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An overview of socio-economic and ecological perspectives of Fiji's inshore reef fisheries

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ABSTRACT

This paper reviews the socio-economic and ecological context of Fijian reef fisheries. This review is deemed necessary because improved understanding of the state and trends of Fiji's coral reef fisheries on a national level is required for designing an effective management plan for Fiji's inshore reef fisheries. The most important point that emerges from our review is that despite numerous studies of Fiji's reef fisheries, the current status of reef-associated fisheries at the national level is still uncertain due, mainly, to the lack of dependable data on the subsistence fisheries. This in turn leads to uncertainty about how the continuation of fishing, in particular, fishing focused on target species for the coral reef resources trade, will affect fishing communities and the ecosystem.

1. Introduction

Biodiversity rich coral reefs harbour an array of fish that support fisheries, which in turn sustain the dietary and livelihood needs of coastal communities throughout the Pacific. In Fiji, the marine ecosystem is an integral part of coastal Fijian life, forming the foundation of traditions and culture, including a customary marine tenure system [1]. Fiji's coral reef fisheries are mainly the domain of inshore small-scale subsistence and artisanal fishers. However, as with small-scale fisheries throughout the tropics, Fiji's reef fisheries do not receive the management attention they warrant given their importance to socio-economic security and biodiversity [2].

Since the early 1990s, rising demand for fish from a growing population and the introduction and subsequent expansion of coral reef associated trades have contributed to excessive fishing pressure on Fiji's coral reefs. Of Fiji's approximately 400 *qoliqoli* (traditional fishing grounds), around 70 are over-exploited, while 250 are fully developed [3]. Many of Fiji's inshore reef fisheries are now threatened from over-fishing, destructive and illegal fishing, and pollution [4]. The decline in reef fish catches brings socio-economic hardship to Fijian coastal communities, including loss of income and diet changes [5]. Excessive removal of food fish species from coral reefs results in significant ecological changes to coral reef communities [6].

Assessment of Fiji's coral reef fisheries is challenging due to the lack of long term monitoring [3,4], which is exacerbated by a shortage of technical expertise [4]. Management of the inshore fisheries is also not a national priority and thus receives limited financial and human resources [3]. Yet, monitoring is crucial for providing data to assess the status of Fiji's reef fisheries, and for designing strategies that will enable recovery and sustainable management of fish stocks.

On a more positive note, Fiji has become a popular site for coral reef conservation driven initiatives led by various institutions, several of which conduct socio-economic surveys of marine resource use. The Fisheries Division, Fiji Locally Managed Marine Areas (FLMMA) network, and the University of the South Pacific often act as facilitators for these scattered research interests. Nevertheless, there is still an apparent lack of coordinated effort in synthesising all the accumulated knowledge and applying them to manage Fiji's inshore fisheries resource. This paper addresses this major shortcoming by bringing together information from a wide variety of sources to provide an overview of the current status of Fiji's inshore fisheries resources.

Several studies have profiled Fiji's fisheries [3,7–10], and there has been numerous site-specific studies (e.g., [5,9,11–15]). However, to our knowledge there is no national level evaluation of Fiji's reef fisheries. A comprehensive bibliography on articles related to Fiji fisheries was compiled by McDowell [16] in the early 1990s, but which is now outdated. Generally, investigations of coral reef fisheries have been geographically concentrated in southern Viti Levu, Kadavu, northern Vanua Levu, and island groups to the south-east (Fig. 1). Investigations of Fiji's coral reef fisheries have

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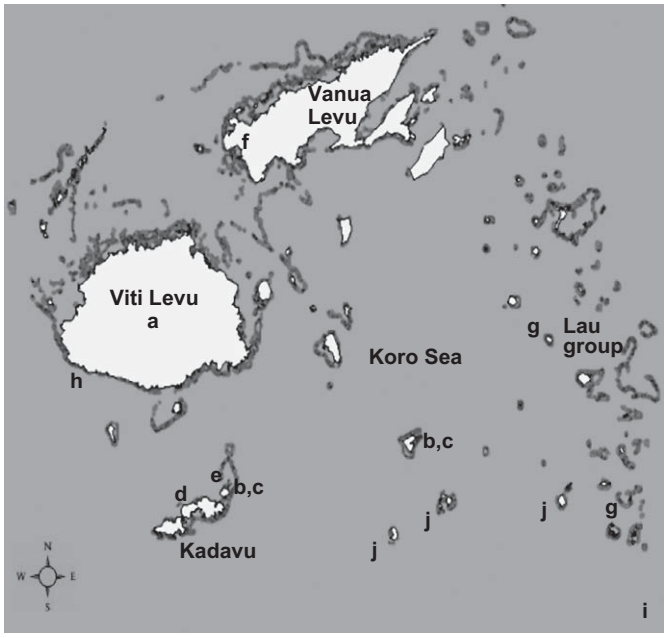

Fig. 1. Geographical coverage of coral reef fisheries related study sites: (a) Rawlinson et al. [9]; (b) Jennings and Polunin [49]; (c) Jenning and Polunin [13,14]; (d) Jennings and Polunin [78]; (e) Jennings [41]; (f) Yeeting et al. [27]; (g) Dulvy and Polunin [82]; (h) Rowlands et al. [56]; (i) Kuster et al. [17,44]; and (j) Turner [5]. *Source*: Reefbase Online GIS 〈http://www.reefbase.org〉.

covered a range of biological and socio-economic aspects (e.g., [5,13,14,17,18]). As Fiji's inshore reef fisheries are very much influenced by socio-economic drivers [5], understanding the role of societal and economic factors on fishing is critical for designing appropriate fisheries management strategies.

In order to facilitate future research and policy development, this paper provides an overview of Fiji's coral reefs fisheries, which comprises the subsistence and artisanal fishing sectors. Our objective is to bring together quantitative and qualitative data pertaining to the socio-economic, ecological, and management aspects of Fiji's reef fisheries, and evaluate the current knowledge on reef fisheries. We will identify sources of data, and highlight gaps in knowledge and suggest how future research and management may address these gaps.

1.1. Approach

Data from primary and grey literature, and online sources were used to provide background on the status of Fiji's subsistence and artisanal reef fisheries, the trade in reef resources, and the social and ecological impacts of such trades. Personal observations from two month-long field visits to Fiji added insights to current fisheries issues. The first visit consisted of secondary data collection and meetings with marine resource academics and researchers, consultants, environmental non-governmental organisations (NGOs), as well as fisheries personnel for the purpose of understanding the dynamics of the fisheries sector in Fiji. The second month long visit involved socio-economic surveys that were carried out in coastal villages, as well as interviews with coral reef resource traders at major towns.

1.2. Site description

Fiji is an archipelago made up of 844 islands, cays, and islets, of which 106 are inhabited. This group of islands is situated in the South Pacific between 15–23°S and 177–178°W, with a terrestrial area of 18 500 km^2 and a coastline of approximately 1130 km [19]. Fiji has a very large Exclusive Economic Zone, which covers 1.26 million km^2 [4]. Viti Levu and Vanua Levu are the two largest and most developed Fijian islands. Together, they make up about 87% of total land area, and are home to over 85% of the population [19]. Fiji's population in 2007 was around 860 740 [20], most of which is concentrated by the coast. The majority (56%) of the population are ethnic Fijian, while Indo-Fijians make up 36% of the population [20]. There has long been tension between populations of Indo-Fijians and native Fijians over access rights to marine resources. Native Fijians have rights to traditional tenure of all inshore resources, while Indo-Fijians have none. This tension has contributed to a series of military coups that have destabilised Fiji since 1987, and led to elevated rates of emigration, particularly of Indo-Fijians. The current population growth rate is estimated at 1.4% [19], with a negative net migration rate.

The fisheries sector is currently the third largest natural resource sector in Fiji, contributing F$92 million to GDP (F$1=US$0.55 as of January 2009), or 2.5% of total GDP [3] and in 2004 fish exports totalled F$85 million [21]. In comparison, the sugar and tourism industries, two of the main sources of foreign exchange, contributed about 8.5% and 19% to GDP, respectively [22].

2. Fiji's subsistence and artisanal reef fisheries

Fijian society has traditionally relied heavily on marine resources for subsistence and livelihoods. Fiji's coral reef fisheries are mainly the domain of subsistence and artisanal (small scale commercial) fishers. In this paper, subsistence is defined as fishing mainly to supply one's own food requirements, with the sale of fish occurring infrequently and only when there is surplus catch. Artisanal fishing is done primarily for sale, although a small portion of the catch is commonly kept for own consumption. However, in the larger more populated islands, subsistence fishing is increasingly being monetised, and there is little distinction between subsistence and artisanal fishing. In fact, a large portion of subsistence catches are supplied to municipal markets, hotels, supermarkets, fish shops, and other outlets [3]. Subsistence and artisanal fisheries comprise two of the three fisheries sub-sectors, the other being the industrial offshore fisheries which are not covered in this review. In this paper, subsistence and artisanal fisheries are collectively referred to as inshore fisheries, and this is inclusive of both finfish and invertebrate fisheries, unless otherwise specified.

Common methods for targeting reef fish are by hand line, spear, gillnet, seine net, hookah (diving with surface supplied air), and reef gleaning [9]. Small-scale pelagic fishing for the local market is carried out by trolling along the reef edge and by pole and line. The use of *duva*, a plant derived poison used to stun fish, is a traditional fishing method that is now banned and illegal under fisheries legislation. It was apparently still widely practiced in the 1990s and still occurs occasionally today (L. Teh unpublished data). Dynamite fishing, another illegal method, also occurs in Fiji, and is common in western Viti Levu [4]. In one case, fishers were able to obtain dynamite from a nearby gold mine to use for fishing, but this practice ceased when the gold mine shut down. In addition to damaging important ecological functions, dynamite fishing also incurs huge economic costs to society [23].

For the period 1981–2005, the number of registered fishing vessels operating in the inshore artisanal fishery reached a peak in 1989, with 2112 registered vessels [24]. The number of registered vessels declined thereafter, reaching a low of 727 in 2004 [25]. In 2003, it was estimated that Fiji's fisheries sector provided

employment for 2137 artisanal inshore fishers and 3000 subsistence fishers [3]. However, the true number of subsistence fishers in Fiji is largely unknown. Estimates provided by the Food and Agriculture Organisation (FAO) of the United Nations indicated that there are 30 000 subsistence fishers in Fiji [26], although it is not reported how this number was calculated. The FAO further reported that half of all rural households partake in some form of subsistence fishing [26]. Applying this approach yields over 43 000 subsistence fishers in Fiji.

Fishers who want to fish within a specific *qoliqoli* must obtain a licence from the Fisheries Department. More importantly, these outsider fishers must obtain the village chief's permission to fish within the *qoliqoli*, without which disputes may arise. In fact, the Fisheries Department seeks authorisation from respective *qoliqoli* owners before issuing fishing licences to outsider fishers. Between 1981 and 1995, the annual number of crew recorded by the Fisheries Department averaged 3964 fishers. This fell to an average of 1888 fishers between 2001 and 2004. It should be noted that the number of recorded crew include only those who have a fishing licence and do not capture the considerable number of fishers who obtain fishing permission directly from village chiefs (thereby bypassing the Fisheries Department), or those fishers who remain within their own *qoliqoli* [11]. Veitayaki et al. [11] found that the majority of fishers in northeast Macuata province (Vanua Levu) did not have a fishing licence, due to the high cost (FJ$650) of obtaining one [11]. In addition, the application process is long and tedious, requiring fishers to obtain approval from several government ministries (Fisheries official, pers. comm. 2008).

Inshore fishers fish over shallow coral reef and reef associated habitats close to shore using small, non-powered or outboard powered canoes and dinghies. Communities on outer islands fish almost exclusively over coral reefs, while in coastal villages on Viti Levu, lagoons and fringing reefs are considered the most important fishing habitats [9]. There are numerous site studies of subsistence and artisanal fishing activities which represent a good geographical coverage of both remote and more populated regions in Fiji (e.g., [5,9,11–13,15,17,27]). Subsistence fishery landings occur throughout the coastal areas in Fiji, whereas two-thirds of artisanal landings are concentrated in three main urban areas: Suva, Lautoka, and Labasa [26]. Profiles of various artisanal fisheries, including reef finfish and molluscs, can be found in Richards et al. [8]. These profiles cover the period from 1986 to 1992, and include information on catches, economic value, and stock assessments for the fisheries. The Fiji Fisheries Department is now creating an inventory of inshore marine resources in all *qoliqoli*, and routinely undertakes socio-economic and biological surveys in coastal villages.

Sea turtles have cultural value to many Fijians and have traditionally been captured and consumed as a prestige food and also as a seasonal subsistence food. Four species of sea turtles are found in Fiji—the green turtle (*Chelonia mydas*, Cheloniidae), Pacific hawksbill (*Eretmochelys imbricate*, Cheloniidae), loggerhead (*Caretta caretta*, Cheloniidae), and leatherback turtle (*Dermochelys coriacea*, Dermochelyidae), of which the green turtle is the most valued [28]. In the past 25 years, nesting populations of sea turtles have been depleted throughout the southern Pacific, including Fiji [29], where the number and total catch weights of large sea turtles have declined [28,29]. A five year moratorium banning the catch of sea turtles in Fiji was in effect until 2008; nevertheless, commercial fishing and sale of turtle meat still occurs, and limited take for cultural use is permitted [30]. Morgan [28] reported that turtle catches in one village averaged 3–4 turtles per fisher per week during the turtle seasons of October and November in 1996 and 2001. In September 2007, more than 40 sea turtles were killed for a church conference in the northern province of Macuata [31]. This event led to conflict between the conservation group working in the area and the local communities, and illustrates some of the complexities involved in managing Fiji's marine resources, where traditional customs and perspectives sometimes clash with conservation-oriented goals.

2.1. Niche market fisheries

A sub sector of the artisanal reef fishery is driven mainly by overseas demand for coral reef resources. These include the *bêche-de-mer*, trochus, live reef fish, live rock, and coral trades. The collection of live reef fish as food fish and for marine aquarium trades both spread to Fiji as stocks of these live fish diminished in other parts of Southeast Asia where they have been heavily targeted [32].

2.1.1. The invertebrate trades: bêche-de-mer and trochus

The *bêche-de-mer* trade has been operating in Fiji for over a century [33], and involves about 20 species of holothurians which are almost all collected exclusively for export [34]. This sector exhibits a 'boom and bust' cycle, with the most recent boom taking place in the mid 1980s. Due to the ease of access and lack of technological requirements[1] for fishing, participation in collecting *bêche-de-mer* is high along coastal villages, where women, children, and men are all involved. Continuous and intensive exploitation has led to localised depletion of *bêche-de-mer* stocks, as observed at some villages in southern Viti Levu and Bua province in Vanua Levu.

Similarly, trochus is an export commodity that generates supplemental income for many coastal households throughout Fiji [35]. There are five companies involved in the trochus sector, who directly export raw trochus shells and/or are involved in the downstream processing of button blanks from raw shells. Based on interviews in villages in western Viti Levu, participation in trochus gathering appeared to be on a smaller scale than *bêche-de-mer* (L. Teh unpublished data). On the other hand, a study in northeast Macuata (Vanua Levu) found that the highest participation in other fisheries besides finfish was in the trochus fishery, with 38% of fishers engaged in this fishery followed by 31% in *bêche-de-mer* [11].

2.1.2. The live reef food fish fishery

Foreign interest in setting up live reef food fish (LRFF) operations in Fiji led the Fisheries Department to initiate the fishery in 1998 as a means of generating income for local communities. Before developing the LRFF fishery, an assessment of target fish stocks was undertaken at the primary fishing grounds in Bua Province [27]. Underwater visual surveys estimated that Bua Province had an overall LRFF stock of around 3750 ton, which included around 1600 ton of squaretail grouper (*Plectropomus areolatus*), the most abundant LRFF target species.

Up to eight companies participated in the LRFF trade, but many companies subsequently withdrew from Fiji due to factors such as limited cargo space for exporting, and the high costs of operating in remote areas [36]. By 2002/2003, only two companies remained in operation. Each of these two companies employed 40 or more fishers from local villages, and used mother vessels to collect fish from locations around Vanua Levu, which were then brought to Nadi for export [36]. However, by 2008, the LRFFT was operating at only one village in Bua Province, with around 25 fishers involved in the trade (L. Teh unpublished data). Poor working relations between village fishers and the LRFF company was cited as a reason for the other company's departure.

[1] However, in some cases, collectors will use SCUBA or hookah equipment to collect *bêche-de-mer* species which live in deeper waters.

Compared to other countries, the Fiji Fisheries Department has put considerably more effort into ensuring that the LRFF fishery in Fiji is sustainable by developing a set of guidelines for the sector (see [36] for details). Nevertheless, the sustainability of LRFF target species is a management concern as interviews with local fishers suggested that spawning aggregations of *Plectropomus* spp. and other groupers are regularly fished [27], and that catches of LRFF species have declined from the past.

2.1.3. The marine aquarium trade

The marine aquarium trade includes ornamental fish, invertebrates, coral, and live rock [37]. There are five aquarium companies in Fiji; these companies operate in 25 *qoliqoli* located along the Coral Coast and islands off the Western Division [38]. Pacific island nations supply about 18% of the 3.4 million ornamental fishes that are traded annually on the international market, with Fiji alone contributing 5% [39]. Similarly, Pacific island nations supply 25% of internationally traded live corals, with Fiji supplying 4% [39]. Overall, Fiji is ranked fourth after Indonesia, China and the Philippines in the export of marine aquarium products globally [38]. Demand for live rock from Fiji in particular has grown steadily since the late 1990s [38], due to its distinctive colour, and Fiji is now one of the major global exporters of live rock. Both wild and cultured live rocks are exported. Walt Smith International, an aquarium company, was the first operator to develop cultured live rock in Fiji, and in 2004 cultured rock made up 16% of its total exported live rock production [40].

2.2. Fish catch composition

A wide variety of coral reef fish species are captured for food in Fiji, including herbivorous, carnivorous, and omnivorous families [8]. Jennings [41] reported that over 68% of the fisheries yield from a remote Fijian reef consisted of partly piscivorous fishes, mainly groupers (Serranidae) and emperors (Lethrinidae). Similarly, groupers and emperors were among the top five most frequently reported targeted species from fringing reefs around Viti Levu [9,42], with tunas and mackerels (Scombridae), snappers (Lutjanidae), and mullets (Mugilidae) making up the other main families. Important species targeted for the live reef food fish trade are the coral groupers (*Plectropomus areolatus*, *P. leopardus*, and *P. laevis*), other groupers (*Epinephelus* spp.), and humphead wrasse (*Cheilinus undulatus*, Labridae) [27], which is now illegal to catch owing to its status as an IUCN Red Listed species. Butterflyfish (Chaetodonidae), damselfish (Pomacentridae), and angelfish (Pomacanthidae) are the primary target species for the ornamental fish trade.

Fishers trolling along the reef edge often catch pelagic species such as Spanish mackerel (*Scomberomorus commerson*), dogtooth tuna (Scombridae), rainbow runners (*Elagatis bipinnulata,* Carangidae), and queenfish (*Scomberoides* spp.). Seventy to 80% of troll catches in Fiji are made up of scombrids [42]. A comprehensive summary of catch composition for Fiji's various reef fisheries can be found in Dalzell et al. [42]. Large predatory fishes still comprise the majority of reef fish catches in Fiji, with Lethrinidae, Serranidae, and Scombridae comprising 18%, 13%, and 19% of reef fish catches, respectively. This can be taken as a positive sign of the state of the fisheries [43].

Besides finfish, invertebrates are also an important target species from fringing reefs, with trochus shell (*Trochus niloticus*) and clams (*Tridacna* spp.) being the most frequently targeted species. Invertebrates accounted for 72% of artisanal catches by weight, and almost 50% of subsistence catches around Viti Levu [9]. Seaweed, lobster, mud crab, molluscs, and certain species of sea cucumbers are also important components of the subsistence fishery [8,26]. Based on creel surveys, Kuster et al. [44] found that invertebrates made up approximately 30–35% of the total catch on the island of Ono-i-Lau. Aside from their nutritional value, trochus shells are also processed locally in the production of button blanks, which are subsequently exported to be made into mother-of-pearl buttons [45]. As well, other invertebrates such as dried sea cucumbers (*bêche-de-mer*) and pearl oysters are valuable export items due to high demand from Asian markets [8,42].

2.3. Reef fisheries productivity: fish catches, yield and biomass

2.3.1. Reef fish catches

Fiji's growing local demand for fish has led to a decline in fish yields around heavily populated coastal areas [4,13]. Artisanal catches from 1996 to 2002 showed a declining trend that was attributed to high fishing pressure driven by high fish prices [46]. In contrast, Jennings and Polunin [14] found that catch rates did not vary significantly over 20 years at several remote *qoliqoli*. Zann and Vuki [47] estimated subsistence fish catches of 17 000 ton from Fiji's coral reefs annually, while Gillett and Lightfoot [48] estimated that subsistence fisheries landings were about 21 600 ton annually. The true volume of subsistence catches is uncertain due to the inadequacy of the estimation methods and the lack of monitoring mentioned earlier.

Subsistence fisheries contribute over 50% of Fiji's fishery production [48], making it the largest contributing sector to Fiji's fisheries. Together, subsistence and artisanal fisheries (i.e., inshore reef fisheries) make up 60 to 85% of the nation's catches (Table 1), thus underlining the importance of coral reefs in maintaining Fiji's fisheries and ultimately, food security.

2.3.2. Reef finfish fisheries yield and biomass

Estimates of fisheries yield from Fiji's coral reefs have been provided in several studies, the most recent being Kuster et al. [17], which found that reefs in the remote Lau island groups were able to sustain a yield of between 2.9 and 3.7 ton km^{-2} of reef fish in the years 1982 to 2002. At another remote fishing ground in the

Table 1
Annual subsistence, artisanal (finfish and non finfish), and offshore longline catches.

Year	Inshore fisheries (ton)			Offshore longline fishery (ton)	Inshore as % of total catch
	Subsistence	Artisanal	Total inshore	Offshore	
1997	17 400	5820	23 220	4256	85
1998	17 600	6813	24 413	4801	84
1999	21 600	7390	28 990	5025	85
2000	21 600	6681	28 281	11 441	71
2001	21 600	7086	28 686	12 219	70
2002	21 600	6872	28 472	16 472	63
2003	21 600	6671	28 271	12 205	70

Source: ADB 2005.

Great Astrolabe Reef, Jennings [41] found that the yield was around 0.9 ton km^{-2} in 1992/1993, while Jennings and Polunin [49] estimated that yields from six different fishing grounds ranged from 0.3 to 10.2 ton km^{-2} year^{-1}. One of the earlier estimates from the mid 1970s indicated that reef fisheries are capable of yielding 5-ton km^{-2} year^{-1} [50], and an annual sustainable finfish yield of 10 ton km^{-2} year^{-1} was estimated by Russ [51]. Overall, Fijian yield estimates correspond with those from other South Pacific reef fisheries [42]. Craig et al. [52] recently calculated reef fisheries yield of 2.3 ton km^{-2} year^{-1} in American Samoa.

Several studies have used underwater visual census to assess the abundance of target reef fishes [27,49,53–56]. Jennings and Polunin [14] estimated and compared the biomass of target species in six different *qoliqoli* subject to different fishing effort. Yeeting et al. [27] assessed stock potential for the live reef fish trade in Bua Province, where the trade is centred. They estimated that the mean biomass ($\pm$standard error) of live reef food fish species in the province was 8.7 $\pm$ 4.4 kg 1000 m^{-2}, which translated to a mean stock of 3750 $\pm$ 1610 ton. The stock of squaretail coral grouper (*Plectropomus areolatus*), the most abundant live food fish species, was around 1600 ton. In a regional context, Fiji's reef fish biomass falls in the low end of biomass estimates from other mid Pacific reefs, where the average biomass was 110 and 300 ton km^{-2} for 'fished' and 'lightly fished' reefs, respectively [52]. However, such direct comparisons must be viewed cautiously in light of differences in the types of fishes that were estimated, as well as underlying habitat and productivity differences.

2.4. Catch rates and catch per unit effort (CPUE)

In a survey of catch rates for fishers in Viti Levu, gill netting on fringing reefs had the highest catch rate at 5.7 kg h^{-1} [9]. Similarly, in a compilation of catch rates for reef species in Fiji, gillnet fishing had the highest CPUE, yielding mean catches of 19–32 kg set^{-1} [42] (Table 2). In contrast, spear fishing had the lowest CPUE, with mean catches of 1.2–1.5 kg fisher^{-1} h^{-1} (Table 2). A more recent study carried out at the isolated Lau group of islands estimated CPUE for spear fishing to be 2.1 $\pm$ 0.3 kg fisher^{-1} h^{-1} (mean $\pm$ standard error), while it was 1.4 $\pm$ 0.3 kg fisher^{-1} h^{-1} for hand lining [44] (Table 2). The CPUE for hand line is substantially lower than the mean hand line catch rate recorded a decade earlier by Dalzell et al. [42] (2.3 kg line^{-1} h^{-1}). However, the real extent of the decline, if at all, is inconclusive, as the catch rates were recorded at different locations and targeted slightly different reef species. The mean catch rates recorded for the Fijian spear and hand line fisheries are comparable to those for shallow reef species in other South Pacific fisheries [42].

2.5. Socio-economic aspects of Fiji's reef fisheries

Fish is an important source of nutrition-depending on village location, fish consumption ranges between 187 g person^{-1} day^{-1} for urban areas [9], to 260–270 g person^{-1} day^{-1} [44] and 280–470 g person^{-1} day^{-1} at smaller outer islands. Estimates of annual Fijian fish consumption ranged from about 40 kg capita^{-1} year^{-1} [4] to 56 kg capita^{-1} year^{-1}, of which 46% was supplied by the subsistence fishery [48]. Interestingly, a recent study indicates that a decline in fish consumption was associated with households of better economic status [5].

A survey in the mid 1990s found about 91% of Fijian households located in coastal villages on the main island of Viti Levu were involved in fishing [9]. Thirty five percent of these households fished for subsistence, while 64% fished mainly for artisanal purposes. Similarly, on the outer islands, 40% and 57% of fishing was done for subsistence and artisanal purposes, respectively [9]. Jennings and Polunin[13] found that on the outer islands of Viti Levu, 12.5–50% of total catch was sold, while 54% of Fijian households in coastal communities in Viti Levu sold marine products [9]. On the other hand, Yeeting et al. [27] reported that most fishers in the remote area of Bua Province on Vanua Levu did not sell their catch at all. Similarly, in the Lau Islands, another remote region, fish is primarily consumed locally [5]. When broken down by ethnicity, there is a distinct difference between native Fijian and Indian fishing households. Fijians not only fished more regularly (87% versus 31% of Indians) [9], but also tended to catch their own food whereas Indians bought most of the marine products they consumed [9]. Generally, all fishers can be considered to be at least partial subsistence fishers as even those who fish primarily to sell tend to keep aside some fish for home consumption.

In spite of the high involvement in fishing, its economic significance varies from household to household. Interviews carried out with villagers in the Lau Islands revealed that even though 80–100% of all households reported that they were engaged in fishing, fishing was actually considered of low importance compared to other occupations [5]. On the other hand, another study conducted in northeast Macuata found that fishing supplied households with 59% of their income [11]. The different emphasis on fishing likely exists due to fishers' access to

Table 2
Catch per unit effort (CPUE) by gear in Fiji.

Fishery	Main target families	Mean ($\pm$ s.e.)	Range	Reference
Invertebrates	Holothuroidea	16 pieces h^{-1}	12–20 pieces h^{-1}	[42]
Hand line	Lethrinidae, Lutjanidae, Serranidae, Carangidae	2.27 kg line^{-1} h^{-1}	0.14–12.12 kg line^{-1} h^{-1}	[42]
Hand line	Serranidae, Sphyraenidae, Carangidae		0.33–0.47 kg h^{-1}	[9]
	Lethrinidae, Acanthuridae, Scaridae, Serranidae	1.41 $\pm$ 0.31 kg fisher^{-1} h^{-1}		[44]
Hand line and spear	Unspecified reef fish	1.25 kg h^{-1}	1.20–1.29 kg h^{-1}	[13,14]
Spear	Serranidae, Acanthuridae, Lutjanidae, Carangidae	1.20 kg man^{-1} h^{-1}	0.81–1.6 kg man^{-1} h^{-1}	[42]
	Lethrinidae, Lutjanidae, Serranidae, Scombridae	1.51 kg man^{-1} h^{-1}	0.12–5.7 kg man^{-1} h^{-1}	
Spear	Serranidae, Lethrniade		1.72–4.05 kg h^{-1}	[9]
	Lethrinidae, Acanthuridae, Scaridae, Serranidae	2.07 $\pm$ 0.31 kg fisher^{-1} h^{-1}		[44]
Gillnet	Mugilidae, Carangidae, Leiognathidae		0.53–5.65 kg h^{-1}	[9]
	Lethrinidae	18.9 kg set^{-1}	15–26 kg set^{-1}	[42]
	Lutjanidae, Mugilidae, Holocentridae	31.8 kg set^{-1}	10–60 kg set^{-1}	

markets to sell their fish. Nevertheless, it was found that fishing is pursued by most households due to the immediate financial benefits it provides compared to planting crops, which requires waiting longer before financial returns can be realised. Fishing thus appears not to play the same role within the livelihood strategies of fishing households, a matter that should be surveyed more thoroughly in an attempt to assess the socio-economic importance of reef fisheries to coastal communities.

Women play an important role in Fijian fisheries, as they undertake a substantial portion of household subsistence fishing [57–59] by collecting shellfish and other invertebrates, which constitute an important part of coastal villagers' diets. Subsistence fishing by women is not normally accounted for in official statistics. Yet, their catch contributes significantly to food security and increasingly, to providing income, for the household [57,58]. Detailed descriptions about the fishing practices and roles of women in Fijian fisheries can be found in Vunisea [60]. As well, the SPC publishes a "Women in Fisheries Information Bulletin", which is an up to date and useful source of information covering the Pacific islands.

2.5.1. Economic value and trade of finfish and non-finfish

Increasing local and foreign market demand for fish has led fishing in Fiji to become more commercialised. At the same time, the Fiji Fisheries Department has focused more on product development rather than resource management of inshore fisheries [3]. Both these factors have expanded opportunities for fishers to sell their catch. Fishers have several options for selling their fish, including: (1) direct to consumers at the wharf; (2) to middlemen at the wharf; (3) direct to consumers from road side stalls; (4) direct to consumers at municipal markets; and (5) direct to hotels, restaurants and shops [61]. Alternatively, fishers may sell their catch to a fishing cooperative in villages where these are established [1]. The method of sale impacts the profit to the fisher, and is an issue to be considered when conducting economic analysis of artisanal fisheries. Income for fishers at small offshore islands ranged from F$90 to F$600 person^{-1} year^{-1}, depending on the proportion of catch that was sold for consumption outside the *qoliqoli* [13]. Meanwhile, weekly income for artisanal fishers around Viti Levu was F$34 [9], or approximately F$1770 year^{-1}. More recent studies show that fishing incomes have increased across Fiji, although it is important to take into consideration annual average inflation, which has ranged from 0.8% to 4.8% in the past decade [20]. In a study covering Viti Levu, Vanua Levu, Yasawa islands and Kadavu, average net fishing income for subsistence fishers who occasionally sold their catch ranged from F$96 to F$175 person^{-1} week^{-1}, while artisanal fishers earned between F$217 to F$327 person^{-1} week^{-1} (L. Teh unpublished data). Veitayaki et al. [11] found that income from artisanal fishing averaged F$470 household^{-1} month^{-1} in four villages in Macuata province. In Muaivusa Peninsula near Suva, income from the sale of fish and invertebrates was considerably higher, at F$613 household^{-1} month^{-1} [12].

It has been shown that the largely undocumented economic contribution of small-scale fisheries in other Pacific island nations has been underestimated by a factor of 5 [62]. There are limited economic valuations of Fiji's small-scale reef fisheries, yet these fisheries undoubtedly make a significant economic contribution to coastal communities in Fiji. O'Garra [12] does conduct an economic valuation for inshore fisheries, but the geographical coverage is limited to one *qoliqoli*. Using a 5% discount rate, O'Garra estimated that the Net Present Value for fisheries from Navakavu *qoliqoli* was F$11.8 million over a 10 year period.

In 2003, Fiji's subsistence fishery was estimated to contribute F$48.6 million to total GDP, while the inshore artisanal sector contributed F$27.6 million [3]. The Fiji Fisheries Department used 'value to consumer' as a measure of the subsistence fishery's economic value, estimating it to be US$7.2 million in 2003 [34]. Another study by Dalzell et al. [42] valued 16 600 metric tonnes of subsistence fisheries production at US$45.8 million,[2] while the total value of Fiji's inshore artisanal and subsistence fisheries was US$64 million. An earlier estimate reported that Fiji's subsistence and artisanal sectors were worth F$50 million to F$60 million [48]. Overall, given limited resources available for government monitoring of Fiji's inshore fisheries, it is likely that the economic significance of this sector is substantially underestimated. Gillett and Lightfoot's [48] re-estimation of fisheries contribution to Fiji's GDP was 34% higher than that calculated by the Fijian government.

Fiji's *bêche-de-mer* sector began as a small industry producing between 20 and 30 ton year^{-1} [63], with exports never exceeding 50 ton until the mid 1980s, when annual production started to rise. In 1988, exports experienced a surge and reached a peak at over 700 ton, which translated to a fresh weight of close to 10 000 ton [64]. Following this peak, *bêche-de-mer* exports declined by up to one half, to between 300 and 400 ton year^{-1} [65], and in 2003, *bêche-de-mer* exports were at 295 ton with an associated export value of F$8.4 million [34].

According to an estimate of worldwide trochus harvest in the early 1990s, almost 60% of the world's production came from the Pacific Islands, of which Fiji's contribution was approximately 15%, or 271 ton year^{-1} [45]. Steady decline in trochus harvest saw annual exports in 2001 drop to around 153 ton[3] [66]. The decline is consistent with the view of an established trochus exporter, who indicated that current quantities of harvested trochus had fallen roughly by half from 15 to 20 years ago.

In the live reef food fish (LRFF) sector, 21 250 kg of live fish valued at F$1.1 million were exported in 2003 by two companies active in the live reef food fish trade [36]. By 2004, the single remaining company exported 5100 kg of live fish valued at about F$255 000 [36]. That same year, total free on board (FOB, i.e., exporters' price) value of ornamental fish and invertebrates was F$1.8 million [38], while live rock and coral products exports from Fiji were about F$4.4 million [38]. This gave Fiji's export oriented live fish fisheries a value of almost F$6.5 million. On the other hand, another report valued aquarium fish exports at F$1.5 million, while live rock and live coral exports were individually valued at F$8 million and F$4.5 million, respectively [3]. In 2001, 311 097 aquarium fish were exported from Fiji, according to the Fisheries Department's annual estimate [67], while the Convention on International Trade of Endangered Species (CITES) database recorded that 169 143 ornamental fish and 31 900 invertebrates were exported from Fiji in 2004 to overseas markets. The Fisheries Department's export estimates are inconsistent with exporters' own estimates, which has prompted some authors to question the Department's methodology in tracking export statistics [67].

There is relatively more coverage of Fiji's aquarium coral trade compared to its aquarium ornamental fish trade. CITES tracks live coral exports from Fiji [68]. Table 3 was extracted from the CITES database in July 2005 and lists aquarium organisms supplied by Fiji to markets mainly in the US, Hong Kong, Japan, and Europe. Between 2000 and 2004, annual live rock exports from Fiji increased steadily from 800 000 kg in 2000 to 1.3 million kg in

[2] In 1996, the average exchange rate was US$1=F$1.4 (source: 〈http://www.oanda.com/convert/fxhistory〉).

[3] Total trochus exports is calculated as the total of trochus shells (105.86 ton), trochus shell scrap (13 ton), and trochus button blanks (6.8 million pieces). A conversion rate of 200 pieces button blanks per 1 kg of trochus was used based on information from a trochus industry operator.

Table 3
Fiji reef resource exports, 2004.

Reef resource	Pieces/no. of individuals
Hard and soft coral	161 927
Live rock	1 360 000
Ornamental fish	169 143
Invertebrate items	31 900

Source: Lal and Ceralala [38].

2004 [38], while live coral (hard and soft) exports ranged between 60 000 and 92 000 kg during the same time period [38].

Surveys are carried out at municipal fish markets, hotels, and roadside stalls to monitor fish catches and sales from the artisanal sector. Data on commercial (artisanal) sales of major reef fish families (emperor, parrotfish, groupers, surgeonfish, and snappers), *bêche-de-mer*, lobsters, and trochus from the mid 1980s to early 1990s are available in Richards et al. [8], and for earlier years in Cook [7]. Fish are graded into classes A, B, and C, and typically sold in bundles ranging from 1 fish to more than 15 fish depending on fish size, at prices of F$10 to F$15 per bundle. Emperors are one of the most important inshore reef fish species, and are one of the most highly prized food fishes in Fiji, with an average landed price of around F$3.50 to F$4 kg^{-1}. The most valuable fish are those species targeted for the LRFF trade, where the most heavily targeted leopard coral grouper (*Plectropomus leopardus*) fetches a price of F$8 kg^{-1} (L.Teh unpublished data). However, on an international scale, Fijian fishers get comparatively lower prices for their live reef fish catch. For example, fishers in Malaysia can earn up to F$20 kg^{-1} for the sale of leopard coral grouper. Nevertheless, LRFF fishers in Fiji can earn between F$300 and F$700 per week [36], compared to F$34 for artisanal fishers in Viti Levu [9].

Coral reef fish are also valuable when left in the ocean and not harvested, as they are an important generator of dive and tourism revenues. In Fiji, recreational benefits arising from coral reefs, lagoons, and beaches were estimated at F$336 million (in 1994 prices) [69].

2.6. Ecological effects of exploiting coral reef resources

There is general consensus that reef fish catches in Fiji have decreased [2], so much so that some communities actively asked Fisheries officers to help them set up their own marine reserves (L. Teh, personal observation). Reef fish stocks near main population centres have been under heavy fishing pressure since the early to mid-1980s [70,71], although the rural areas were still not overfished at that time. However, local depletion of species such as mullet (Mullidae), rabbitfish (Siganidae), coral grouper, and bumphead parrotfish (*Bolbometapon muricatum*), have been recorded since the early 1990s [8]. At the same time, catches of emperors were declining, and stocks possibly over-exploited in the late 1980s and early1990 s. Since then, the live reef food fish trade has increased fishing pressure on vulnerable grouper stocks as well as humphead wrasse [32,72].

Invertebrates are over-fished in many Fijian reefs. A survey by the Fiji Fisheries Department covering 1984–1988 showed that giant clams in most parts of Fiji had already been harvested beyond sustainable levels [4,73], and the giant clam *Tridacna gigas* has likely been driven to extinction in Fiji [74]. Stocks of *bêche-de-mer* have declined throughout Fiji, especially the main target species of *Holothuria fuscogilva*, *Holothuria scabra*, and *Holothuria nobilis* [8]. In fact, concerns about the sustainability of sea cucumber exploitation in Fiji were raised as early as 1990 [75], and they are now considered overfished [76]. Fiji's pearl oyster (*Pinctada margaritifera*) stocks are also considered to be depleted due to a combination of terrestrial based pollution and fishing pressure [73]. Trochus (*Trochus niloticus*) are vulnerable to overexploitation due to the ease of collecting them, and it is believed that recruitment overfishing, followed by a decline in major stocks of trochus may have occurred at some intensely fished reefs during the mid 1980s and early 1990s [8]. Further information about stock status for invertebrate and other reef finfish are provided in Richards et al. [8].

Fishing on coral reefs directly affects target species, and it also leads to indirect effects on non-target species and reef habitats [6]. A comprehensive coverage of these ecological effects can be found in [77]. In Fiji, Jennings and Polunin [14] examined the impact that different levels of fishing intensity (measured as the number of persons per kilometre of reef front) had on the structure of reef fish communities, and found that removal of 5% of fish biomass annually by fishing may cause significant changes in reef fish communities. Higher fishing intensity correlated significantly with lower biomass of piscivorous fish [78], and was also associated with lower average fish weight and sizes [79]. Graham et al. [80] showed that increasing fishing pressure resulted in a decline in abundance of all size classes of fish in the coral reef fish assemblage. As well, Jennings and Polunin [78] found that the biomass of piscivorous fish was lower at more intensely fished *qoliqoli*. Dulvy et al. [81] indicated that the removal of important predatory species may indirectly affect coral reef ecosystem structure and function. On the other hand, Jennings and Polunin [78] found that predation by piscivorous fishes did not appear to play a significant role in structuring Fijian reef fish communities.

In the mid 1990s, yields of up to 10.2 ton km^{-2} and comprised mainly of carnivorous species were recorded in *qoliqoli* south-east of Viti Levu [49]. Moreover, fishers at these *qoliqoli* had not shifted fishing effort towards the lower trophic level fish species indicative of more depleted fisheries [43,51]. However, recent reports suggest that certain commercially important species in other inshore areas have been overexploited [26]. Surveys in the Coral Coast (Viti Levu) indicated that many commercially important fish families such as groupers and emperors appeared to be growth overfished [56]. At the Great Astrolabe Reef, one of Fiji's more pristine reefs and site of a long term monitoring programme, permanent reef transects that have been surveyed since 1989 showed that marine invertebrates and finfish have declined, likely due to commercial harvesting [4]. There is also evidence that bumphead parrotfish, which were once abundant around the Lau islands, are now extremely rare [82]. The same situation exists for humphead wrasse [72]. Fortunately, humphead wrasses are now protected as an IUCN Red Listed species, and trade in humphead wrasse is prohibited in Fiji. Nevertheless, with expanding demand for inshore fisheries resources, it is likely that more reef fish populations will come under threat.

Collection of reef organisms for the marine aquarium trade has negatively affected the coral reef ecosystem. A pilot study using underwater visual surveys carried out to assess the effect of aquarium fish collection found that sites where fish were collected had lower fish populations than sites where there was no collection [83]. Since 1998, it is estimated that an average of 35 ha of fringing reef (equivalent to 50 rugby pitches) had been mined annually to supply live rock for export [40]. Further, harvesting live rock may reduce fish biodiversity and abundance [84]. Underwater pictures taken at live rock collection sites along Fiji's Coral Coast showed that with the exception of brown seaweeds, mined areas were barren of other marine life inshore [40]. The authors also found that un-mined areas had higher diversity and longevity of corals, and richer fish populations than

at live rock collection sites. Reefs that were harvested for live rock also displayed higher levels of algae and lower levels of coral growth [56].

On top of direct human impacts, indirect impacts arising from climate change and ocean acidification also pose survival threats to coral reefs [85]. The serious consequences these phenomena hold for food security and economic stability highlight the inseparability of managing people and resources on local and regional scales if overall ecosystem health and resilience is to be achieved.

3. Management of reef fisheries

3.1. Inshore fisheries governance

Traditionally, Fijian and other Pacific Island communities managed their coastal resources by applying customary practices such as temporary no take areas and seasonal bans on using certain gear or taking certain species [18,86,87]. These strategies enabled communities to protect their food sources, and are based on a community marine tenure system whereby *qoliqoli* are used and controlled by adjacent coastal communities. In many parts of Fiji, reef fisheries are still managed under a traditional marine tenure system, which is recognised by the government [86].

Traditional users also hold certain powers and privileges in controlling access to their customary fishing grounds. Often, permission from the village chief has to be obtained before fishing is permitted [18]. Village chiefs also have the authority to impose policies such as prohibiting fishing on Sundays, banning the take of certain species, and banning the use of certain fishing gears such as gillnets and SCUBA diving equipment for spear fishing [88]. In 1990, village chiefs in Macuata province banned commercial gillnet fishing due to the negative impacts it was thought to be having on subsistence fisheries [89]. This ban was supported by the government although it was technically illegal, as ownership of all resources and the seabed rightfully belong to the government.

Companies that collect marine aquarium products from traditional fishing grounds make a goodwill payment to the *qoliqoli* chief in exchange for permission to fish. This amount varies widely, and some villages actually undercharge given the high income that fishers could derive from accessing the *qoliqoli* resources [13].

In the past, compliance with the traditional system was enforced through a system of retribution [90]. More recently, there have been instances of customary marine area owners confronting outside fishers and tourist operators who were considered to be abusing their marine resources [90]. Some customary marine area owners employ fish wardens to patrol and enforce their marine territory. Consequently, it appears that in some cases, customary marine ownership is conducive to some extent in protecting coastal reef resources. However, in reefs close to urban areas such as Viti Levu, traditional practices have eroded and might no longer exist [13,91]. Overall, the Fijian government plays a limited role in managing inshore reef fisheries [18], but it retains ownership over the seabed, including titles to *qoliqoli*. There is, however, a proposed law that will see the Fijian government return ownership of customary fishing areas and their adjacent land to traditional owners of those fishing grounds [3].

The sustainability of the marine aquarium trade is a definite concern in Fiji, and numerous studies have been conducted to establish baseline ecological and trade data, and assess the impact of extracting coral reef resources (e.g., [37,40,83,92]). Coral and live rock exports in Fiji are subject to CITES regulations, and there is a quota system in place for operators involved in the trades. In 2002, Fiji was reprimanded by the CITES Secretariat for having insufficient legislation to implement CITES, which the government responded to by passing legislation to implement CITES at the national level in 2003. However, there have been ongoing concerns about the quality of quota enforcement as well as about under-reporting within the industry to meet export quota limits.

There is a movement by NGOs to encourage coral and live rock culture as an alternative to harvesting from the wild, although it is not known at this stage whether cultured coral is a financially viable option for rural communities [38].

3.2. Fisheries monitoring

Recently, the Fisheries Department started to monitor fish landings at selected fishing communities with the help of village-based fish wardens. The Fisheries Department does track the volume of landed fish at select municipal and non-municipal market outlets in Fiji, which allows an approximation of fish catches from the artisanal sector. However, the subsistence sector is almost completely unaccounted for, with very little data pertaining to subsistence fishing effort, fish landings, and fishing grounds.

The Fisheries Department is generally considered to be underestimating subsistence fisheries landings [3]. This is due to a statistical method whereby each year's production is based on a 1979 survey which was not representative of fishing households—every year since then, the annual subsistence catch has been estimated by merely adding 200 metric tonnes each year to the questionable 1979 figure. Even where subsistence estimates have been made, Raj and Evans [46] pointed out that these were likely inaccurate as it is difficult to obtain data when fish are consumed close to the point of capture. Community based monitoring is starting to address this problem to some extent, through programmes set up by the Fiji Locally Managed Marine Areas (LMMA) network and some NGOs.

3.3. Fisheries legislation

The Fijian Fisheries Act (Chapter 158, Section 9) is the legislation that makes provisions for fisheries in Fiji. However, it provides no guidelines on resource management aside from denoting the protection of native customary rights owners [93]. Instead, the Act focuses on regulating licences and registrations, mesh sizes, prohibited methods and areas, fish size limits, and applications for licences [94]. Nevertheless, there is limited awareness of these regulations among rural coastal communities, and despite the presence of designated fish wardens who enforce fisheries regulations, many communities still operate according to traditional systems that govern subsistence fishing by setting closed seasons for certain species or declaring certain fishing areas as *tabus* (i.e., no-take areas) [94].

The second piece of Fijian legislation which is relevant to fisheries management is the Marine Spaces Act, which defines the 200 mile Exclusive Economic Zone. Although the provisions of this act are generally stricter than the Fisheries Act in controlling fishers, it is directed largely towards activities of foreign and industrial fisheries rather than local inshore fisheries [95]. A recent assessment of Fiji's fisheries regulations found that management response to Fiji's dynamic reef fisheries is slow, and misdirected at increasing production rather than resource conservation and protection [3]. The lack of management plans to guide inshore fisheries development and Fiji's outdated fisheries policies were also noted. In particular, there is consensus that the Fisheries Act is antiquated and its lenient penalties for offences

like dynamite fishing fail to properly protect fisheries resources and fishers in Fiji [96].

3.4. Locally managed marine areas (LMMAS)

In response to the deterioration of inshore fisheries and the shortcomings of the Fisheries Act, some communities have rediscovered and implemented a form of customary marine management—LMMAs [90,97], which are aimed at restoring depleted fish or invertebrate stocks. Currently, there are 205 LMMA sites in 116 *qoliqolis*, covering an area of approximately 8425 km^2. Veitayaki et al. [93] provide a comprehensive overview of the principles, goals, and successes of LMMAs in Fiji, while the LMMA Network website (〈http://www.lmmanetwork.org〉) serves as a central information centre for LMMAs throughout the Pacific and Southeast Asia region.

The LMMA network in Fiji is made up of 275 participating villages and 18 partner organisations, including government departments, regional bodies such as the Secretariat of the Pacific Community (SPC), conservation NGOs, and the University of the South Pacific. Projects involving locally managed marine areas are carried out by this partnership in areas where there is interest in community based conservation. The LMMA approach has been in use in Fiji for over a decade, having been applied for the first time in Ucunivanua (Viti Levu) in the early 1990s to recover clam stocks [98]. Recovery of local clam stocks in Ucunivanua also resulted in increased village incomes [97]. Similar outcomes in increased incomes, fish and invertebrate sizes and abundance after the establishment of no-take areas have been documented in the Yavusa Navakavu LMMA near Suva [15]. At the same time, however, some concerns have been raised over the length of LMMA closures [15].

4. Discussion and concluding remarks

The aim of this paper was to gain a better understanding of the socio-economic and ecological characteristics of the reef based subsistence and artisanal fisheries in Fiji. Generally, reefs removed from main population centres appeared capable of sustaining relatively high finfish yields [49], and supported coral reef fish populations that were generally found to be not over-fished [13,17]. However, even in rural areas, villagers are increasing exploitation of marine resources to meet the demands of an economy increasingly focused on monetary goods and services [1]. This demand stems from the market for live fish, subsistence requirement, growing fish demand from urban centres [13], and, when stabilised, a sizeable tourism industry. These can have far reaching economic and social impacts on all parts of Fijian society, and there is therefore a need to understand and quantify these impacts.

In comparison, many invertebrate species are already depleted, to the extent that two species of giant clams are extinct due to overexploitation [4]. Anecdotal evidence suggests that *bêche-de-mer* have declined in certain parts of Fiji by as much as three times since the early 1980s (L. Teh unpublished data), and that the industry is in the 'bust' phase of a boom and bust cycle. These indications imply that invertebrates may be more seriously depleted than fish populations, a condition brought about by easy accessibility to fishing from shore and an established and lucrative overseas market for *bêche-de-mer*.

Our review revealed that reefs located in different parts of Fiji are subject to different degrees of fishing pressure, leading to a wide variation in the condition of reef fisheries. This extends also to fishing communities' reliance on reef resources–coastal communities display diverse livelihood strategies that are influenced by the availability of economic opportunities other than fishing [5]. Furthermore, previous studies have shown that fishing intensity is related to the fishing activity and behaviour of fishers [49,54]. Ultimately, this means that socio-economic conditions have a bearing on the ecological health of reef resources [99], yet this association is seldom studied. Further research in this topic is warranted, as it can provide insights for management objectives such as designing appropriate alternative livelihood strategies to deal with fishing overcapacity.

It also appears that coastal communities pay more attention to customary marine resource use practices than national fisheries regulations. In this regard, government can uphold and strengthen customary marine practices in areas where these are still actively adhered to, or create a legislative framework for incorporating traditional practices as extensions of federally mandated fisheries management tools in areas where customary marine practices have lapsed. For example, the creation, implementation, and monitoring of *tabu* areas can be standardised as a type of marine protected area. As it stands, Fiji's Fisheries Act is too weak to uphold fisheries regulations and management capacity. This shortcoming is widely recognised and steps are underway to change it. A positive outcome has been the success of LMMAs, and as suggested by other researchers, it may be beneficial for the government to institutionalise this framework [3].

In the Indo-Pacific, the live reef fish trade has become one of the main threats to the sustainability of target reef fish species (e.g., [27,32]). Authorities in Fiji appear to have taken precautionary action in managing the live reef food fish trade in Fiji [36]. Nevertheless, economic benefits derived from the live reef fish trade have not been adequately evaluated [36], and it remains unclear how the live reef food fish trade will ultimately impact Fiji's coastal communities and fisheries resources. The use of cyanide for capturing live fish for the global marine aquarium and live reef food fish trade is widely implicated for destroying reefs [100], and this practice occurs in Fiji as well. At the same time, exporting live rock for the aquarium trade may emerge as the bigger threat as it not only destroys coral growth but also degrades fish habitat. In addition, Fiji is the largest global exporter of live rock to the lucrative United States market [68]. This may have already led to the collection of unsustainable volumes, which threaten Fiji's coral reef ecosystems.

Focus should be placed on cost studies related to the economics of artisanal inshore fisheries in Fiji. To our knowledge, only a limited number of economic analyses have been carried out [12,38,61,101,102]. Data gaps on this topic include assessments of the potential benefits associated with small-scale reef fisheries, who will benefit, and how these benefits will affect current socio-economic and ecological conditions.

Due to the government's methodology of calculating subsistence catches, it is widely recognised that the official statistics are likely misrepresentative of the real subsistence catch. There are no reliable time series of subsistence catch volume and value, although point estimates are available in publications (e.g., [17,49]), and these can be used as anchor points in reconstructing past catches for these fisheries. In this regard, in-depth socio-economic surveys and/or interviews can supply time series information to substantiate how present fishing conditions compare to those of past years.

Previous published and grey literature provides us with a fairly good understanding about the general characteristics of Fiji's subsistence and artisanal reef fisheries. It appears that various NGOs, along with the Fisheries Department, are currently conducting periodic surveys of the inshore fisheries of *qoliqoli* throughout Fiji. Collaborative work of this type is a positive sign for tackling the data problems in the subsistence fisheries. At the same time, it is of utmost importance that the various agencies

disseminate and share the results of their studies and monitoring activities. Ideally, this can be done by having a central depository where all ongoing or unpublished studies and/or socio-economic surveys of reef resource use can be collected. Ultimately, inter-agency collaboration can produce a comprehensive review of the various individual surveys that have taken place, so as to provide collective knowledge, which can then be applied towards assessing the status of Fiji's reef fisheries on a national level.

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