boundaries and edges (see Fig. 5 as an example) for designing marine protected areas. The analysis of these categories reveals that the rationalizations of this classificatory system are not always the same: in some cases the vegetal cover defines the patch (e.g., mangroves and sea grassbeds) and sometimes it is a specific type of geological morphology (e.g., river banks, sand banks, capes). In addition, these patches are far from homogeneous in size and distribution: open ocean presents large, continuous patches, while inner lagoon reefs (shallow or mid-depth) are relatively small, fragmented, and unevenly distributed. River mouths and lagoon passages, while being habitats in their own right, are also typical ecotones, or transition areas between well-defined patches. This classification system also shows high differentiation among reef categories, probably associated with high fish productivity potential. In terms of physical phenomena affecting foraging, ethnoecological knowledge involves the consideration of change and climatic variability and the flexibility to adapt to such cyclical changes. These phenomena are significant because they periodically affect the accessibility and relative abundance of resources across multiple patches and ecological scales.

Finally, local knowledge informs Roviana inhabitants on how to exploit their environment most efficiently. The fishing techniques used across the lagoon connect species behavior, habitat characteristics, and tidal conditions. The study of extractive practices and associated knowledge is relevant to ecological analysis because it can offer interpretative clues to important elements such as the relative abundance of a species due to extraction of predators, population dynamics, and so on. Ethnographic research has uncovered a number of different fishing techniques, the successful use of which requires a deep understanding of the local ecological conditions and animal behavior on the part of the inhabitants.

Conclusion

The Roviana people have developed ethnoscientific knowledge (biological, climatological, ichthyological, etc.) that helps them understand and take advantage of their complex and variable environment. The annual flux of species' spatio-temporal distribution offers fishermen opportunities to harvest numerous organisms at different times, the variation being determined by lunar and seasonal cycles. Monthly lunar aggregations, such as those of orange-striped emperor on new moons and yellow-margined seaperch and paddletail snapper during full moons, are spatio-temporally predictable phenomena that potentially increase fishermen's harvestable stocks throughout the year. In addition, at certain times fishermen become *specialists* by targeting a limited number of species, while at others times they act as *generalists* by exploiting all species in shallow reefs, grassbeds, and mangrove habitats.

This information has allowed us to analyze the relationship between ecological complexity, ethnobiological knowledge, and the ways in which the knowledge is used for productive purposes. In turn, this has allowed us to recognize the characteristics of human-marine interactions and design and implement management regimes (MPAs and watershed management) that move towards ecosystem-based resource management. The idea was that a systematic articulation of local cultural knowledge and ecological values through anthropology and marine science could better promote local participation in the design and development of community-based marine protected areas and produce a more inclusive approach to conservation.

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