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Spawning Aggregations of Coral Reef Fish in Roviana Lagoon, Western Province, Solomon Islands: Local Knowledge Field Survey Report

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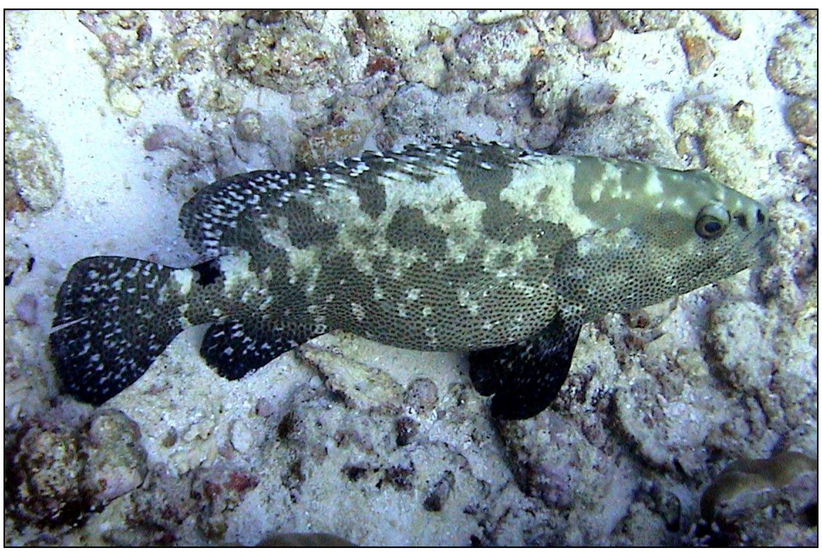

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Cover photo: A gravid female *Epinephelus polyphekadion* (A. Smith).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Many large commercially valuable species of reef fish aggregate in the hundreds or thousands at fixed sites during specific lunar and seasonal periods for the purpose of spawning (Domeier and Colin, 1997). Not surprisingly, fishers have often taken advantage of this predicable behavior, as exceptionally high catches can be made from spawning aggregations (Johannes, 1978). Although fishers have been aware of spawning aggregations for centuries, biological interest in them is far more recent (Colin *et al*., 2003). There is now a growing awareness among marine biologists and coastal managers of the need to understand the biological parameters of spawning aggregations and the effects of fishing these aggregations (Vincent and Sadovy, 1998; Levin and Grimes, 2002). This awareness has stemmed from the realization that; firstly, spawning aggregations of many commercially important species have often been rapidly overfished, and secondly, the spawning aggregation phenomena represents a bottleneck in the life histories of many reef fish species, and their conservation and management is critical for ensuring the persistence of the populations that form them (Sadovy and Vincent, 2002).

Although many species of reef fish aggregate to spawn, recent research on coral reef fish spawning aggregations has predominantly concentrated on groupers (e.g. Samoilys, 1997; Zellar, 1998; Johannes *et al*., 1999; Rhodes and Sadovy, 2002). This family's large size, susceptibility to overfishing and importance in destructive commercial ventures such as the Live Reef Food Fish Trade (LRFFT) has brought global attention to the spawning aggregation phenomena (Levin and Grimes, 2002; Pauly *et al*., 2002). The Live Reef Food Fish Trade actively targets spawning aggregations of reef fish, and is considered one of the major threats to spawning aggregations worldwide (Sadovy and Vincent, 2002).

In the Pacific there is currently little awareness of the importance of the spawning aggregation phenomena, and limited capacity to address the threats being placed on spawning aggregations. The Nature Conservancy (TNC) is seeking to address these issues through a variety of awareness and capacity building initiatives. A component of these initiatives is documenting local knowledge on spawning aggregations. The TNC local knowledge surveys focus on Melanesia, in areas where scientific databases are scarce or non-existent, and commercial LRFFT ventures are operating, or are likely to operate in the near future.

In this report we provide an overview of indigenous ecological knowledge on spawning aggregations that are located in Roviana Lagoon. We also outline differences between existing customary sea tenure estates in Roviana Lagoon, and report on recent community-based conservation efforts in this region that have been facilitated by The Roviana and Vonavona Lagoons Resource Management Program. We achieve this in three ways: firstly, by reviewing published and unpublished literature. Secondly, by drawing on our past experiences in this region[1], and thirdly, by utilizing local knowledge that we documented while conducting field interviews with Roviana fishers between March 21-28, 2004. In the last section of this report we overview spawning aggregation monitoring programs that were established in this region in March 2004. Four individuals from Roviana Lagoon represented The Roviana and Vonavona Lagoons Resource Management Program at the TNC run spawning aggregation monitoring workshop at Gizo in March 2004 (Rhodes, 2004). Immediately after this workshop, Dr. Kevin Rhodes and Dr. Richard Hamilton assisted these four individuals in designing and establishing spawning aggregation monitoring programs at several aggregation sites in Roviana Lagoon. Routine monthly monitoring at these sites commenced in April 2004. In 2004 the field costs of these monitoring programs were met by TNC and The Roviana and Vonavona Lagoons Resource Management Program. TNC provided regular scientific expertise and advice to the Roviana monitoring team throughout 2004. It is hoped that this report will assist in future collaborative conservation efforts between TNC, the Roviana and Vonavona Lagoons Resource Management Program, local NGOs and the local communities of Roviana Lagoon. Below we provide an overview

[1] Warren Kama is an expert fisher from Roviana Lagoon and Dr. Richard Hamilton has carried out scientific and ethnographic research in this region since 1996.

of indigenous ecological knowledge and customary marine tenure. Both need to be understood in order to appreciate how they may be utilized and incorporated into spawning aggregation research and management in Melanesia.

INDIGENOUS ECOLOGICAL KNOWLEDGE

Indigenous Ecological Knowledge (IEK) is an important component of the intellectual and cultural property of many indigenous societies, and it plays an integral part in a wide range of social and cosmological dimensions of these communities' lives (Carrier, 1987; Foale, 1998). From a rationalist viewpoint, indigenous knowledge bases also contain a great deal of information that is useful for management and science. Fishers often know much more than biologists about the location of critical habitats such as spawning grounds (Johannes, 1981 and 1989; Hamilton, 2003a), feeding areas (Hamilton, 1999) and nursery areas (Johannes and Ogburn, 1999; Hamilton, 2004a; Aswani and Hamilton, 2004a). IEK can also be useful in providing a perspective on the historical state of reef fish resources (Johannes *et al*., 2000), and in instances where large-scale ecological changes have occurred within the lifespan of fishers, knowledge of such changes can be extremely detailed (Hamilton, 2003b). There is now a burgeoning body of literature advocating the documentation of IEK and its integration with more quantitative types of research (e.g. Christie and White, 1997; Johannes, 1998).

UTILIZING LOCAL KNOWLEDGE FOR SPAWNING AGGREGATION RESEARCH

The value of utilizing local knowledge in the initial stages of spawning aggregation research is becoming increasingly well recognized, and there have been recent attempts by biologists to develop broad guidelines for obtaining this cultural information (Colin *et al*., 2003). It is noteworthy however that the precision and depth of documented local knowledge on spawning aggregations has varied widely between both regions and researchers (Graham, 2002), no doubt reflecting:

- The amount of local knowledge present in each region
- The willingness of local fishers to divulge this information
- The skills of the researcher and appropriateness of the methods used to obtain local knowledge
- The amount of time spent documenting this cultural information

Detailed anthropologically based studies that have focused purely on documenting the local knowledge of Pacific island fishers have revealed that as well as knowing the locations of spawning sites, local fishers can also provide highly precise information on the annual and lunar periodicity of spawning aggregations, species composition at mixed species spawning sites, the spawning behavior of aggregating fish and changes in the status of aggregation over time (Johannes, 1981 and 1989; Johannes and Kile, 2001; Hamilton, 2003a).

It is important to highlight that although indigenous marine knowledge can be enormously rich and of great practical value to scientists and conservationists, there are several common problems associated with documenting local knowledge that need to be taken into account:

1. Indigenous ecological knowledge exists as part of complex cultural systems. Consequently, researchers require an understanding of the cognitive framework of the indigenous culture, and must use anthropological methodologies, such as interviewing and participant observation, to accurately document this material. Obstacles such as language barriers frequently face foreign scientists wishing to work with IEK (Foale, 1998).

2. IEK is often stratified by gender, age and geographical location (Hviding, 1996; Christie and White, 1997) and specific knowledge pertaining to specific families of fish is often restricted to expert fishers who specialize in targeting those species (Hamilton, 1999; Johannes *et al*., 2000).

3. Most indigenous knowledge of marine ecology is ultimately directed towards identifying patterns that maximize capture success. Thus some details of fish biology that are important to a marine biologist studying reef fish ecology may well be irrelevant to a local knowledge base, since these biological parameters have no influence on subsistence practice (Hamilton and Walter, 1999).

4. While indigenous knowledge on recent changes in the abundance or size structure of local fish stocks will often be very accurate, local explanations for the mechanisms underlying these changes may not be compatible with scientific paradigms "In some places declining yields may be attributed to sorcery or a failure to propitiate the gods" (Ruddle *et al*., 1992:262).

5. Fishers' knowledge, like scientists', is fallible, and this cultural information needs to be gathered systematically and treated with the same critical scrutiny that is applied by scientists to any other data set (Johannes *et al*., 2000).

CUSTOMARY MARINE TENURE

Customary marine tenure (CMT) is a situation in which identifiable groups of people have informal or formal rights to coastal areas, and in which their rights to use and access resources are, in principle, excludable, transferable, and enforceable, either on a conditional or permanent basis (Ruddle, 1996). Virtually all Melanesian coral reef fisheries operate within well developed CMT systems, where ownership of, and hence access to, coastal areas depends on a range of culturally defined variables including descent line (e.g. Carrier and Carrier, 1983; Hviding, 1996; Aswani, 1999). Various authors working in the coastal Pacific have promoted the idea that in countries where governments do not have the legislative or financial capacity to enforce management rules, CMT systems could be used as an effective basis for managing inshore fisheries (e.g. Ruddle *et al*., 1992; Foster and Poggie, 1993; Johannes, 1998; Thomas, 2001).

In some regions of the Pacific CMT estates and IEK has been successfully incorporated into contemporary inshore management programs (e.g. Johannes, 1998; Fa'asili, and Kelekolo, l999; Aswani and Hamilton, 2004b). However, it has become apparent that CMT systems alone will not conserve marine resources in many countries, especially when the economic incentives to harvest these resources are high and tenure disputes among differing parties are unresolved (Foale 1998; Aswani, 1999). It has been argued that CMT systems throughout the Pacific and Asia were developed primarily for "gain not restrain" (Carrier and Carrier, 1983; Polunin, 1984; Ruttan, 1998) and this issue has been the point of some controversy among academics (Hviding, 1996; Aswani, 1998). Regardless of the mechanisms behind the development of CMT systems, their obvious and undisputed management benefits are:

1. They can provide an existing culturally recognized ownership structure around which management incentives can be based (Johannes *et al*., 1993)

2. Robust CMT systems can effectively restrict outsiders access to traditional fishing grounds (Johannes, 1981; Hviding, 1996) hereby eliminating some of the problems associated with common property that are prevalent in many of the world's inshore fisheries (Hardin, 1968).

It is important to recognize that CMT systems vary markedly between different regions, and the intricacies of these systems and their robustness and appropriateness to management or conservation objectives need to be carefully evaluated for each region in question. A successful sea tenure regime requires that boundaries be well defined, that they are recognized within the local region, that there is little or no poaching by neighboring groups, that there is the local capacity to enforce rules, and that most of the stakeholders are willing to endorse a management initiative. In other words, it is meaningless to implement community based marine management measures, no matter how rich the biodiversity, if harvest restriction rules and exclusion of non-members cannot be enforced (Aswani and Hamilton, 2004b).

ROVIANA LAGOON

This fieldwork was conducted in Roviana Lagoon, New Georgia Archipelago, Western Solomon Islands. The New Georgia Archipelago is made up of nine main islands that extend for approximately 270 km. The largest island is New Georgia, which is fringed by Roviana and Vonavona Lagoon to the southwest and Marovo Lagoon to the northeast (Figure 1).

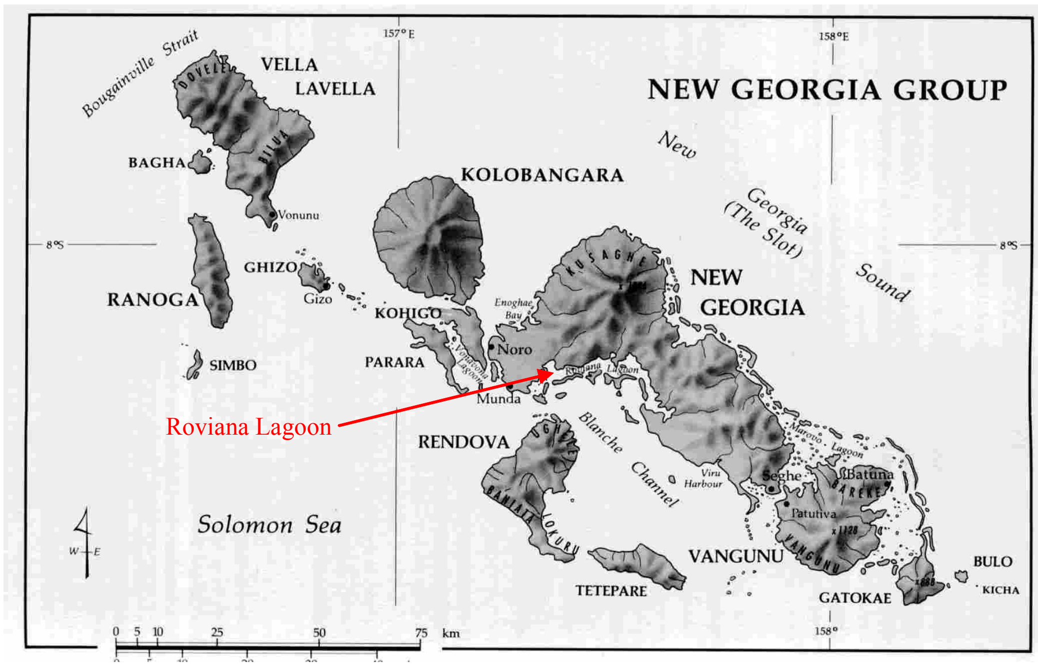

Figure 1: The New Georgia Group

Roviana Lagoon extends for over 50 km eastwards from Munda, New Georgia's second largest settlement. The bulk of Roviana Lagoon is enclosed between the New Georgia mainland and a series of uplifted coral reef islands lying two to four kilometers offshore. The lagoon encompasses a variety of habitats that include grass beds, mangroves, freshwater swamps, shallow reefs, outer reef-drops, and river estuaries. The outer lagoon shoreline is characterized by rugged notched limestone with numerous small bays, islets, sandy beaches and moats (Stoddart, 1969). Unobstructed water exchange between the inner lagoon and the outer reef areas occurs via several deep passages.

Roviana Lagoon is occupied by a number of closely related tribal groups who inhabit a dozen or so large villages scattered along the mainland and barrier islands as well as a number of smaller residential clusters. In Roviana Lagoon each tribal group exercises entitlement and access rights to land and sea estates, with these tribal territories in Roviana extending from the top of the mountains of South New Georgia to the barrier islands which form Roviana Lagoon and out into the open sea (Aswani, 1998). Roughly twelve thousand people inhabit the Roviana and Vonavona Lagoon region (National Census 1999).

The Roviana subsistence economy is based on shifting horticulture. The main protein intake is from marine resources (Aswani, 1997), but pig and chicken husbandry and small scale hunting of wild pigs also takes place. Subsistence activities are subsidized by wage labor, local and export fisheries, copra production, timber and baitfish royalties and remittances from family members working in the capital, Honiara. Today a rising population in Roviana region coincides with an increasing desire to exploit marine resources for cash, so that locals can pay their children's school fees, buy petrol for their outboard engines and access the wide range of western consumer goods now available to them

(Hamilton, 2004). Valuable non-perishable marine products such as trochus, shark fin and beche-de-mer are heavily exploited in this region, and demand for reef fish at the provincial centre of Munda is strong. Serranids form an important component of the local fisheries through New Georgia, and local fishing communities in this region are renowned for their highly detailed indigenous knowledge on grouper spawning aggregations (Hviding, 1986; Aswani, 1997; Johannes, 1999; Hamilton, 1999). In recent years many of the well-known grouper spawning aggregation sites in New Georgia have been heavily exploited by local fishers to supply the LRFFT (Johannes and Lam, 1999).

COMMUNITY LIAISON AND INTERVIEWING PROCEDURE

The locations of approximately two thirds of the aggregations detailed in this report have been known to the authors for some time. However, prior to this field trip, we had not attempted to document detailed local knowledge on the majority of these aggregations. In this brief field trip, we revisited aggregation sites in Roviana Lagoon that were known to us, and interviewed expert local fishers from surrounding communities on their knowledge of these spawning aggregations. During this process we also learnt of several aggregations that we had previously not been aware of. The community liaison procedure was very low key, as we were already well acquainted with the majority of fishers we interviewed. We simply sought out fishers we wanted to interview, and when we located them, explained what we were doing and asked them if we could interview them on their knowledge of spawning aggregations. The questions in the Society for the Conservation of Reef Fish Aggregations (SCRFA) questionnaire (see http://www.scrfa.org/server/studying/introduction.htm) formed the template of the questions covered. Interviews were conducted in Solomon Island Pijin and Roviana.

LOCAL KNOWLEDGE ON SPAWNING AGGREGATIONS

Fishing practices in Roviana Lagoon are strongly influenced by detailed indigenous ecological knowledge of the lagoon environment. Knowledge of the tides, lunar stages and seasonal aggregations of certain species inform fishers when and where they should go fishing (Aswani, 1997; Hamilton, 1999). The lunar cycle plays a major role in structuring Roviana subsistence and artisanal fishing systems, since many predictable fish behaviors can be correlated with reference to a specific lunar stage. Roviana fishers' extensive knowledge of the way in which the lunar cycle and tidal states influence the movement and aggregating behavior of Carangidae within Roviana Lagoon is one example of this (Hamilton, 1999). The presence or absence of moonlight is also known to have a strong affect on the nocturnal behavior of various marine species, and fishing activities are timed accordingly (Hamilton, 2004). The importance of the lunar cycle to Roviana fishers is reflected through the Roviana language, with most of the days of the lunar months having specific names in Roviana.

Annual seasonality of certain fish species is another important aspect of Roviana fishers' knowledge. For example, from February-April trolling in the open ocean from paddle canoes for schools of skip-jack tuna intensifies, and from August until November the majority of Roviana males concentrate their fishing effort on drop lining at night in outer passages and specific areas in the open sea, targeting seasonal aggregations of barracuda. From October to the end of January is widely known as the grouper season, and fishing pressure shifts to known aggregation sites.

A brief summary of local knowledge on 16 single and multi-species aggregation sites in Roviana Lagoon is shown in Table 1. Species that had spatially overlapping territories were deemed to occur at the same aggregation site. For 15 of these aggregations their precise location was marked using

Global Positioning System (GPS)[2] and oral histories of the fisheries (status, exploitation, methods employed) were documented. Detailed information for each aggregation site, including the direct and indirect evidence of spawning for each species is presented in tables in Appendix 1. The aggregation parameters in these tables are adapted from the SCRFA questionnaire guidelines.

Table 1: A summary of the aggregation data documented from around Roviana Lagoon, showing species known to aggregate at each site, the moon phase(s) when these aggregations occur and the months of formation.

Detailed information on each aggregation site can be found in Appendix 1.

Aggregation Site No.	Aggregating species	Moon Phase	Months of formation
1	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*	Third quarter – New moon	Unclear. But known to have an extended season, possibly with a peak season between October to January
2	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion* *Epinephelus ongus* *Lethrinus erythropterus*	Third quarter – New moon	Unclear. But known to have an extended season, possibly with a peak season between October to January
3	*Plectropomus areolatus* *Epinephelus fuscoguttatus*	Third quarter – New moon	October - January
4	*Lethrinus erythropterus*	Third quarter – New moon	Unclear. But known to have an extended season, possibly with a peak season between October to January
5	*Epinephelus ongus*	Third quarter – New moon	October - January
6	*Epinephelus ongus*	Third quarter – New moon	October - January
7	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*	Third quarter – New moon	October - January
8	*Epinephelus ongus*	Third quarter – New moon	October - January
9	*Epinephelus ongus*	Third quarter – New moon	October - January
10	*Epinephelus ongus*	Third quarter – New moon	October - January
11	*Epinephelus ongus*	Third quarter – New moon	October - January
12	*Lethrinus obsoletus*	New Moon	Every month of the year
13	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*	Third quarter – New moon	October - January
14	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*	Third quarter – New moon	October - January
15	*Epinephelus fuscoguttatus*	Third quarter – New moon	October - January
16	*Plectropomus areolatus*	Third quarter – New moon	October - January

[2] In accordance with fisher's requests and in an effort to protect these sites from heavier exploitation, the GPS coordinates of each aggregation site, reef names and the names of informants interviewed have been removed from the aggregation tables in Appendix 1.

THE MAIN BIOLOGICAL FINDINGS OF INTEREST

- All aggregations reported in this study occur around the same lunar periods, that is in the third quarter and during the early part of the new moon phase.

- *Plectropomus areolatus, Epinephelus fuscoguttatus, Epinephelus polyphekadion* and *Epinephelus ongus* are reported to have a peak spawning season in many areas of Roviana Lagoon that occurs between October and January each year. It is becoming obvious, however, that at some sites at least, spawning aggregations form over a much more extended period of the year. Quantitative evidence of this is discussed in a later section of this report.

- The small emperor *Lethrinus obsoletus* forms spawning aggregations around the new moon every month of the year.

- *Lethrinus erythropterus* aggregates in large numbers around the new moon in Roviana Lagoon, with spawning occurring at night. *Lethrinus erythropterus* sampled from a spawning aggregation Site 2 at 11 pm on the new moon in March 2004 were all hydrated, providing strong support to local fishers claims that spawning in this species occurs around midnight (See Appendix 2).

- The vast majority of spawning aggregations in the Roviana region occur in, or very near to, deep water passages that connect the inner lagoon to the open sea. Similar observations have been made for Marovo Lagoon (Johannes and Lam, 1999). Two large multi-species spawning aggregations are known to occur on outer reef promontories.

- In Roviana large numbers of barracuda (*Sphyraena jello* and *S. putnamiae*) aggregate in deep water passages and in open sea areas between the months of August and January each year. It is likely that these barracuda aggregations represent spawning aggregations, since gravid females are captured at this time. These aggregations are heavily fished by local fishers during these months. Similarly, yellowmargin (*Pseudobalistes flavimarginatus*) and titan triggerfish (*Balistoides viridescens*) are known to aggregate and nest at numerous passage mouths in Roviana Lagoon between the months of September to December. No further mention of these aggregations is made in this report. Further information can be found by referring to Aswani (1997), Hamilton (1999) and Johannes *et al*. (2000).

FISHING PRESSURE PLACED ON SPAWNING AGGREGATIONS

In Roviana Lagoon spawning aggregations are targeted by subsistence, artisanal and commercial fisheries. These fisheries have had marked effects on many of the spawning aggregations in Roviana Lagoon, and in several cases spawning aggregations have been fished almost to the point of extirpation. Not surprisingly, in Roviana Lagoon aggregations that are in close proximity to large human settlements and market outlets are generally in poorer shape than aggregations that are some distance from both market outlets and human settlements. An overview of each of these fisheries and their impacts on spawning aggregations is given below.

SUBSISTENCE FISHING

Nearly all of the aggregations reported in this survey are exploited for subsistence purposes. Many of the serranid aggregations that are situated in deep water passages that join the inner lagoon to the open sea are in very close proximity to large villages, and these aggregations have been exploited for many generations. In such instances, local knowledge on seasonality and location of these aggregations is widely known, and communities fishing effort shifts to these highly productive locations during spawning seasons. Today the main forms of subsistence fishing at aggregation sites are hook and line and spearfishing (both day and night). Subsistence fishing is generally considered much more sustainable than either small-scale artisanal or large-scale commercial fishing, however, even subsistence fisheries have had a marked impact on some spawning aggregations in Roviana Lagoon in recent decades.

The aggregations of *Lethrinus obsoletus* at Site 12 provide an example of this. Aggregations of *L. obsoletus* are known to form monthly around the new moon at Site 12 and these aggregations have been exploited for generations for subsistence purposes. Artisanal fishing pressure on this aggregation has remained very low, as Site 12 is located in a region of the lagoon that is a considerable distance from market outlets at Munda. Despite the fact that the aggregation at Site 12 has predominantly been exploited for subsistence purposes, there has been a ten fold decline in catch rates from this aggregation over the last two decades, with numbers of aggregating *L. obsoletus* now very low (see Appendix 1).

An interesting example of how declining finfish stocks in general impact on subsistence fishing patterns and perceptions is the exploitation history of aggregations of *Epinephelus ongus* at Sites 8, 9, 10 and 11. The seasonality and location of these *E. ongus* aggregations have been known for generations, but in the past these aggregations were not heavily exploited. Until very recently *E. ongus* was regarded by many of the individuals who were aware of these aggregations as a third grade fish——the last thing they would want to eat. Indeed, up until the late 1980's captured *E. ongus* were often thrown back into the water and referred to as "old people's fish", relating to the fact that their extremely soft flesh meant that no teeth were required to eat them. This scenario has changed over the last 10-15 years. As other fish resources in this region have become scarcer, more and more individuals are specifically targeting these aggregations for subsistence purposes and fish are no longer thrown back.

ARTISANAL FISHING

In this report the term "artisanal fishing" refers to local fishers who are fishing specifically for the purpose of harvesting fish for sale. The predominant fishing method used by artisanal fishers at aggregation sites is nighttime spearfishing, with fishers typically limiting their activities to lunar days when aggregation numbers are known to peak. Night spear-fishers use a variety of equipment. The most basic gear consists of a pair of goggles, an underwater flashlight and a handheld steel spear that is thrust into sleeping fish. The most advanced technologies involve using underwater flashlights, masks, snorkels, fins and rubber powered steel spears or short homemade spearguns. Night spearfishing commenced in Roviana Lagoon in the mid 1970's, with the introduction of this method relating to the increasing availability and affordability of underwater flashlights in trade stores at Munda town. Very large catch rates of reef fish could be obtained by night divers compared to other fishing methods, and when commercial fisheries centers developed at Munda town, night diving became a lucrative means of raising cash (Hamilton, 2003b).

In Roviana Lagoon aggregating species that are targeted by night spear-fishers include *P. areolatus, E. fuscoguttatus, E. polyphekadion, E. ongus* and *L. erythropterus*. The most widely targeted species at multi-species aggregation sites is *P. areolatus*. This species is a prime target because:

- During peak spawning periods large numbers of *P. areolatus* aggregate in very shallow water on the reef, where they are often exposed and clearly visible (Figure 2 and 3).

- *P. areolatus* is very inactive at night and consequently easy to spear (this contrasts with *E. polyphekadion* and *E. fuscoguttatus* which often flee from divers at night).

- *P. areolatus* is an intermediate size that is easy for spear-fishers to catch and handle. (Many spear-fishers stated that they did not spear *E. fuscoguttatus* when they came across them, as these fish bent their spears and occasionally escaped with the spears lodged in them).

- *P. areolatus* is generally more numerically abundant than *E. fuscoguttatus* and *E. polyphekadion* at aggregation sites, and this is especially true in shallow water ranges that are accessible to free divers.

- Some spear-fishers report that they cannot be bothered spearing *E. fuscoguttatus* since they would have to spend considerable time filleting this species before sale. (*P. areolatus* is purchased whole at fisheries centers in Munda). It is noteworthy, however, that such statements are made by spear-fishers targeting large aggregation sites that still support a high abundance of *P. areolatus*. At overexploited aggregations where numbers of all aggregating serranids are low, any serranid sighted is speared. For example, *E. fuscoguttatus* is speared at night at Site 3, where this species can be found residing in small caves in the passage wall.

- Maximum catch rates of *P. areolatus* from relatively healthy aggregation sites can be very high. A CPUE survey of 41 night spearfishing trips carried out between January and April 2001, showed that spear-fishers targeting spawning aggregations at Site 1 had maximum catch rates of 16.8 kg *P. areolatus* /hr /fisher, with two fishers removing 132 *P. areolatus* from Site 1 in two consecutive nights, that being just prior to the new moon in March 2001 (Hamilton *et al*., 2005). These catch rates are reported to be much lower than catch rates made at this aggregation site in the mid-1990's.

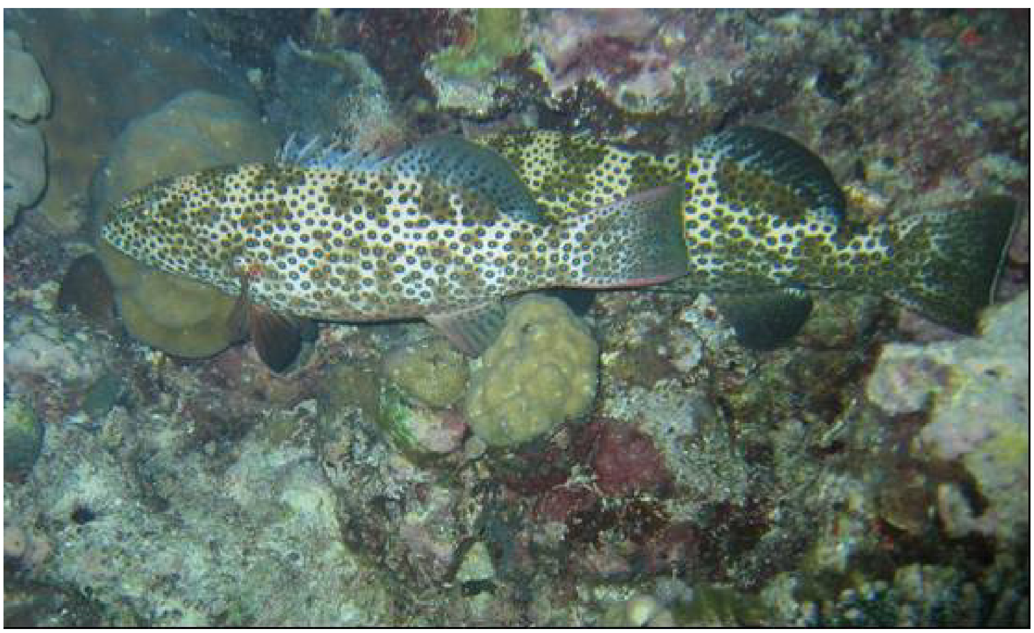

Figure 2: Two *P. areolatus* sleeping out in the open in shallow water (< 5 m) at a spawning aggregation site. Both fish are displaying the camouflage color phase.

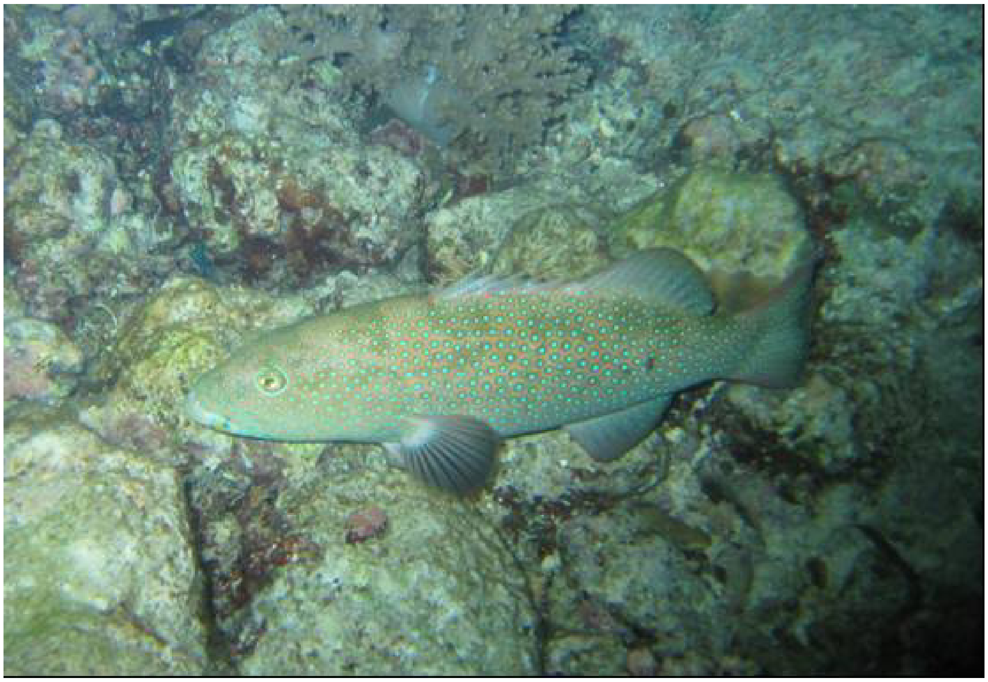

Figure 3: A disturbed female *P. areolatus* at an aggregation site swimming very slowly away from free divers. This fish was photographed at night and is displaying the yellow/green color phase that is only seen in females.

Although *E. fuscoguttatus* and *E. polyphekadion* tend to reside in deeper water than *P. areolatus*, both species are sometimes seen stationary on the reef at night in water depths that are frequently within the range of free diving spear-fishers that are using fins (Figure 4).

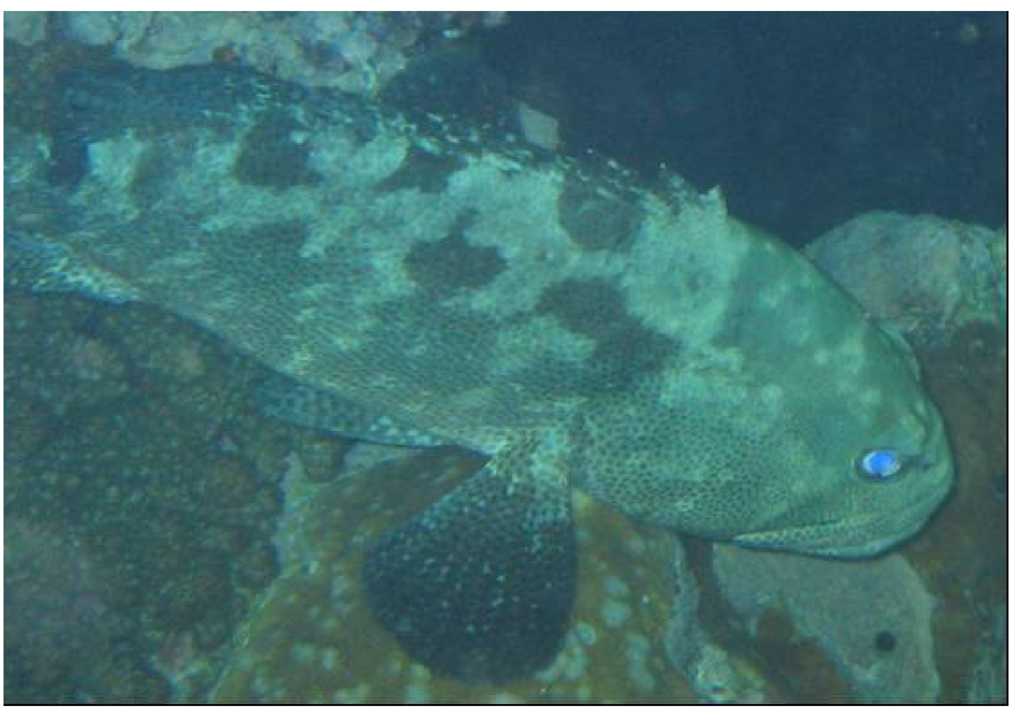

Figure 4: An *E. fuscoguttatus* sleeping in fairly shallow water (approximately 10 meters) at a spawning aggregation site.

In at least one case, nighttime spearfishing pressure alone has been sufficient to overfish an aggregation of *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* to the point of extirpation. Up until the early 1980's spear-fishers report being able to catch large numbers of all three species in very shallow water at Site 2. A fisher who has exploited this site for over three decades reports that in the 1970's and early 1980's approximately 500 – 1000 *P. areolatus* and several hundred *E. fuscoguttatus* and *E. polyphekadion* aggregated here during peak seasons. When spearfishing at this site commenced here in the late 1970's, fishers report that a party of two or three spear-fishers could catch 100 *P. areolatus*, 50 *E. polyphekadion* and 50 *E. fuscoguttatus* in a single night. Catch rates declined steadily through the late 1980's and early 1990's, and since the mid-1990's aggregations have not formed in significant numbers. The same fisher who exploited this aggregation since the 1970's said that since the mid-1990's, the maximum number of *E. fuscoguttatus* and *E. polyphekadion* he has seen at this site is less than 10, and the maximum number of *P. areolatus* is less than 20. He also stated that these aggregating serranids were all very small fish. This aggregation is in close proximity to market outlets, its location is widely known and it is exploited by a large number of individuals from various tribal groups. The small to medium sized emperors are highly sought after in Roviana Lagoon, and spawning aggregations of *L. erythropterus* are also heavily exploited by night spear fishers at Site 2 (See Appendix 2).

COMMERCIAL FISHING – THE LIVE REEF FOOD FISH TRADE.

Live Reef Food Fish Trade (LRFFT) operations began in Vella La Vella Lagoon in the Western Province of the Solomon Islands in 1994 (Johannes and Lam, 1999), later spreading to Roviana and Marovo Lagoons in the Western Province in the mid-1990s, with the most recent ventures starting up in the remote northern atoll of Ontong Java in 1999 (Donnelly *et al*., 2000). Historical LRFFT operations in the Solomon Islands have predominantly been pulse fishing events that target seasonal spawning aggregations of serranids, and there is concern among local fishers and fisheries biologists over the social and biological impacts that the LRFFT has had in this country (Johannes and Lam, 1999; Kile *et al*., 2000; Johannes and Kile, 2000; Donnelly *et al*., 2000; Samoilys and Donnelly, 2001). Concern over LRFFT operations in the Solomon Islands were brought to a head in 1999 where a licensed LRFFT company vessel that was surveying potential fishing grounds in Isabel was discovered to be carrying equipment consistent with that found on board cyanide fishing vessels in Indonesia and Philippines (Donnelly *et al*., 2000). The Solomon Island government subsequently imposed a moratorium on all new LRFFT licenses in February 1999, which was lifted in late 2000.

In mid-2001 LRFFT companies again began to seek out new unexploited fishing grounds around the Western Province of the Solomon Islands, and in the same year a management plan for the LRFFT was drafted in Honiara (Donnelly, 2001). This draft management plan sought to totally protect the spawning aggregations of the three main target species of the LRFFT (*P. areolatus, E. fuscoguttatus* and *E. polyphekadion*) by placing a ban on aggregation fishing for five days either side of the new moon during the three months of the year when aggregations of these groupers are known to form (Donnelly, 2001). Several of the main recommendations of the draft plan were incorporated into a 2002 revised version of the LRFFT interim license conditions, although specific months for closures were not specified in the license, as aggregations seasons vary between regions and are in many cases are unknown (Graham, 2003).

To date, these new requirements of the LRFFT license coupled with price disputes have effectively halted all LRFFT operations in the Solomon Islands. LRFFT company officials claim that operations will not be economically viable if they cannot fish themselves, stating that the on-off nature of local fishers will provide inadequate supplies of fish (Hamilton, 2003a). In the Solomon Islands, LRFFT operations have significantly increased fishing pressure on known grouper aggregation sites (Hamilton, 1999; Kile *et al*., 2000). A two-year seasonal LRFFT operation in Roviana Lagoon that targeted Site 3 was intensive enough to fish this aggregation to the point of extinction. Historically this aggregation supported large numbers of *P. areolatus* and *E. fuscoguttatus* and had been exploited for subsistence purposes for generations. Between October and January in 1996 and 1997 approximately 3-4 tonnes of serranids were removed from this small site for a LRFFT operation

(Allen Hixion, Sasavele village, personal communication). This aggregation site is located in a sheltered passage besides a large village, and at the time that the LRFFT was operating this spawning aggregation was targeted on a 24-hour basis, with women, children and men hook and line fishing at this site (Hamilton, 1999). Fishing was intensive enough that fishers noticed a major decline in catch rates after only one year of targeting this aggregation for commercial purposes, and in 2001 when the LRFFT returned, local fishers informed company officials that it was no longer worth targeting this site, as the aggregations had not reformed since 1997. Indeed, very few *P. areolatus* or *E. fuscoguttatus* were taken in a CPUE survey of nighttime spearfishing that was conducted in and around this region between August 2000 and July 2001 (Hamilton, 2004). Numbers of *E. fuscoguttatus* at this site are reported to be slowly returning. Warren Kama surveyed this site during the peak aggregating season in November 2003 and estimated that *P. areolatus* numbers were less than ten, and *E. fuscoguttatus* numbers were less than 20. The very low numbers of *P. areolatus* (this species is normally more numerically abundant than *E. fuscoguttatus* at multi-species spawning aggregation sites) may relate to the ease with which this species is captured by spear-fishers.

CUSTOMARY TENURE IN ROVIANA LAGOON

Roviana Lagoon is divided into the political districts of Saikile and Kalikoqu in the east, each being a collection of villages ruled by a paramount chief. In the Munda area to the west of the independent hamlets of Nusa Roviana, Dunde, Kekehe, Lodu Maho, and Kindu are each controlled by a chief and/or council of elders (Figure 5, Aswani and Hamilton, 2004a). "In Roviana, descent is cognatic and is cumulative, which means that people trace their descent through maternal and paternal ancestors, and can amass entitlement rights to the estates of either parent". (Aswani and Hamilton, 2004a).

Although all Roviana inhabitants recognize similar hereditary property rights to their respective sea estates, traditional leaders of some sea territories are more capable of managing their resources than are leaders of other sea estates. This relates back to different historical settlement processes across the region and the proximity of the majority of entitlement holders to an indigenous sea estate (Aswani 2000). For example, Aswani (1999) showed that, as a result of various settlement processes, Kalikoqu and Saikile inhabitants have exclusive rights over their respective estates while concurrently having powerful rights over those of Nusa Roviana and Munda area villages. On the other hand, Nusa Roviana and Munda inhabitants have no control or access rights to the territories of Kalikoqu or Saikile.

These subtle differences in access rights across Roviana Lagoon translate into differences in traditional leaders' abilities to enforce management objectives within their respective sea estates. In brief, areas like Kalikoqu and Saikile can be regarded as having secure tenure estates, where local leaders can enforce management controls on their own people and also exclude outsiders from fishing in their customary grounds. On the other hand, in areas such as the Munda region, many different tribal groups can claim customary access to these grounds. As a consequence, in the Munda area tenure is less secure, management strategies are less likely to be respected and will be more difficult to enforce. Aswani has called these differences in tenure the 'territorial-enclosed regime' and the 'mosaic-entitlement regime'. It should be noted that a secure tenure regime does not mean that a community will necessarily be interested in conserving its resources; simply that it has the capacity to do so with relative ease. The take home message is that sea tenure regimes and communities abilities to enforce management controls varies on small scales in this region, and indeed, throughout Melanesia. It is thus important to map forms of sea tenure prior to drafting any form of co-management policies between local fishers and government or non-government organizations (Aswani and Hamilton, 2004a).

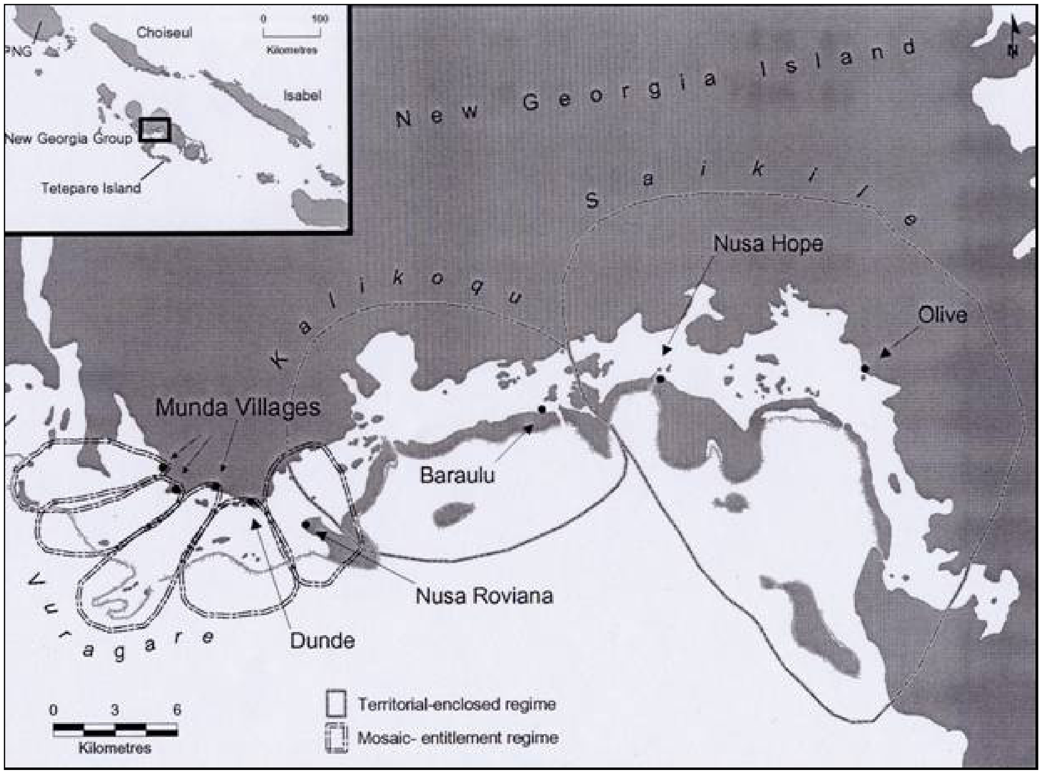

Figure 5: Sea tenure boundaries in Roviana Lagoon. Note that these are only conceptual boundaries and not definitive (Aswani and Hamilton, 2004a).

COMMUNITY-BASED MANAGEMENT IN ROVIANA LAGOON

Like many parts of coastal Melanesia, chiefs and elders of various sea estates in Roviana Lagoon have a long history of periodically placing bans on fishing in certain areas of their customary fishing grounds. The reasons for these closures varied, but the most common practice that is still in place today is that of stockpiling resources. This process involves closing an area of a valuable marine resource for a period of time in order to allow these resources to increase in abundance. These resources are then harvested in one go in order to raise cash or a large supply of food for an important community event. These practices are seen throughout the Pacific, and in Roviana such practices continue today to some extent. For example, at the beginning of 2000 local elders and chiefs closed a large mangrove shell fishery in the Kalikoqu region of Roviana Lagoon, so that stocks would recover and a large harvest could be made for a church celebration that occurred later in that year. It is noteworthy that in the majority of instances, any conservation benefits that have come about as a result of traditional customary closures in Roviana Lagoon have been the by-product of these closures, not the intention.

Since 2000, the Roviana and Vonavona Lagoons Resource Management Program (headed by anthropologist Shankar Aswani) has assisted local communities in the Roviana and Vonavona Lagoons in establishing a network of Marine Protected Areas (MPAs) under customary sea tenure. To date twelve MPAs have been established (Figure 6, Aswani and Hamilton, 2004b). Most of these MPAs are situated in the inner lagoon, protecting shallow inner-lagoon coral reefs, inner-lagoon sea grass beds, mangroves, and coastal swamps, and strand vegetation. Several deep water passage areas also protected, and critical habitats such as nursery grounds and nocturnal resting areas of bumphead parrotfish and humphead wrasse have also been protected (e.g., Aswani and Hamilton 2004a). Site 13, which is a possible spawning aggregation site for *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* is also protected. This site falls within the Nusahope/Heloro MPA (Figure 6).

In Roviana and Vonavona Lagoon, sites selected for management have been chosen through a combination of locally driven assessments and the information gained from a decade of social and marine science research in this area. MPA governance is held by both the customary owners and the communities neighboring the MPAs. The existing projects have also worked towards local development needs by assisting with infrastructure development (e.g. schools and community halls). The majority of established MPAs have intentionally been situated within secure tenure regimes, where local communities are capable and willing to enforce management measures. Recently, several Roviana and Vonavona communities have formed new governance institutions to strengthen existing traditional ones (Aswani and Hamilton, 2004b).

The work of the Roviana and Vonavona Lagoons Resource Management Program is ongoing, and the establishment of more MPAs has already been discussed with local communities in Roviana and Vonavona Lagoon. Two key components of future phases are: Firstly, to increasingly focus on environmental education, in order to move beyond the capital dependency created by financial incentives as components of conservation projects, and secondly, to identify and protect spawning aggregations that form at outer reef and passage habitats.

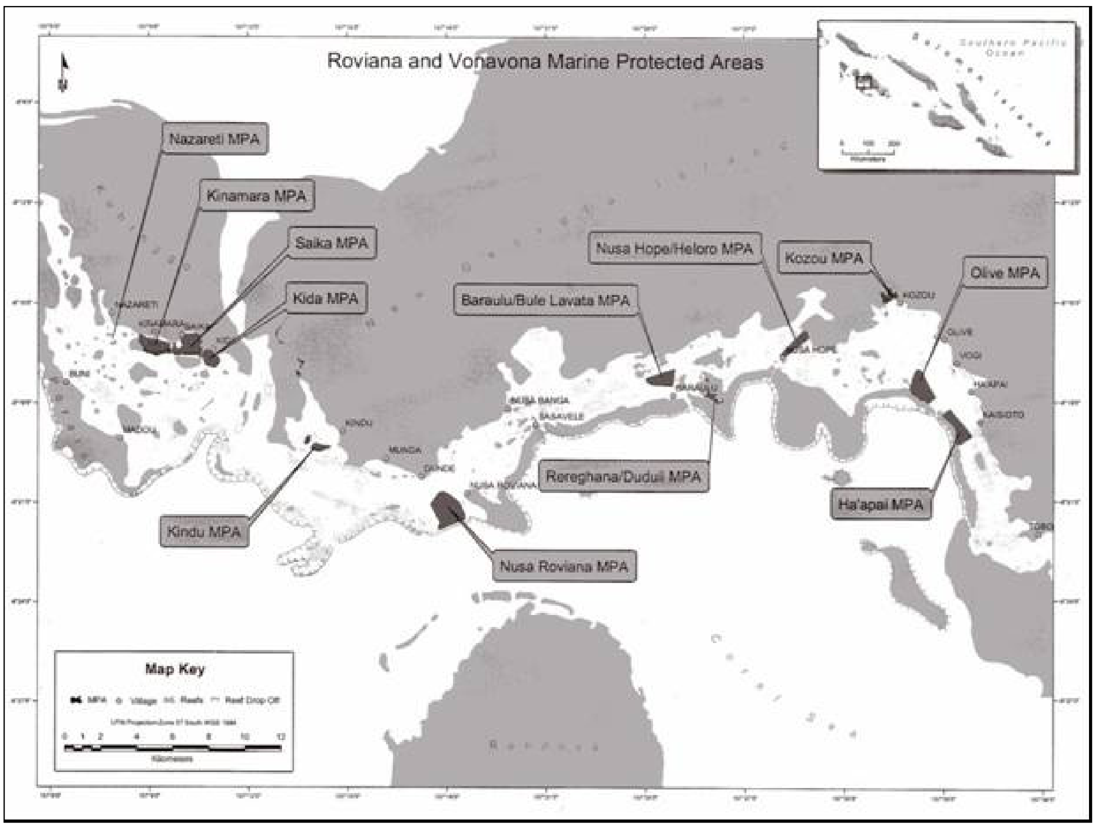

Figure 6: Roviana and Vonavona marine protected areas (Aswani and Hamilton, 2004b).

GIZO SPAWNING AGGREGATION MONITORING WORKSHOP

Between March 13-21, 2004, Warren Kama, Sunga Baso, Michael Giningele and Gumi Gadepeta from Roviana Lagoon attended a workshop in Gizo on spawning aggregation monitoring and training. These four individuals from Roviana represented the Roviana and Vonavona Lagoons Resource Management Program. The spawning aggregation monitoring and training workshop was conducted by The Nature Conservancy. "The workshops are designed to promote an awareness on the importance of spawning aggregations and their vulnerability, and to introduce local resource mangers and conservationists to basic monitoring techniques for identifying, recording and responding to change within spawning populations" (Rhodes, 2004). All four individuals from Roviana Lagoon are qualified divers and highly skilled spear-fishers who frequently target spawning aggregation sites. It was envisaged that by having them attend this course, they would be given new perspectives on the biological importance of spawning aggregations, and at the same time gain the skills required to undertake Underwater Visual Census (UVC) monitoring at key spawning aggregation sites in Roviana Lagoon. The specific details of this workshop are outlined in Rhodes (2004).

Once the workshop at Gizo was complete, the Roviana group, Kevin Rhodes and Richard Hamilton traveled down to Roviana Lagoon, were we surveyed spawning aggregation Sites 1 and 7 on the March 22-23 (Appendix 1). The purpose of the UVC surveys was to locate a large aggregation site that was suitable for basing future monitoring efforts. After diving at both sites it was quickly decided that Site 1 was the more suitable of the two sites. The aggregations at Site 1 were much larger than at Site 7, formed in relatively shallow water and the currents at Site 1 were less extreme.

COMMUNITY MEETING AT DUNDE

Site 1 is located within a 'mosaic' sea tenure regime (Figure 5). The Dunde community is one of the communities that claim primary ownership over this site. In order to discus the importance of spawning aggregations with the Dunde community and seek approval for monitoring at Site 1, a community meeting in Dunde was planned for the morning of March 26, 2004. Local counterparts from the Roviana and Vonavona Lagoons Resource Management Program organized this meeting and delivered letters of invitation to all members of the Dundee Resource Management Committee.

The meeting was held at the Dunde Community Hall and around 40 individuals attended. It was opened with a prayer and Richard Hamilton was then invited to speak. He began by introducing himself and described what spawning aggregations were and why conservationists were concerned about the global status of spawning aggregations. He then talked about why TNC had organized and run the recent spawning aggregation workshop in Gizo. Following this, he talked about the current status of spawning aggregations in many regions in the Pacific. To aid with this a graph was drawn on a blackboard showing the changing status of a hypothetical spawning aggregation site over time, and the type of factors that were leading to these changes (Figure 7).

Richard Hamilton then highlighted that past experience from other regions in the world has shown that under heavy fishing pressure, fish numbers in transient spawning aggregations can decline to zero, and the aggregations are lost. He then asked some of the older fishers if they could share their experiences on the history of spawning aggregations in their area. Once older fishers had finished talking about their experiences, Richard Hamilton outlined the lifecycle and biology of some of the larger aggregating serranids, and how their life history characteristics make them vulnerable to overfishing.

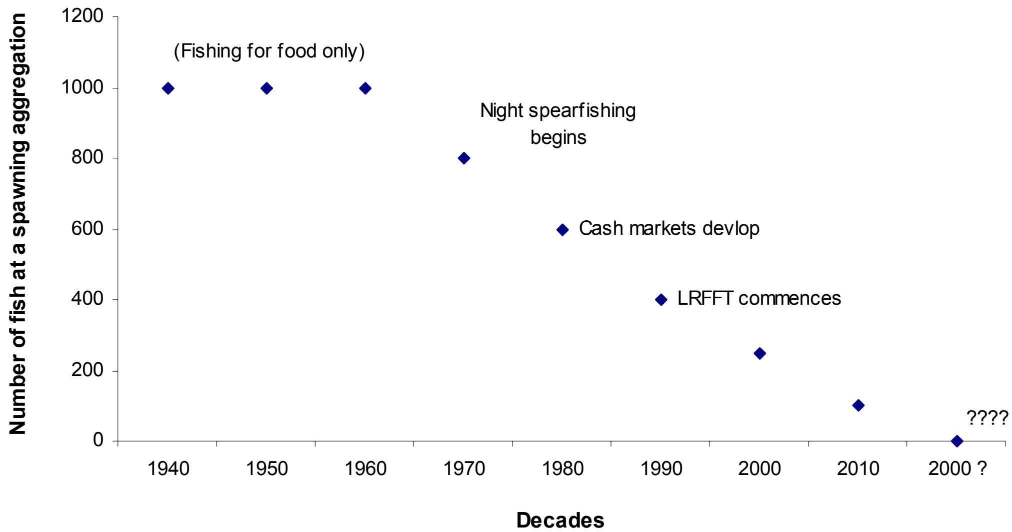

Figure 7: A hypothetical example of the type of pressures being placed on many transient spawning aggregations in the Pacific, and the subsequent impact on aggregation numbers.

At the end of the presentation there was considerable debate over what management options should be taken for several spawning aggregations in this region, and debate the merits of the proposed monitoring. Sunga Baso, Michael Giningele and Gumi Gadepeta who all reside in the Munda region stood up and spoke passionately about the importance of conserving spawning aggregations and the importance of conducting UVC monitoring. Largely based on these individuals' arguments, permission were eventually given to set a permanent transect at Site 1 and begin monitoring immediately. The Dunde community decided that management measures for several known aggregations within their jurisdiction would be decided upon at a later date, when data obtained through monitoring was available and the issues had been discussed further with the wider community. One scenario the community was keen on was a closed season, with local observers placed on nearby islands to enforce management measures at this time. The meeting ended with a prayer.

MONITORING EFFORTS IN ROVIANA LAGOON

As well as monitoring Site 1, it was also decided that a second site should be monitored, and Site 3 was chosen. This aggregation site is within the customary fishing grounds of Warren Kama, and Warren discussed the proposed research with Chief Solomon Roni and subsequently gained permission to monitor this site in April 2004. Although Site 3 has been heavily overfished, aggregations appear to be recovering, and it was felt that data obtained from surveying this site would be useful for assessing rates of recovery and raising awareness on the importance of spawning aggregations in this region. Data collected from a second site will also allow an assessment of small scale spatial variability in seasonality between aggregation sites.

AIMS OF MONITORING

Aim 1: Determine the seasonality with which aggregations of *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* form in this region.

Determining the peak seasonality of *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* in this region is primary important for designing future management measures such as seasonal closures. Knowing the peak spawning seasons of these species is also vital for designing future cost effective monitoring programs in this region, where annual surveying can be limited to the months of peak seasonality. Determining seasonality of these three species in Roviana Lagoon will also help us better understand the spawning seasons of these three species in the wider region of Western Province. In Marovo Lagoon, local fishers state that the spawning season of *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* is from approximately February to June each year (Johannes, 1989; Johannes and Lam, 1999). Whereas in the nearby Roviana Lagoon the spawning season for these three species and *E. ongus* is widely reported by local fishers to be between the months of October and January (Aswani, 1997; Hamilton, 1999; Johannes and Lam, 1999). These widely reported differences in seasonality have lead researchers to assume that the spawning seasons between these two closely located regions are completely different. However, the indigenous knowledge of several expert fishers and recent UVC survey results indicate that differences may not be as pronounced as previously thought. Several expert fishers from Roviana Lagoon report that *P. areolatus* aggregations at Site 1 can form as late as June. Recent monthly monitoring at Site 1 has reveled that aggregations of *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* formed here in March and April 2004, with a smaller single species aggregation of *P. areolatus* also forming here in May 2004.

Clearly the spawning season in Roviana Lagoon is more extended than it is widely perceived to be. In Kavieng and Manus Provinces in Papua New Guinea, *P. areolatus* is known to form spawning aggregations every month of the year, with aggregations peaking during 2-3 months of the year. In Manus the peak aggregations of *P. areolatus* are known to occur from March –May, and it is during this peak season that other transient spawners such *E. fuscoguttatus, E. polyphekadion, E. ongus, L. erythropterus* and *S. spilurus* also aggregate to spawn at the same aggregation sites (Hamilton *et al*., 2004). It appears that a similar scenario may be occurring in Roviana Lagoon, with *P. areolatus* aggregations having a protracted spawning season, with a peak season of 3-4 months (possibly between October – January). During this peak season large numbers of *E. fuscoguttatus* and *E. polyphekadion* may also aggregate to spawn. Ongoing monitoring efforts in Roviana Lagoon will help clarify this.

Aim Two: Collect baseline data on the relative abundance on each of these three species at Site 1 and 3.

Baseline survey data can be used as reference data to evaluate how future fishing pressure or management measures (such as closed seasons or MPAs) at these sites affect these aggregating populations.

CURRENT MONITORING EFFORTS AT SITE 1

A 250 meter long ten meter wide transect was placed at a depth of 20 meters at Site 1 on March 26-27, 2004, giving a total transect area of 2500 m. sq. Previous surveys of this area that were conducted on March 22, 2004 (one day after the new moon) had revealed that *P. areolatus* were distributed from 5-30 m throughout the aggregation area, while *E. fuscoguttatus* were densely aggregated around two spatially separated promontories between the depths of 15-30 m. Low numbers of *E. polyphekadion* were scattered throughout the aggregation area. The horizontal length of the aggregation was estimated to be approximately 300 m, and it was decided that a 250 m long transect with a mid-point at 20 m that passed through both *E. fuscoguttatus* aggregations would provide a good representative sample of the relative abundance of *P. areolatus* and *E. fuscoguttatus*. 78 one meter long steel rebar rods were used to permanently mark the mid-point and outer perimeters of the transect, with a rebar rods been hammered in to the reef at 10 meter intervals along the mid-point and upper and lower perimeters of the transect. One meter long PVC sleeves were then placed over each rebar to make the transect boundaries clearly visible. For a detailed description of the methodology used for establishing these belt transect refer to Pet *et al*., (2005).

The Roviana monitoring team elected Warren Kama as their team leader and it was decided that monitoring would be conducted at Site 1 in the afternoon on every new moon for a continuous 24 month period, with surveying commencing in April 2004. The survey procedure is as follows: both divers swim side by side above the mid-point of the transect recording the abundance of all *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* sighted within the transect boundaries. Since both divers record abundance data simultaneously, it allows standard errors in divers' counts of each species to be estimated. Spawning signs in each species are also noted by each diver.

CURRENT MONITORING EFFORTS AT SITE 3.

It was initially decided that a transect would also be placed at Site 3, however a survey at this site conducted two days before the new moon in April 2004 reveled that numbers of *P. areolatus* and *E. fuscoguttatus* were so low that a transect was not required. Divers transverse the entire area of the aggregation site at a depth of approximately 20 m recording the number of all *E. fuscoguttatus, E. polyphekadion* and *P. areolatus* sighted. Warren Kama has free-dived at this site for two decades, and is well aware of what the spatial parameters of this aggregation were before it was overfished. Surveys of this site are ongoing and will be conducted two days prior to the new moon for 24 consecutive months.

RECOMMENDATIONS

1. TNC should provide long-term scientific advice and expertise to the Roviana monitoring team. While the Roviana monitoring team is doing a great job, they still require scientific advice on monitoring methodologies, research design and data analysis. Having a scientist actively involved with the Roviana monitoring program will build local capacity and help ensure that the monitoring programs remain scientifically rigorous.

2. At some stage the Roviana monitoring team will need to assistance in estimating the total areas of the *P. areolatus* and *E. fuscoguttatus* spawning aggregations at Site 1. The estimation of aggregation areas needs to take place during the next peak season, which perceivably will be between October 2004 to January 2005. Estimating total aggregation area at Site 1 is required so that:

   - Monthly abundance data obtained from surveying transects can be scaled up to give relative abundance data for the entire aggregation sites.

   - The absolute area of the aggregations can be estimated and compared from year to year, to establish changes in fishing pressure at these sites is resulting in changes in the total aggregation area.

3. It would be valuable to investigate the specific lunar days on which each aggregating species spawn and subsequently disperse, and determine if this varies on a monthly basis both within and between the two monitored sites. This would involve surveying every day for approximately a week at each site during an aggregation period, ending surveys once all aggregated species of interest have dispersed. For the purpose of looking at intra-site variability, these intensive weekly surveys would need to be repeated at each site at least twice in a year. Obtaining this data would enable communities to develop management strategies that involved short-term lunar closures on fishing at these spawning sites.

4. Continue to build the capacity of Roviana monitoring team. While the Roviana monitoring team have gained basic skills in monitoring by attending the TNC spawning aggregations workshop in Gizo, they still lack experience and expertise in many areas such as length-size estimation, data processing, interpretation of data and how to present their findings back to their local communities. As the Roviana team becomes more experienced, it would be valuable to have some

of them partake in an advanced monitoring training, where monitors are taught about the skills listed above.

5. Conduct community awareness programs in Roviana Lagoon on what spawning aggregations are and the importance of conserving them. These workshops should initially be tailored to communities that hold customary ownership over the aggregation sites that are currently being monitored. The individuals involved in monitoring at Roviana sites and local community educators who are employed by the Roviana and Vonavona Lagoons Resource Management Program should be closely involved in any future awareness campaigns in this region.

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APPENDICES

APPENDIX 1. Data tables for aggregations around Roviana Lagoon

At several sites up to five species aggregate at the same site during the same lunar and seasonal phases. When there was detailed data for each species that aggregated at a multi-species aggregation site, then separate tables for each species were computed. However, if the information documented was generic for all species that aggregated at a multi-species aggregation site, then only one table of parameters was computed. In one instance, several single species aggregations of *E. ongus* occurred within close proximity to each other. The local knowledge colleted on these aggregations is also summarized in a single table. When no information was available for an aggregation parameter that row is left blank[3].

Note: Aggregation area was estimated as follows: Local fishers who had taken us to an aggregation site were asked to demarcate the approximate boundaries of the aggregation, which they did either from the boat or at times by snorkeling besides the slowly moving boat. Aggregation boundaries were marked using a handheld GPS. Local fishers were also asked to estimate the vertical depth ranges of the aggregation. The aggregation area was then estimated by multiplying the vertical depth range (in meters) of the aggregation by the total horizontal distance (meters) between aggregation boundaries, as determined by the GPS. Since the vertical depth estimates do not account for the slope of the reef walls, these aggregation area estimates they should be considered as a rough estimate of minimum aggregation area.

[3] Sensitive information that was documented under the aggregation parameters 'Site name, Location, Coordinates and Source (informants interviewed)' has purposely been omitted from all of the aggregation tables in this appendix.

Aggregation Site #	**1**
Site name.	
Species names	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*
Local name	Pazara is the generic name for serranids in Roviana. The species names for *P. areolatus* and *E. fuscoguttatus* are pazara haquma and pazara veata respectively. *E. polyphekadion* is only known by its generic name.
Location	
Coordinates	
Depth (m)	*P. areolatus* 5- 30 m. *E. fuscoguttatus* 15-30 m.
Habitat	Promontory. *P. areolatus* aggregated on sand and coral on the promontory and in a bay behind the promontory. *E. fuscoguttatus* only aggregated on coral around promontory.
Duration	Between seven to ten days.
Month(s) of formation	Unclear. *P. areolatus* reported to form most months of the year, but aggregation size highly variable. Aggregations of *P. areolatus* formed in January and March 2001 and March, April and May 2004. Seasonality of *E. fuscoguttatus* and *E. polyphekadion* not well known. Aggregation of *E. fuscoguttatus* also formed in March and April 2004.
Sign of spawning	Multiple gravid females, fighting, chasing and color changes associated with spawning.
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and several days into the new moon
Fish numbers	This site was surveyed on SCUBA on March 22, 2004, two days after the new moon. No attempt was made to count the number of serranids aggregating at the site, but a rough approximate was made. *P. areolatus*: approx. 500 *E. fuscoguttatus*: approx. 200 *E. polyphekadion*: < 50 The aggregation appeared healthy and sex ratios for *P. areolatus* were approximately 1:1. This site was revisited on March 26, 2004 (that being 6 days after the new moon). All aggregating species had completely dispersed, with no *P. areolatus, E. fuscoguttatus* or *E. polyphekadion* sighted.
Area (m. sq)	Approx. 10 000 -12 000 m. sq. (total aggregation area). *E. fuscoguttatus* aggregated over two spatially separated core areas that are both approximately 2000 m. sq.
Year discovered	1995
How discovered	The aggregation site was discovered by chance by an artisanal fisher when he was spearfishing for bumphead parrotfish (*Bolbometopon muricatum*) at night.
Year first exploited	1995
Gear used	Spearfishing (night). Limited spearfishing in the day. Hook and line fishing does not occur here. The main species targeted at this site is *P. areolatus. E. fuscoguttatus* is rarely taken by spear-fishers at this site for 2 reasons: Firstly, its large size means spears are often lost, and secondly, fisheries centers at Munda only buy fillets (as apposed to the entire fish) from large species such as *E. fuscoguttatus*. Divers reported that because of this, they cannot be bothered spearing *E. fuscoguttatus* since they would have to spend consider time filleting this species. *E. polyphekadion* is only occasionally taken by spear fishers at this site. It either forms in low numbers at this site or occurs at depths outside of the range of free divers.

CPUE trend	Declining for *P. areolatus*
Current status	Declining for *P. areolatus*. Unchanged for other species.
Status parameters	In the first two years that spear-fishers exploited this site (1995/1996) several individuals could remove over 200 *P. areolatus* in several hours during peak aggregation periods. Fishers report a notably decline in maximum catches from 1997 onwards, and in 2001, maximum catches of P. areolatus for the several spear-fishers targeting a peak aggregation were 79 *P. areolatus* in a night.
Management/Protection	Under consideration by the Dunde Council of Chiefs. See this report.
Additional notes	Relatively few individuals know of the location and timing with which aggregations form at this site. It is estimated that less than 10 individuals exploit this aggregation on a regular basis. All are highly skilled Roviana spear-fishers. This is a popular tourist dive site. Numerous species of sharks are common at this site, which appears to have prevented many fishers from diving here at night. Four individuals from Roviana who attended the TNC run Gizo spawning aggregation monitoring workshop in March 2004 are currently monitoring this site. All of these individuals are spear-fishers who targeted this site regularly in the past. Monitoring at this site commenced in April 2004, and it is envisaged that this site will be monitored monthly on the new moon for at least 24 months. This will enable us to evaluate peak spawning seasons for each species, which will in turn enable us to advise on when seasonal closures should be imposed at a local and possibly provincial level. Local fishers state that *P. areolatus* is always most abundant species at this site, followed by *E. fuscoguttatus* and *E. polyphekadion*.
Source	Hamilton *et al*., (2005)

Aggregation Site #	**2**
Site name.	
Species names	*Plectropomus areolatus, Epinephelus fuscoguttatus* and *Epinephelus polyphekadion*
Local name	Pazara is the generic name for serranids in Roviana. The species names for *P. areolatus* and *E. fuscoguttatus* are pazara haquma and pazara veata respectively. *E. polyphekadion* is only known by its generic name.
Location	
Coordinates	
Depth (m)	2 -30 m. All three species historically aggregated into very shallow water at this site.
Habitat	Reef slope and shallow reef flat above reef slope.
Duration	7-10 days
Month(s) of formation	Unclear. Aggregation size was known to be highly variable.
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and new moon
Fish numbers	Historically in the 100's. Today, it appears that this aggregation has almost been fished to extinction.
Area (m. sq)	10 000 -15 000 m. sq
Year discovered	Location of this aggregation has been known for generations
How discovered	
Year first exploited	Exploited for generations
Gear used	Predominantly night spearfishing
CPUE trend	Declined almost to zero
Current status	Declining and seriously threatened
Status parameters	A fisher who has exploited this site for over three decades reports that in the 1970's and early 1980's the aggregation here was larger than aggregations at Site 1. With approximately 500 – 1000 *P. areolatus* and several hundred *E. fuscoguttatus* and *E. polyphekadion* in peak seasons. Fishers report being able to catch approximately 100 P. areolatus, 50 *E. polyphekadion* and 50 *E. fuscoguttatus* in a single night when they first spear fished here at night during a peak aggregation in the 1970s. Catch rates declined steadily through the late 1980's and early 1990's, and since the mid 1990's aggregations have not formed in significant numbers. The same fisher who exploited this aggregation since the 1970s said that since the mid 1990's, the maximum number of *E. fuscoguttatus* and *E. polyphekadion* he has seen at this site is less than 10, and the maximum number of *P. areolatus* is less than 20. He also stated that these aggregating serranids were all very small fish. The almost complete disappearance of this once large aggregation coincided with the introduction of night spearfishing in this region and the development of commercial market outlets at the nearby provincial centre of Munda.
Management/Protection	None – But full protection under consideration by Dunde Council of Chiefs. Enforcing any management strategies in this area will be an issue.
Additional notes	Spear-fishers report that catch rates of all species have declined by one or two orders of magnitude in the last two decades. Numbers of bumphead parrotfish that historically aggregated here at night in huge numbers have greatly reduced in abundance.
Source	Hamilton *et al*., (2005)

Aggregation Site #	**2**
Site name.	
Species names	*Lethrinus erythropterus*
Local name	osanga mila bongi
Location	
Coordinates	
Depth (m)	1 m – 5 m
Habitat	Shallow reef top adjacent to deep water drop off.
Duration	3-4 days
Month(s) of formation	Possibly every month of the year. Aggregation size is known to be highly variable from month to month.
Sign of spawning	Multiple gravid and hydrated females, spawning observed.
Type of aggregation	Transient
Time of spawning	Nocturnal group spawning observed at this site.
Type of spawning	Group spawning. 5-10 fish dart up from the aggregation and spawn at the surface. Spawning fish are so tightly clustered in a small area that fish stack up horizontally on top of each other.
Moon phase	End of third quarter and new moon
Fish numbers	> 1000 during peak aggregations.
Area (m. sq)	Aggregation area > 5000 m. sq Actual spawning area: Approx. 1000 m. sq
Year discovered	1991
How discovered	Discovered by chance by a fisher who was spearfishing at night.
Year first exploited	1991. (Subsistence). First commercially exploited in 1997 when the fisher who discovered this aggregation realized that local fisheries outlets would purchase this species.
Gear used	Nighttime spearfishing
CPUE trend	Declining
Current status	Declining
Status parameters	The first time that this aggregation was fished for commercial purposes fishers removed over 400 kg of *L. erythropterus* in a single night, representing approximately 2000 fish. Since then the location and timing of this aggregation has become fairly widely known, and artisanal night spear-fishing pressure at this site has intensified. Total numbers and catch rates made at this site have dropped markedly. The fisher who discovered this site reports that by 2003, the number of aggregating fish and catch rates had declined by an order of magnitude.
Management/Protection	None – But full protection under consideration by Dundee council of chiefs. Enforcing any management strategies in this area will be an issue.
Additional notes	*Epinephelus ongus*, known locally as pazara kalula, also aggregate at this site during the same lunar and seasonal periods. Peak aggregations of E. ongus occur at the same time as peak aggregations of *L. erythropterus*, with many 100's of *E. ongus* aggregating at this site. Total numbers and catch rates of *E. ongus* are also said to have declined noticeably at this site over the last five years. Local fishers prefer to catch *L. erythropterus* than *E. ongus*, stating that if the numbers of both species are high, they do not bother with *E. ongus*. Both species frequently reside within shallow staghorn corals at night. These corals have been extensively damaged by nighttime spear-fishers, who will break the coral structures surrounding a speared fish in order to remove it from the coral. (See Appendix 2).
Source	Hamilton (2005)

Aggregation Site #	**3**
Site name.	
Species names	*Plectropomus areolatus* *Epinephelus fuscoguttatus*
Local name	pazara haquma and pazara veata
Location	
Coordinates	
Depth (m)	5 –30 m
Habitat	Passage wall that supports fairly extensive cave systems.
Duration	Approximately 10 days
Month(s) of formation	Peak season reported to be from October – January.
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter – new moon
Fish numbers	This spawning aggregation has been fished almost to the point of extirpation. Historically this aggregation supported large numbers of fish, with 3-4 tonnes of serranids being removed from this small site in between October- January in 1996 and 1997 to supply a LRFFT operation. An estimate of fish numbers in peak season in 2003 is provided below. This is based on Warren Kamas observations while free diving at this site. This site is located within Warren's traditional fishing grounds and he has fished here for three decades. *P. areolatus*: Less than 10 *E. fuscoguttatus*: Less than 30
Area (m. sq)	5000 -8000 m. sq
Year discovered	Known for generations
How discovered	
Year first exploited	Exploited for generations.
Gear used	Hook and line and spearfishing.
CPUE trend	Declining
Current status	Declining and threatened
Status parameters	This aggregation has been severely overfished by LRFFT operations and night spear-fishers. LRFFT operations targeted aggregation on a seasonal basis in 1996 and 1997, and by 1998 this aggregation had been fished to commercial extinction. Being opposite to a large village in a sheltered passage, this aggregation was targeted on a 24 hour basis in 1996 and 1997, with men, women and children hook and line fishing at this site (Authors, personal observations, 1996, 1997). Fishing was intensive enough that fishers noticed a major decline in catch rates after only one year of targeting this aggregation for commercial purposes. Very few *P. areolatus* or *E. fuscoguttatus* were taken in a Catch Per Unit Effort (CPUE) survey of spearfishing trips that were conducted in and around this region between August 2000 – July 2001 (Hamilton, 2004).
Management/Protection	None. This site is currently being monitored – see this report.
Additional notes	*E. fuscoguttatus* reside in caves at night, and are targeted by nighttime spear-fishers at this time.
Source	Johannes and Lam, 1999; Hamilton (1999; 2004).

Aggregation Site #	**4**
Site name.	
Species names	*Lethrinus erythropterus*
Local name	karapata
Location	
Coordinates	
Depth (m)	1 m – 20 m plus
Habitat	Passage slope
Duration	3-4 days
Month(s) of formation	Possibly every month of the year with a peak aggregation period towards the end of the year (i.e. From October to January).
Sign of spawning	Multiple gravid and hydrated females, spawning observed.
Type of aggregation	Transient
Time of spawning	Nocturnal group spawning in this species has been observed by a local fisher at Site 2 (see Appendix 2).
Type of spawning	Group spawning. 5-10 fish dart up from the aggregation to the surface and spawn.
Moon phase	End of third quarter and new moon
Fish numbers	> 10 000 during peak aggregations.
Area (m. sq)	> 20 000 m. sq.
Year discovered	
How discovered	The authors came across a very large aggregation of *L. erythropterus* here completely by chance in October 2000.
Year first exploited	
Gear used	Spearfishing
CPUE trend	
Current status	Stable
Status parameters	Local knowledge on the timing with which this particular aggregation forms appears to be very limited, consequently, it appears that this aggregation is only lightly and sporadically exploited by nighttime spear-fishers when they happen to come across this aggregation.
Management/Protection	None
Additional notes	A very large aggregation of *L. erythropterus* was encountered here by chance at night in October 2000. The total number of fish in this aggregation were estimated to exceed 10 000 fish. Maximum densities were estimated to exceed 30 fish per m. sq. This aggregation was encountered two days before the new moon. A smaller aggregation of this species formed several days later on the opposite side of the passage. Maximum and average sizes of *L. erythropterus* in Roviana Lagoon are lower than in other parts of this species range (See Appendix 2).
Source	Hamilton (2005)

Aggregation Site #	**5**
Site name.	
Species names	*Epinephelus ongus*
Local name	pazara kalula
Location	
Coordinates	
Depth (m)	1-5 m
Habitat	Passage slope and reef top above passage slope
Duration	1-2 weeks
Month(s) of formation	November, December, January
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and new moon
Fish numbers	Several 100
Area (m. sq)	Approx. 8 000 m. sq
Year discovered	Location, annual seasonality and lunar periodicity known for generations
How discovered	
Year first exploited	Exploited for generations
Gear used	Throw away line with baited hook (i.e. no sinker) and spearfishing
CPUE trend	Declining
Current status	Declining
Status parameters	Major declines in catch rates have occurred at this site, with fishers stating that catches have declined steadily since the 1970's. Prior to the 1970's a fisher could take over 100 *E. ongus* in several hours from this aggregation site. By 2000, a spear fisher searching for this species during an aggregation period would typically get no more than 10 *E. ongus* over several hours. The aggregation is within minutes paddling distance of a large village. The close proximity to market outlets in Munda has also resulted in this aggregation being targeted by artisanal fishers.
Management/Protection	None
Additional notes	This aggregation has been over fished to the point where many older fishers no longer bother to target it, stating that pazara kalula no longer form in sufficient numbers to make fishing here worthwhile.
Source	

Aggregation Site #	**6**
Site name.	
Species names	*E. ongus*
Local name	pazara kalula
Location	
Coordinates	
Depth (m)	1-6 m
Habitat	Shallow inner lagoon reef that is adjacent to a deep passage
Duration	1-2 weeks
Month(s) of formation	November, December, January
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and new moon
Fish numbers	Several hundred
Area (m. sq)	Approx. 10 000 m. sq
Year discovered	Location and season known for generations
How discovered	
Year first exploited	Exploited for generations
Gear used	Throw away line with baited hook (i.e. no sinker) and spearfishing
CPUE trend	Declining
Current status	Declining
Status parameters	Major declines in catch rates have occurred at this site, with fishers stating that catches have declined steadily since the 1970's. Prior to the 1970's a fisher could take over 100 *E. ongus* in several hours from this aggregation site. By 2000, a spear fisher searching for this species during an aggregation period would typically get no more than 20 *E. ongus* over several hours. The close proximity of this aggregation to two large villages has been detrimental for it. The close proximity to market outlets in Munda, has also resulted in this aggregation being targeted by artisanal fishers.
Management/Protection	None
Additional notes	This aggregation has been over fished to the point where many older fishers no longer bother to target it, stating that pazara kalula no longer form in sufficient numbers to make fishing here worthwhile.
Source	

Aggregation Site #	**7**
Site name.	
Species names	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*
Local name	pazara is the generic name for serranids in Roviana. The species names for *P. areolatus* and *E. fuscoguttatus* are pazara haquma and pazara veata respectively. *E. polyphekadion* is only known by its generic name.
Location	
Coordinates	
Depth (m)	5-35 m
Habitat	Promontory. A 20 m wide 150 -200 m long platform occurs on the outer reef wall slope at approximately 25 m. This platform is said to be covered in aggregating fish of all three species during peak aggregations.
Duration	Between one and two weeks
Month(s) of formation	Peak season reported to be from October –January, but aggregations occur more frequently than this. An aggregation of *E. fuscoguttatus* and *P. areolatus* was sighted here in March 2004.
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and new moon
Fish numbers	Many hundreds of each species are said to aggregate here during peak seasons. Numbers are reported to have significantly reduced in the last decade as a result of LRFFT operations. This site was surveyed on SCUBA on March 23, 2004, three days after the new moon. No attempt was made to count the number of serranids aggregating at the site, but a rough approximate was made. *P. areolatus*: approx. 60-80, *E. fuscoguttatus*: approx. 50-70, *E. polyphekadion*: < 10
Area (m. sq)	Between 12 000 -15 000 m. sq.
Year discovered	Known for generations
How discovered	
Year first exploited	Exploited for generations
Gear used	Hook and line, spearfishing
CPUE trend	Declining
Current status	Declining
Status parameters	This aggregation was targeted by LRFFT operations in 1996, 1997 and 2001. A local fisher who assisted the LRFFT in all of these operations, reports that catches in 2001 were far lower than in 1996 and 1997, although he did not specify to what extent.
Management/Protection	None
Additional notes	A survey of this site on March 23, 2004 reveled that there was extensive anchor damage to the coral in this region, and old fishing line and hooks and sinkers were littered all over the reef, evidence of past LRFFT operations. Although LRFFT operations are reported to have impacted detrimentally on this spawning aggregation, very large numbers of aggregating serranids were sighted here in 2003 by a local dive guide who was SCUBA diving here with tourists. He estimated that there was over 1000 fish (made up of *P. areolatus, E. fuscoguttatus* and *E. polyphekadion*) in the aggregation, but could not remember the month in which he had seen this large aggregation.
Source	

Aggregation Site #	**8, 9, 10 and 11**
Site name.	
Species names	*E. ongus*
Local name	pazara kalula
Location	Local fishers identified four spatially separated aggregations that are all in very close proximity to each other in a passage environment.
Coordinates	
Depth (m)	1 -10 m
Habitat	Upper portion of the passage wall and the shallow inner lagoon reef that is adjacent to the deep passage.
Duration	Two weeks
Month(s) of formation	October - January
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and new moon
Fish numbers	In the thousands
Area (m. sq)	Individual aggregation areas were not estimated, but the areas of all aggregations combined was estimated to exceed 20 000 m. sq
Year discovered	Known for generations
How discovered	
Year first exploited	Exploited for generations
Gear used	Hook and line fishing with hermit crabs and sardines as bait. Fishers say that you can see the *E. ongus* rushing out to fight for the bait as soon as it enters the water. These fish are also captured using traditional derris root poisoning methods, although this is becoming less common.
CPUE trend	Stable
Current status	Stable
Status parameters	Although fishing effort is increasing on these aggregations, fishers report that catch rates have remained stable. It is noteworthy that fishers are a considerable distance from market outlets, so even today the majority of fishing pressure on these aggregations is for subsistence purposes only.
Management/Protection	None.
Additional notes	Until recently, *E. ongus* was regarded by many inhabitants in this area as a third grade fish, the last thing they would want to eat. Up until the late 1980's captured *E. ongus* were often thrown back into the water and referred to as "old peoples fish", relating to the fact that their extremely soft flesh meant that no teeth were required to eat them. This has changed over the last 10-15 years. As other fish resources in this region have become scarcer, more and more individuals are targeting these aggregations, and fish are no longer put back.
Source	

Aggregation Site #	12
Site name.	
Species names	*Lethrinus obsoletus*
Local name	ramusi
Location	
Coordinates	
Depth (m)	1 - 5 m
Habitat	Inner lagoon reef flats that are adjacent to a major passage that links the inner lagoon to the open ocean.
Duration	3-4 days
Month(s) of formation	Every month of the year
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	New moon
Fish numbers	In the past in the 1000's, today in the 100's
Area (m. sq)	Not estimated but greater than 10 000 m. sq.
Year discovered	Known for generations
How discovered	
Year first exploited	Exploited for generations
Gear used	Hook and line fishing (unweighted lines) with hermit crabs used for bait. Fishing mainly concentrated in the evenings and at night.
CPUE trend	Decreasing
Current status	Declining
Status parameters	Up until the 1970's a single individual hook and line fishing could capture several hundred *L. obsoletus* from an aggregation in a single night. By the mid 1980's maximum catch rates for a fisher using identical methods were reported to have declined to approximately 100 fish a night. Today fishers report that they will catch less than 20 *L. obsoletus* in a night during an aggregation period. This represents a 10-fold decline in catch rates for the same method. Fishers are well aware that abundances have declined markedly, reporting that numbers are nothing like they used to be.
Management/Protection	None.
Additional notes	This aggregation is widely known and forms around an Island on which a large village is located, meaning that it is very convenient to target. Consequently it has been heavily over fished.
Source	

Aggregation Site #	**13**
Site name.	
Species names	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*
Local name	pazara is the generic name for serranids in Roviana. The species names for *P. areolatus* and *E. fuscoguttatus* are pazara haquma and pazara veata respectively. *E. polyphekadion* is only known by its generic name.
Location	
Coordinates	
Depth (m)	5 -30 m
Habitat	Reef slope
Duration	Several weeks
Month(s) of formation	October - January
Sign of spawning	No evidence of spawning other than unusually high numbers of these three species fish in a localized area
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter- New moon
Fish numbers	Unknown
Area (m. sq)	Undetermined
Year discovered	??
How discovered	
Year first exploited	1997 was the first year that concentrated fishing effort focused on this site. But undoubtedly subsistence fishing has occurred here for generations.
Gear used	Hook and line
CPUE trend	Stable
Current status	Stable
Status parameters	Prior to protection, fishers did not notice declines in total catches or catch rates from this site.
Management/Protection	This site and surrounding passage area has been protected since 2002 under the Nusahope MPA. See this report.
Additional notes	If this is indeed a spawning aggregation site, it appears to be a fairly minor one. Only 300 kg of grouper were captured from this site during several weeks of experimental fishing in this area in November 1997 by the LRFFT. Due to low catches LRFFT operators abandoned this region and focused their efforts on other nearby passage areas where larger aggregations were known to form. The considerable distance from the passage mouth is highly unusual for a serranid spawning aggregation, and it may be that this site represents normal habitat for these species rather than a spawning aggregation site. Confirmation that this is a spawning site will require UVC surveys during the spawning season.
Source	

Aggregation Site #	**14**
Site name.	
Species names	*Plectropomus areolatus* *Epinephelus fuscoguttatus* *Epinephelus polyphekadion*
Local name	pazara is the generic name for serranids in Roviana. The species names for *P. areolatus* and *E. fuscoguttatus* are pazara haquma and pazara veata respectively. *E. polyphekadion* is only known by its generic name.
Location	.
Coordinates	
Depth (m)	
Habitat	Passage wall. Aggregations form at the seaward end of the passage.
Duration	Between one and two weeks.
Month(s) of formation	Peak season October - January
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and new moon
Fish numbers	No numbers given, but fish said to be present in their hundreds.
Area (m. sq)	5000 -10000 m. sq.
Year discovered	Known for generations
How discovered	
Year first exploited	Exploited for generations
Gear used	Hook and line and spearfishing. *P. areolatus* is commonly taken by night spear-fishers.
CPUE trend	Stable. This aggregation is reported to have been exploited in 1997 and 1998 for the LRFFT, with no notable reduction in catches. A local fisher who worked for this site reports that catches at this aggregation site far exceeded other areas of the lagoon.
Current status	Stable
Status parameters	Catch rates from this aggregation site are known to be much higher than at other sites exploited for the LRFFT in this region, and are reported not to have declined.
Management/Protection	None
Additional notes	This aggregation is currently exploited for subsistence purposes by individuals from several surrounding communities. Both these communities are a considerable distance from commercial fisheries outlets of Munda, and consequently, artisanal fishing pressure on these aggregations is light. Two MPAs have been established near this site, but neither of them currently encloses this aggregation site. The need to incorporate this spawning aggregation site into existing community based MPAs will be addressed through The Roviana and Vonavona Lagoons Resource Management Program in the future.
Source	

Aggregation Site #	**15**
Site name.	
Species names	*Epinephelus fuscoguttatus*
Local name	pazara veata
Location	
Coordinates	
Depth (m)	
Habitat	Seaward facing slope of a patch reef that is located in the middle of a large deep water passage. This aggregation site is several hundred meters from the passage mouth.
Duration	Several weeks
Month(s) of formation	October - January
Sign of spawning	Multiple gravid females
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter –new moon
Fish numbers	
Area (m. sq)	
Year discovered	1997
How discovered	A local fisher working for the LRFFT reported that this aggregation was discovered in 1997 by LRFFT operators who were conducting experimental fishing during a known aggregation season.
Year first exploited	Commercially exploited for a LRFFT operation in 1997 and 1998.
Gear used	Hook and line
CPUE trend	A local fisherman who targeted this aggregation in order to supply fish to a LRFFT operation in 1997 and 1998 reports that his maximum catch was 120 kg of *E. fuscoguttatus* in a day, which he captured over approximately 6 hours.
Current status	Stable
Status parameters	Catch rates were reported to have remained stable over the two years that this aggregation site was targeted to supply a LRFFT operation.
Management/Protection	None
Additional notes	This aggregation is similar to Site 13 in that is some distance back from the passage mouth (approximately 500 m). On the day we visited this site the water looked like a muddy river, a reflection in part of almost ten years of logging on the Saikile mainland.
Source	

Aggregation Site #	**16**
Site name.	
Species names	*Plectropomus areolatus*
Local name	pazara haquma
Location	
Coordinates	
Depth (m)	
Habitat	Passage wall
Duration	Approximately 10 days
Month(s) of formation	October – January is reported to be the peak season, may form smaller aggregations outside of this period.
Sign of spawning	Multiple gravid females, chasing behavior associated with spawning
Type of aggregation	Transient
Time of spawning	
Type of spawning	
Moon phase	Third quarter and new moon
Fish numbers	
Area (m. sq)	
Year discovered	
How discovered	
Year first exploited	Exploited by the LRFFT in 1997 and 1998
Gear used	In the past hook and line fishing to supply LRFFT operations, currently main method is nighttime spearfishing.
CPUE trend	
Current status	
Status parameters	Unknown
Management/Protection	None
Additional notes	Very little information on this aggregation was documented. There is only one very small community living in close proximity to this aggregation, and only one individual targets this aggregation regularly, spearfishing here at night during peak aggregation periods. Unfortunately he was not available to be interviewed at the time that we visited this site.
Source	

APPENDIX 2. Spawning aggregations of the longfin emperor, *Lethrinus erythropterus* (Valenciennes, 1830) in Roviana Lagoon, Western Solomon Islands.

Introduction

Lethrinus erythropterus (Valenciennes, 1830) is a medium sized species of the genus *Lethrinus* that is common in the tropical Indo-Pacific (Sato, 1978). This species primarily inhabits coral reefs and adjacent sandy areas and is normally around 300 mm in length, with a maximum size of 500 mm (Carpenter and Allen, 1989). In the Roviana language *L. erythropterus* is known as both *Karapata* in the eastern part of the lagoon and *Osanga mila bongi* around the Munda region.

Species of the family Lethrinidae are bottom-feeding carnivores that primarily feed at night on benthic invertebrates and fish (Carpenter and Allen, 1989). They are very abundant in coastal waters of the tropical and subtropical Indo-Pacific (Sato, 1978) and are of considerable importance in subsistence and artisanal coral reef fisheries, being captured predominantly by hand lines (Wright and Richards, 1985; Jennings and Polunin, 1995). To date there is only a limited amount of information on this species reproductive biology and a dearth of information on spawning behavior in this family (Allen, 2002). One of the only accounts of spawning in this family comes from a brief general description by Johannes (1981), who reported in his book 'Words of the Lagoon' that Palauan fishermen were aware that some lethrinid species migrate in large numbers to spawning sites at the inner or outer edge of fringing reefs during new moon periods. Spawning was reported by Palauan fishers to occur at night (Johannes, 1981). In a study on the reproductive biology of Lethrinus nebulosus around the Okinawan waters Ebisawa (1990) stated that spawning aggregations of this species were assumed, given that large catches of L. nebulosus with fully mature gonads were made from limited areas during March to April. The limited available data on spawning behavior in lethrinids resulted in Domeier and Colin, (1997) listing Lethrinidae among a number of families of coral reef fishes that may aggregate to spawn, but for which spawning aggregations had not been confirmed.

Local knowledge of *L. erythropterus* spawning aggregations

The aggregating and spawning behavior of *L. erythropterus* was brought to one of the authors (RH) attention in 1999 by Michael Giningele, an artisanal spear-fisher from Roviana Lagoon who is an exceptional natural historian. Michael Giningele discovered this aggregation at Site 2 by chance in the early 1990's when spearfishing at night, and he has exploited this aggregation on a regular basis since then. Large numbers of ripe *L. erythropterus* are known to aggregate at a fixed site on the inner edge of the Munda Bar outer barrier reefs just prior to the new moon, with group spawning in this species occurring around midnight. For a full account of Michael Giningele's local knowledge on the aggregating and nocturnal spawning behavior of *L. erythropterus* in Roviana Lagoon see Hamilton (2005).

Field Observations

On the new moon in March 2004 (21-Mar-04), we accompanied Michael Giningele and several other Roviana fishers to Site 2. We entered the water at this site at 11 pm and immediately located approximately 300 -500 *L. erythropterus* in a small area, residing in among shallow corals in water 1 - 5 meters deep. We investigated the core area where *L. erythropterus* are known to spawn, but fish were not aggregated there in densities any higher than in surrounding areas. Michael Giningele and other local fishers who exploit this site stated that this was a very small aggregation. *Epinephelus ongus* were also aggregated among the same corals as *L. erythropterus*, but in lower numbers. Approximately 50 – 80 *E. ongus* were sighted at this site. A sample of aggregating fish was randomly speared by fishers over a twenty minute period so that gonads and reproductive state of these fish could be investigated. In total 26 *L. erythropterus* and eight *E. ongus* were speared (Figure 8).

Figure 8: *L. erythropterus* and *E. ongus* that were speared at Site 2. Several *E. ongus* can be seen in the bottom right hand corner of the picture.

Reproductive state and sex specific size structure of L. erythropterus

All *L. erythropterus* speared were measured to the nearest mm (Total Length) and sexed macroscopically. All females sampled had visibly swollen bellies, and a mass of watery clear hydrated oocytes could be expelled by simply applying light pressure to the abdomen of female fish (Figure 9). Males were also running ripe, with some males expelling milt as soon as they were placed into the boat. The sex specific length frequency distribution of the fish sampled is shown in Figure 10. Male *L. erythropterus* had a normal size frequency distribution, with males present in all size ranges sampled. The female size frequency distribution was skewed towards to left. The operational sex ratio of this sample was male bias, with males outnumbering females 1.6:1.

The maximum and average sizes of *L. erythropterus* in Roviana Lagoon appear to be considerably lower than in other parts of this species range. The mean size of the 26 *L. erythropterus* sampled from Site 2 was 237 mm, with a maximum size of 260 mm. This low mean size does not appear to simply reflect heavy historical fishing pressure at this site. 43 *L. erythropterus* were sampled from a large relatively unexploited aggregation in 2000 (Site 5) were in a similar size range (authors personal observations).

Figure 9: Two gravid female *L. erythropterus* that were speared at night at Site 2.

The eggs of the female on the right were cut from the gut cavity immediately before taking this photo, and it can be seen how the watery almost honey-like hydrated oocytes of this female have spilled out all over the piece of timber that these fish were photographed on.

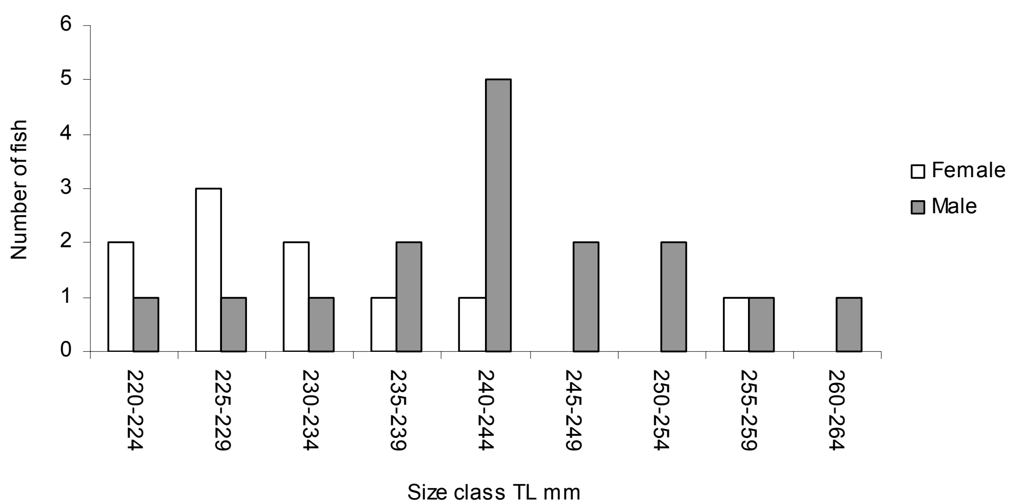

Figure 10: Size frequency distribution of *L. erythropterus* in 5 mm size classes (n = 26).

Reproductive state of *E. ongus*

All *E. ongus* speared were measured to the nearest mm (Total Length) and sex macroscopically. Sampled fish ranged in length from 200 – 330 mm. All fish had developed gonads that allowed them to be sexed macroscopically. There were four females and four males. None of the females had visibly swollen bellies or hydrated eggs. Due to the very small sample size, a size frequency distribution graph for this sample has not been presented.

Exploitation history and current status of this aggregation

The spawning aggregation of *L. erythropterus* at Site 2 were first fished for commercial purposes in 1995. In the first night that this aggregation was commercially fished, two artisanal spear-fishers removed 400 kg of spawning *L. erythropterus* in single night, representing approximately 2000 fish. They stopped fishing after several hours because their boat was in danger of sinking under the weight of their catch. Fish were said to be so densely aggregated that 3-4 *L. erythropterus* could be speared with a single thrust of a spear into the spawning aggregation. Since 1995 the location and lunar periodicity with which this aggregation forms has become increasingly widely known, and artisanal nighttime spearfishing pressure at this site has intensified. In turn, total numbers of aggregating fish and catch rates have dropped markedly. Michael Giningele states that by 2003, the number of aggregating fish and catch rates had declined by at least an order of magnitude. Numbers of the less abundant and less sought after *E. ongus* are also reported to have declined steadily.

During the short time that we were at this site on the night of March 21, 2004, another boatload of spear-fishers from Munda arrived at this aggregation site. One of the fishers in our boat told the other fishers that the aggregation had not yet formed, so they moved on to another site without getting in the water. However, several hours later when we were returning from Site 1, another fishing party was harvesting *L. erythropterus* and *E. ongus* from Site 2.

Discussion

By drawing on observations that Michael Giningele has made at this aggregation site over many years (Hamilton, 2005), it has been possible to provide one of the first detailed accounts of spawning behavior in the family Lethrinidae. Below we review the main points of interest:

L. erythropterus aggregates in very large numbers at fixed spawning sites around the new moon, with group spawning in this species occurring at night. The hydrated females that were captured from this aggregation site at 11 pm on March 21, 2004 concur with Michael's observations that this species spawns around midnight, as the eggs of female fish typically only become hydrated one or two hours prior to spawning (Colin *et al*., 2003).

Spawning fish form into a very tight cluster over a relatively small area, often being so densely aggregated that fish lie horizontally on top of each other. Fish in these aggregations are very easy to approach and appear to be in a trance like state, where they are not easily disturbed. Such behavior has been noted in other species that form spawning aggregations, and is referred to as 'spawning stupor' by Johannes (1978).

This species shows set lunar periodicity in its reproductive behavior, with spawning aggregations occurring only around the new moon in Roviana Lagoon. This fish also appears to have an annual spawning season, although existing local knowledge of this season is not detailed. These factors indicate that despite this species only obtaining a moderate size, it is likely to be a transient spawner, as opposed to a resident spawner (Domeier and Colin, 1997).

It appears that this species may aggregate to spawn in very large numbers in many parts of Melanesia. This species is also known to aggregate at multi-species transient spawning aggregation sites in Manus, Papua New Guinea. In Manus, *L. erythropterus* aggregates in a passage environment in the thousands around the new moon in the months of March, April and May (Hamilton *et al*., 2004).

Conclusion

Recent interviews have revealed that the spawning aggregations of *L. erythropterus* at Site 2 have been heavily overfished by nighttime spear-fishers in recent years. The shallow staghorn corals

(*Acropora sp.*) at this site have also been extensively damaged by nighttime spear-fishers, who will break the coral branches surrounding a speared fish in order to remove it from the coral. It seems very likely that this aggregation is under threat of being fished to extirpation in the next few years if it is not protected. Indeed, spawning aggregations of *P. areolatus, E. fuscoguttatus* and *E. polyphekadion* that once formed at this site appear to have been fished almost to extirpation by night spear-fishers as long ago as the late 1980's (Appendix 1). There is clearly an urgent need to place and enforce a complete ban on fishing at this spawning aggregation site. The Dundee Council of Chiefs that claim ownership of this area is currently in the process of considering implementing a community-based MPA at this site.