Indigenous ecological knowledge (IEK) of the aggregating and nocturnal spawning behaviour of the longfin emperor, *Lethrinus erythropterus*

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Introduction

Many species of reef fish form spawning aggregations, in which large numbers (up to many thousands) of mature fish travel to a specific location at a specific time to reproduce (Domeier and Colin 1997; Colin et al. 2003). Some spawning sites are used by multiple species, either simultaneously or at different times of day, month or year, while other sites host only a single species (Colin et al. 2003). Although fishers have been aware of spawning aggregations for centuries (Johannes 1978; 1981), biologists' interest in them has been far more recent (Colin et al. 2003). In the last decade there has been mounting recognition among marine scientists and coastal managers of the need to understand the biological parameters of spawning aggregations and the effects of fishing them (Vincent and Sadovy 1998; Levin and Grimes 2002; Peterson and Warner 2002; Pauly et al. 2002). This recognition has stemmed from two realisations: first, that spawning aggregations of many commercially important species have often been rapidly overfished (Sala et al. 2001; Colin et al. 2003) and second, that spawning aggregations represent bottlenecks in the life histories of many reef fish species, and aggregation conservation and management is critical for the survival of the populations that form them (Sadovy and Vincent 2002). The logistical difficulties of locating spawning aggregations that form at localised areas for brief periods of time has meant that marine biologists wanting to research or protect spawning aggregations have often drawn on the local knowledge of fishers in the initial stages of their field work (e.g. Johannes 1981; Beets and Friedlander 1998; Johannes et al. 1999; Sala et al. 2001).

Detailed ethnographic studies that have focused purely on documenting the local knowledge of fishers have revealed that, as well as knowing about the locations of spawning sites, local fishers can also provide precise information on: the annual and lunar periodicity of spawning aggregations; migration pathways to and from aggregation sites; species composition at mixed species spawning sites; the spawning behaviour of aggregating fish; the response of aggregating fish to human disturbances; and changes in the status of aggregation populations over time (Johannes 1981, 1989; Hamilton 2003a; Hamilton et al. 2004).

In this paper I detail indigenous ecological knowledge (IEK) regarding the aggregating and nocturnal spawning behaviour of the longfin emperor *Lethrinus erythropterus* (Valenciennes 1830) in Roviana Lagoon, Western Solomon Islands. I also report on observations that I have made at several *L. erythropterus* nocturnal aggregation sites in Roviana Lagoon over the last four years. *Lethrinus erythropterus* is a medium sized species of the genus that is common in the tropical Indo-Pacific (Sato 1978). This species primarily inhabits coral reefs and adjacent sandy areas and is normally around 30 cm in length (Carpenter and Allen 1989). The lethrinids are bottom-feeding carnivores that primarily feed at night on invertebrates and fish (Carpenter and Allen 1989). They are very abundant in tropical and subtropical Indo-Pacific coastal waters (Sato 1978) and are of considerable importance in subsistence and artisanal coral reef fisheries, being captured predominantly using handlines (Wright and Richards 1985; Jennings and Polunin 1995). Despite their abundance on reef systems and their importance in coral reef fisheries, there is only limited information available on lethrinid reproductive biology.

Most documented accounts of reproductive behaviour in the family Lethrinidae are based on the IEK of fishers. Johannes (1981) provides a brief general description on lethrinid spawning behaviour, reporting that Palauan fishers were aware that some lethrinid species migrate in large

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numbers to spawning sites at the inner or outer edge of fringing reefs during new moon periods. Palauan fishers reported that spawning occurred at night (Johannes 1981). Titan fishers from Manus, Papua New Guinea, report that very large spawning aggregations of *L. erythropterus* form at fixed sites around the new moon in the months of March, April and May. These spawning aggregations are said to occur at large inner reef passage environments; the white-streaked grouper *Epinephelus ongus*, squaretail coralgrouper *Plectropomus areolatus*, brown-marbled grouper *Epinephelus fuscoguttatus* and the camouflage grouper *E. polyphekadion* also aggregate in overlapping territories at these times (Hamilton et al. 2004). In a study of the reproductive biology of the spangled emperor *Lethrinus nebulosus* around Okinawan waters, Ebisawa (1990) stated that spawning aggregations of this species were assumed to occur, 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 behaviour 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.

Methods

The research reported in this study was conducted in Roviana Lagoon, Western Province, Solomon Islands. The Solomon Islands consist of a double-chained archipelago located east of Papua New Guinea, and extending over 1700 kilometres across the southwest Pacific (Fig. 1). The Western Province includes nine main islands, the largest of which is New Georgia (Fig. 1). Local fishing communities in the New Georgia archipelago are renowned for their comprehensive IEK bases

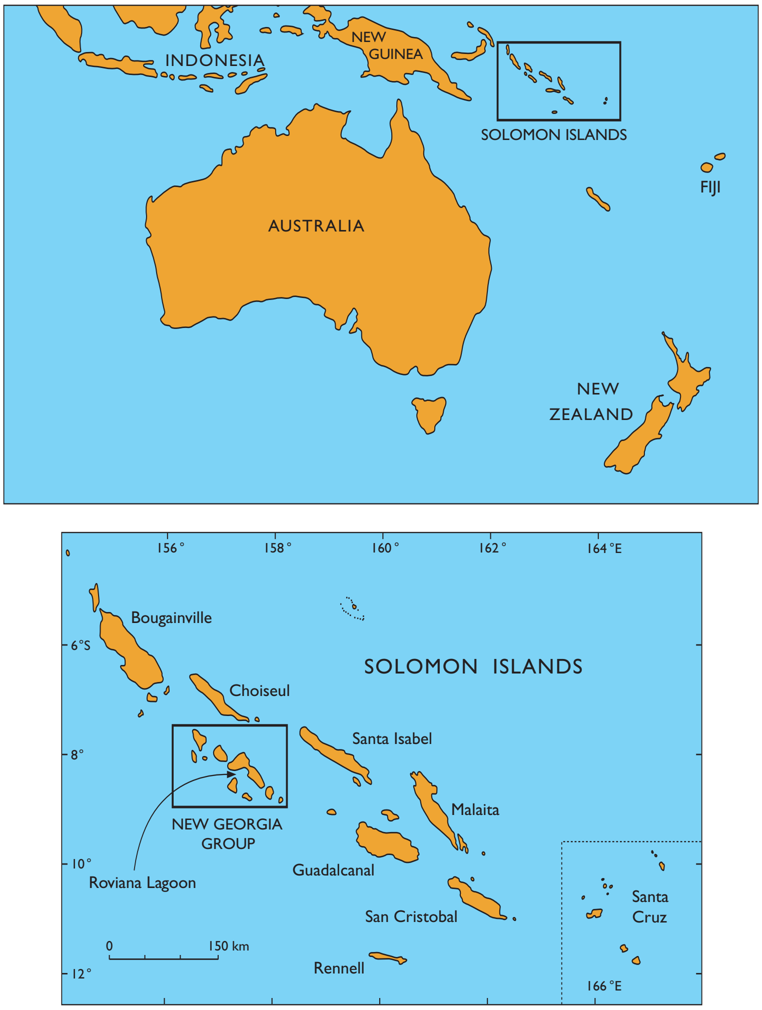

Figure 1. Solomon Islands and the New Georgia Group.

(Hviding 1996; Aswani 1997; Hamilton 1999; Johannes and Hviding 2001). This IEK has been shown to be highly accurate in many instances (Johannes 1989; Hamilton 1999; Hamilton and Walter 1999; Hamilton 2003b; 2004).

Lethrinus erythropterus make up an important component of subsistence catches in Roviana Lagoon, and are taken primarily by handlines. In Roviana folk taxonomy *L. erythropterus* is known as both *karapatu* and *osanga mila bongi*. The latter name is commonly used in the Munda region of Roviana Lagoon. Throughout the rest of this paper I use the Roviana name *osanga mila bongi* when referring to *L. erythropterus*. The nocturnal aggregating and spawning behaviour of *osanga mila bongi* was first brought to my attention in 1997, during a general discussion on reef fish aggregations with Michael Giningele, a renowned artisanal spear fisherman from Munda. Specific IEK on *osanga mila bongi* spawning behaviour at spawning aggregation Site A was obtained in 1999 when I conducted a detailed unstructured taped interview with Giningele in Solomon Pidjin. Observations that I made in 2000 on large aggregations of *osanga mila bongi* at aggregation Site B are also detailed in the results. Finally, I describe some[2] of the observations that I was able to make at Site A during an aggregating period in March 2004.

Results

Indigenous ecological knowledge of osanga mila *bongi spawning aggregations*

Some translated transcripts from the interview conducted with Giningele in 1999 are presented below. These transcripts demonstrate the extensive body of observations that Giningele has been able to make at this spawning site over more than a decade. Prior to 1995 only Giningele and one of his fishing partners knew of and exploited this aggregation, and it has only been in the last five or so years, through word of mouth, that the location and lunar periodicity with which aggregations of *osanga mila bongi* form at Site A have become more widely known in the Munda fishing community. It appears that the vast majority of fishers in Roviana Lagoon are unaware of other aggregation sites (including Site B) for this species in the lagoon. Between 1999 and 2004, I interviewed over 30 Roviana fishing experts about *osanga mila bongi*, but no IEK on this species' aggregating behaviour or aggregation sites (other than Site A) was uncovered.

Spawning aggregation history

> *I first came across this nocturnal aggregation by chance about ten years ago while spearfishing at night, and although it interested me, back then I never bothered to spear* osanga mila bongi*, as I didn't know that the fisheries centre would purchase this fish. About six years ago the fisheries centre at Munda told me they would purchase* osanga mila bongi*, so I asked them how many kilos they wanted. They told me they would buy whatever I caught, and were astounded when one night several weeks latter I turned up with over 400 kg of* osanga mila bongi [representing approximately 2000 fish]. *After that, they told me they only wanted to purchase small amounts of this fish, so normally I do not bother to target this aggregation unless someone specifically requests it.*

Other species that aggregate at this site during this period

> Pazara kalula (E. ongus) *also aggregate at this site during the same lunar and seasonal periods as* osanga mila bongi. *Although the* pazaa kalula *are not as numerous as the* osanga mila bongi, *there are still many hundreds of* E. ongus *here at this time.*

Aggregation site

> *Large numbers of ripe* osanga mila bongi *aggregate at Site A*[3] *on the inner edge of a large outer barrier reef around the new moon. Aggregations form over shallow reef areas that are adjacent to a small passage. Several days prior to spawning, aggregations of* osanga mila bongi *form at Site A between depths of 1 and 6 metres over a reef area of approximately 5000–10,000 m*^{2}*. The reef in this area consists of live corals* [predominantly stag horn coral (Acropora sp.] *sand and coral rubble. Aggregating fish reside in among staghorn corals and out in the open on the sand. On the night that spawning takes place fish aggregate into a small core area of the aggregation site (<1000 m*^{2}*) that is no more 3 m deep.*

Spawning behaviour

> *If you arrive at the* osanga mila bongi *site during a big nocturnal spawning event, you will see thousand and thousands of* osanga mila bongi *aggregated in several metres of water on one*

2. Some of the biological information that was documented in March 2004 (i.e. the length-sex ratios of *osanga mila bongi*) is not reported here. This data can be found in Hamilton and Kama (2004).
3. In an effort to protect sites from heavier exploitation, the precise location of aggregation sites is not given here.

small area of the reef. Spawning occurs around midnight. Spawning fish lie horizontally on the substrate, quivering in a trance like state. There are so many osanga mila bongi *in one small area that the fish actually stack up horizontally on top of each other. I have seen spawning in* osanga mila bongi *many times, where small groups of approximately 5–10 individuals dart up from the aggregation to the surface and simultaneously release clouds of gametes. After this the fish dart down and rejoin the aggregation. At this time it is like swimming through a pool of milk. Often many separate spawning events occur above the aggregation site at the same time. If the light of a flashlight is shone directly on the aggregations, spawning groups abort their spawning ascents and quickly return to the bottom where they return to a trance like state. Once the light is directed away from the aggregations spawning recommences almost immediately.*

Lunar and annual periodicity of aggregation formations

The osanga mila bongi *aggregations only ever form around the new moon period, but the specific days on which nocturnal spawning aggregations form are quite variable, and I have sighted spawning aggregations both before and after the new moon. I have noticed that* osanga mila bongi *aggregations always occur in the same months that spawning aggregations of* pazara haquma (P. areolatus) *form in this region* [See Hamilton and Kama 2004]. *In some months* pazara haquma *aggregations occur after* osanga *aggregations, and in other months the reverse pattern is true.*

Harvesting strategy

Giningele's harvesting strategy provides insights into his acute observational powers and his detailed understanding of this fish's behaviour at spawning aggregations. He had this to say regarding how he identified the ideal night to target spawning aggregations of *osanga mila bongi:*

If I want to harvest osanga mila bongi *I will travel to the aggregation site several days before the new moon in the months when I suspect aggregations are likely to form. I go in the afternoon, and as soon as I am in the water it is easy to tell if an aggregation is going to form, as large numbers of* osanga mila bongi *begin to aggregate around the wider area of the specific aggregation site several days prior to spawning. If I see* osanga mila bongi *aggregating, I will spear four or five of them and press their bellies to see if any eggs or milt come out. If I press their bellies but nothing comes out, then I know the nocturnal spawning aggregation is a day or two away. I will return the next day and repeat this process. When speared fish produce milt and eggs as soon as their bellies are pressed, then I know a nocturnal spawning aggregation will occur that night. If I come back that night the fish are so aggregated and so docile that you can spear three or four fish with a hand spear in a single thrust — there is no need to use the rubber to power the spear, as the* osanga mila bongi *simply lie down on top of each other.*

Observations on nocturnal aggregations of osanga mila bongi *that were made at Site B*

An extremely large nocturnal aggregation of *osanga mila bongi* was encountered at Site B by Giningele and the author on 26 October 2000 between 21:00 and 24:00 hours, two days before the new moon. Site B is one of five deep water passages in Roviana Lagoon that link the inner lagoon to the open sea. The aggregation of *osanga mila bongi* that was sighted on 26 October 2000 had formed on the western seaward portion of the passage. We discovered this nocturnal aggregation completely by chance while spearfishing. The passage wall where this aggregation was sighted descends initially at approximately 90 degrees, sloping into the sandy bottom of the passages at around 40–60 m. The passage slopes support relatively little living coral. A survey of the aggregation site revealed that *osanga mila bongi* were aggregated over an estimated 1 km linear stretch of the passage slope.

Fish were aggregated in cracks and crevices in the coral wall and from a depth of one metre to at least 20 m (this being our maximum free diving range), giving a very conservative aggregation area of >20,000 m^2. In many instances over 20 *osanga mila bongi* could be seen crammed into small holes in the reef wall. Some fish were completely exposed, while others had found some shelter in the reef structure and only parts of their bodies could be seen. *Osanga mila bongi* appeared to have aggregated in every suitable piece of cover that the passage wall had to offer. Because of variable passage wall topography, fish were clumped in their distribution, but maximum densities (number of fish per square metre) were estimated to be in excess of 30 fish m^{-2} in areas that provided suitable shelter. The authors estimated that the total number of *osanga mila bongi* in the aggregation exceeded 10,000 individuals.

Although easily approached, the aggregated fish were not asleep or in a trance like state, and spawning behaviour was not observed. *Osanga mila bongi* moved around within their limited shelters when flashlights were directed at them, and very exposed fish would occasionally move away from the disturbances that the free divers created and attempt to locate more suitable shelter. We speared 43 *osanga mila bongi* from this aggregation. All individuals had well developed (ripe) male and female gonads; however none of the individuals collected were running ripe.

Two nights later on 28 October 2000 (new moon) I returned to this passage to check on the status of this aggregation. Despite an extensive survey of the western side of the passage, no *osanga mila bongi* were sighted, but interestingly, a smaller aggregation of *osanga mila bongi* was sighted on the eastern side of the passage, slightly further down the passage than the aggregation that was sighted on the western side two nights previously. I had dived on the eastern side of this passage two nights previously, but had not seen any aggregating *osanga mila bongi* at that time. Fish had again aggregated over the passage wall between at least 1–20 m, with the aggregation area estimated to be approximately 10,000 m^2, with maximum densities of >10 fish m^{-2}. I speared eight individuals from this aggregation, and all had ripe well developed gonads but none were running ripe. Although I dived extensively at night in this passage environment over an uninterrupted 12-month period between August 2000 and July 2001, this was the only occasion that I sighted aggregations of *osanga mila bongi* here.

Field observations made at aggregation Site A in March 2004

On 21 March 2004 (new moon) I accompanied Giningele and several other local spear fishers to Site A, hoping to observe the spawning aggregations and spawning behaviour of *osanga mila bongi*. I entered the water at 23:00 hours and immediately located approximately 300–500 *osanga mila bongi* in a small area, residing among shallow corals in water depths of one to five metres. I investigated the core area where *osanga mila bongi* are known to spawn, but fish were not aggregated there in densities any higher than in surrounding areas and no spawning behaviour was observed. Giningele and other local fishers who exploit this site stated that this was a very small aggregation. *E. ongus* were also aggregated in among the same corals as *osanga mila bongi*, 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 20-minute period so that the gonads and reproductive state of these fish could be investigated. In total, 26 *osanga* mila bongi and 8 *E. ongus* were speared (Fig. 2).

All *osanga mila bongi* speared were 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 (Fig. 3). Males were also running ripe, with some males expelling milt as soon as they were placed into the boat.

Figure 2. ***Osanga mila bongi*** **and** ***E. ongus*** **that were speared at Site A on the new moon in March 2004. Several** ***E. ongus*** **can be seen in the bottom right-hand corner of the picture.**

Figure 3. **Two gravid female** ***osanga mila bongi*** **that were speared at 23:00 hours at Site A on 21 March 2004. 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 hydrated oocytes of this female have spilled over the piece of timber that these fish were photographed on.**

Discussion

Published accounts detailing coral reef fish spawning aggregations and spawning behaviour have been based predominantly on the observations of marine biologists, almost all of which have made underwater observations exclusively during daylight hours (e.g. Samoilys 1997; Rhodes and Sadovy 2002). The fact that very few marine biologists studying spawning aggregations have conducted underwater field observations at night (see Johannes (1989) as an exception) is likely to explain why there are so few accounts of nocturnal spawning behaviour in coral reef fish. In this paper I have drawn on the observations that Giningele has made while night diving at Site A over more than a decade to provide one of the first detailed written accounts of spawning behaviour in the family Lethrinidae. Specifically:

1. *Osanga mila bongi* aggregate in very large numbers at fixed spawning sites around the new moon, with spawning in this species occurring at night. The hydrated females that were captured from this aggregation site on 21 March 2004 provide independent confirmation that this species spawns at this site. [Undisputed spawning observations and females with hydrated eggs are two direct signs that are used to verify that a group of fish is spawning (Colin et al. 2003)].

2. All females that were captured around 23:00 hours on 21 March readily exuded hydrated eggs, providing some independent support for Giningele's observations that this species spawns around midnight, as females typically only exude hydrated eggs an hour or two before spawning (Colin et al. 2003). Note, however, that Giningele reports that eggs (presumably hydrated) can be exuded from female *osanga mila bongi* in the afternoon prior to a nocturnal spawning event.

3. Spawning fish form into a very tight cluster over a relatively small area in very shallow water, 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 behaviour has been noted in other species that form spawning aggregations, and is referred to as "spawning stupor" by Johannes (1978).

4. This species shows set lunar periodicity in its reproductive behaviour, 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 although this species only reaches a moderate size, it is likely to be a transient spawner as opposed to a resident[4] spawner (Domeier and Colin 1997).

5. Group spawning occurs in this species, where small groups of 5–10 individuals break from the aggregation and make rapid ascents towards the surface (spawning rush), releasing gametes at the peak of their ascent. The direct light of underwater flashlights temporarily disturbs a spawning rush. The fact that the light of a flashlight easily disturbs spawning rushes in *osanga mila bongi* may relate to a defence mechanism in this species, since the most vulnerable moment in a spawning sequence is during the spawning rush (Sancho et al. 2000). Indeed, the use of external video lights is known to disturb spawning behaviour in some species of serranids and for this reason is not recommended when filming aggregations (Colin et al. 2003).

6. The large nocturnal aggregations of *osanga mila bongi* observed at Site B differed from the aggregations at Site A in that the fish were aggregated on a coral passage wall in both deep and shallow water, and aggregating fish covered a much larger area. Furthermore, no spawning behaviour was observed at Site B and the gonads of female fish sampled from this aggregation were not hydrated. I conclude that the aggregations observed at Site B represented aggregations of *osanga mila bongi* that would spawn in a day or so. I could not determine where in the passage actual spawning takes place, but based on Giningele's observations at Site A, it seems likely that the aggregating fish at Site B would have congregated into a small core area within the observed aggregation area for the purpose of spawning.

7. Many reef fish species aggregate at the same location as *osanga mila bongi* during similar lunar and seasonal periods, presumably to spawn. *E. ongus* is known to aggregate in overlapping territories with *osanga mila bongi* at Site A, and *Plectropomus areolatus*, *Epinephelus fuscoguttatus* and *E. polyphekadion* also aggre-

4. Resident spawner aggregations draw individuals from a relatively small and localised area and may form very frequently throughout the year. Aggregations are often small and typically only persist for a short time (several hours to a day). The spawning sites can usually be reached through a migration of a few hours or less and are often located within the home range of the participating individuals (Domeier and Colin 1997).

gated in very close proximity to Site A up until the early 1990s, when these aggregations were fished out by night divers (Hamilton and Kama 2004).

8. Giningele's observations on the aggregating behaviour of *osanga mila bongi* agree closely with observations made by Manus fishers, who report that this species aggregates to spawn at multi species aggregation sites around the new moon in the months of March, April and May (Hamilton et al. 2004). Giningele's observations also agree with those made by Palauan fishers, who state that lethrinids form large spawning aggregations during new moon periods on the inner and outer edges of barrier reefs barrier reefs, with spawning occurring at night (Johannes 1981).

As well as being of biological interest, this study also demonstrates how expert fishers often know a great deal about fish behaviour, a point that has been made many times in the past (e.g. Nordhoff 1930; Johannes 1981; Johannes et al. 2000). Numerous researchers have also highlighted the fact that IEK is often stratified by gender, age, geographical location and clan structure, with specific knowledge pertaining to specific families of fish often restricted to fishers who specialise in targeting those species (Hviding 1996; Johannes et al. 2000; Hamilton 2003a). This study has shown that highly detailed and precise IEK on fish behaviour may be restricted to single individuals who are expert fishers and outstanding natural historians.

It is noteworthy that the information presented here on *osanga mila bongi* spawning aggregations is but one component of Giningele's indigenous ecological knowledge. The remarkable knowledge that Giningele possesses on coral reef fish behaviour and ecology relates in part to his chosen fishing strategy and the overwhelming amount of time that he spends in the water. It is estimated that Giningele has spent over 10,000 hours spearfishing at night on the reefs in Roviana Lagoon over the past 20 years, and an equivalent amount of time spear fishing on these reefs during the day; the night dive time alone is more than most marine biologists acquire in their entire lives. Moreover, the fact that Giningele has focused the majority of his fishing efforts in a small region adds a spatial-temporal element to his observations that transcends that of most biological studies.

The points raised here point to an important methodological issue: how IEK researchers can assess the accuracy of local knowledge. An increasing number of social and natural scientists who are interested in incorporating IEK into resource management or environmental assessment programs have stated that the highest reliability should be assigned to IEK that has been verified by several local experts (Neis et al. 1999; Usher 2000; Davis and Wagner 2003; Mallory et al. 2003). While I agree that aspects of IEK that are consistent and frequently raised by numerous local knowledge experts should be assigned a high degree of credence, I disagree with the assertions that un-corroborated IEK should be discounted or left out of summary reports (Davis and Wagner 2003). While clearly there is a danger in over generalizing from limited information or untested assumptions (Wenzel 1999), it is equally true that not all "experts" are created equal; some fishers are simply superb natural historians, whose knowledge surpasses that of everyone else in the region. Furthermore, most fishing communities know who these people are, and treat their information accordingly. Because these individuals will often know far more than anyone else about local ecologies, much of their local knowledge cannot be corroborated by interviewing other fishers in the region. In cases where a single individual's local knowledge could potentially be very relevant for research or management, efforts should be made to validate this local knowledge using alternative means. It is vital that credible ethnographic research methods are used. This includes taking care to understand the roles, status, expertise and relationships of the persons one is interviewing, rather than assuming that all indigenous people have access to the same body of ideas and knowledge.

A note on the current status of *osanga mila bongi* aggregations at Site A

Recent interviews have revealed that the spawning aggregations of *L. erythropterus* at Site A have been heavily overfished by night spear fishers in the past five years (Hamilton and Kama 2004). Since the late 1990s the location and lunar periodicity of this aggregation forms has become increasingly widely known, and artisanal night spear fishing pressure at this site has intensified. By 2003 both the total number of *osanga mila bongi* aggregating at Site A and the maximum catches of this species had declined by at least one order of magnitude (Michael Giningele, pers. comm. 2004). Numbers of the less abundant and less sought after *E. ongus* are also reported to have declined steadily.

The shallow staghorn corals (*Acropora* sp.) at this site have also been extensively damaged by night time 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 the point of extinction in the near future if current levels of night time spear fishing pressure are sustained. Indeed, night spear fishers appear to have fished out spawning aggregations of *P. areolatus*, *E. fuscoguttatus* and *E. polyphekadion*, which once formed in this area, by the early 1990s (Hamilton and Kama 2004). The council of chiefs that claim ownership over Site A are currently in the process of instituting a community based marine protected area at this site. Aswani and Hamilton (2004) provide a description of recent community based management efforts in Roviana Lagoon.

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First and foremost I thank Michael Giningele for sharing his local knowledge of the *osanga mila bongi* spawning aggregations with me. A superb natural historian, Michael Giningele has taught me a remarkable amount about the sea over the last eight years, and I have been privileged to share in some of his many underwater adventures. I would also like to thank Dr Richard Walter, who made helpful comments on an earlier version of this manuscript. This paper is dedicated to the memory of the late Robert E. Johannes, a pioneer in both indigenous ecological knowledge and spawning aggregation research. It was Bob who urged me to document IEK on the *osanga mila bongi* aggregations when I first told him about them in 1999.

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