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Review Article
An Overview of Sea Cucumber Fishery Management in the Fiji Islands

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Abstract
The Fijian sea cucumber fishery began in the early 1800's in response to demand from Asian markets for bêche-de-mer. The fishery has shown classic 'boom and bust' production cycles for much of its life. From 1984-2012 a total of 8,620 t of bêche-de-mer were exported from Fiji. Particularly large volumes were exported in 1987 (>600 t), 1988 (>700 t) and 1996 (>600 t) and declines in export volumes are notable following these peaks. Subsequent export peaks of around 400 t in 2005 and 2011, are considerably lower than those in the 1980s and 1990s and after 2005, annual exports averaged 243 t. Between 2003 and 2012 export volumes of high value species declined from 14-8%, while that of medium value species increased from 50-59%. Sandfish (*Holothuria scabra*) appeared on export manifests in 2003 and 2004 despite an export moratorium for this species. Despite numerous recommendations to improved sustainability of the Fijian sea cucumber fishery, management measures consist primarily of an export size limit of 7.62 cm for bêche-de-mer. Over-exploitation of the resource and declining sea cucumber stocks have resulted. A historic overview of the Fijian sea cucumber fishery was provided within the context of the various fishery management approached adopted by other South Pacific Island nations. It includes data gathered by interviews with sea cucumber fishermen, bêche-de-mer processors and other stakeholders and makes recommendations for an effective management plan for a fishery that is an important livelihood activity for coastal communities in Fiji.

Key words: Sea cucumber, fishery, management, Fiji Islands, bêche-de-mer

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sea cucumbers provide a vital source of income for fishing communities in most coastal areas of the Fiji Islands where at least 28 species are harvested commercially (Purcell *et al*., 2012b) (Table 1). Sea cucumbers are collected by walking or wading at low tide and by swimming, snorkelling or free-diving in shallow water to depths of 10 m. They are collected from deeper water using SCUBA or hookah equipment or through the use of a 'dri-bomb' composed of a roped, weighted, metal (lead) spike that can be dropped from a boat to spear sea cucumbers in depths of 30-50 m. Although, the use of SCUBA by fishermen is prohibited by the existing Fisheries Regulation in 1997 that states "no person shall in any way collect, take, or dive for fish (sea cucumber) using underwater breathing apparatus; be in possession of underwater breathing apparatus for the purpose of collecting, catching and diving for fish (sea cucumber)", there is ready provision for fishers to obtain exemption from this regulation. The main targets of this fishery are high value species from the genera Holothuria and Actinopyga, such as *Holothuria fuscogilva* (white teatfish) and *H. whitmaei* (black teatfish), and the very high value species *H. scabra* (sandfish). Sea cucumbers are processed and dried to become bêche-de-mer (Adams, 1992; Conand, 1994; Carleton *et al*., 2013b) which are traded into South-East Asian markets (Purcell, 2014) where well-dried 'A' grade product may fetch around $US70-190 per kilogram depending on size and quality (Purcell *et al*., 2012a, b; Eriksson and Clarke, 2015). Bêche-de-mer are regarded as a vital food source for South-East Asian peoples because of their nutritional properties and perceived medicinal benefits. Bêche-de-mer are rich in protein, vitamins, polysaccharides and essential minerals, and important chemicals such as saponins, that reputedly assist in wound healing and have anti-aging and aphrodisiac properties (Bordbar *et al*., 2011; Chen *et al*., 2011; Liu *et al*., 2011; Esmat *et al*., 2013).

Bêche-de-mer processing involves an uncomplicated sequence of steps resulting in a product that is non-perishable if stored in dry, dark conditions (Ram *et al*., 2014a-c). Post-harvest steps incorporate first boiling, slitting and gutting, second boiling, smoking and finally solar drying

Table 1: Sea cucumber species harvested from Fiji Islands

Trade name	Species	Local name	Value group*
Amberfish	*Thelenota anax*	Basi	M
Brown curryfish	*Stichopus vastus*	Laulevu	L
Hairy blackfish	*Actinopyga miliaris*	Dri, driloa	M
Brown sandfish	*Bohadschia vitiensis*	Vula	M
Black teatfish	*Holothuria whitmaei*	Loaloa	H
Curryfish	*Stichopus herrmanni*	kari, lakolako ni qio	M
Chalkfish	*Bohadschia marmorata*	Mundra	M
Deepwater blackfish	*Actinopyga palauensis*	Dri ni cakau	M
Spiky deepwater redfish	*Actinopyga* sp. *affn. flammea*	Tarasea	H
Deepwater redfish	*Actinopyga echinites*	Tarasea	H
Elephant trunkfish	*Holothuria fuscopunctata*	Tinani dairo, dairo ni toba	L
Flowerfish	*Pearsonothuria graeffei*	Senikau	M
Greenfish	*Stichopus chloronotus*	barasi	H
Golden sandfish	*Holothuria lessoni*	Dairo kula	VH
Lollyfish	*Holothuria atra*	Loliloli	L
Loli's mother	*Holothuria coronopertusa*	Tina ni loli	L
Pinkfish	*Holothuria edulis*	Lolipiqi	M
Dragonfish	*Stichopus horrens*	Katapila	M
Prickly redfish	*Thelenota ananas*	Sucudrau	H
Sandfish	*Holothuria scabra*	Dairo	VH
Snakefish	*Holothuria coluber*	Yarabale, ika lo	M
Surf redfish	*Actinopyga mauritiana*	Tarasea	H
Slender sea cucumber	*Holothuria impatiens*	Unknown	Unknown
Stonefish	*Actinopyga lecanora*	Dritabua, drivatu	M
Tigerfish	*Bohadschia argus*	Tiger, vula ni cakau, vula wadrawadra	M
Deepwater tigerfish	*Bohadschia ocellatus*	Tigerfish, vula ni cakau, vula	M
White snakefish	*Holothuria leucospilota*	Unknown	Unknown
White teatfish	*Holothuria fuscogilva*	Sucuwalu	VH

*M: Medium value, L: Low value, H: High value, VH: Very high value

(Conand, 1990, 1994; Preston, 1990; Adams, 1992). Although these steps are uncomplicated, it requires continuous attention to detail to obtain a standard dry product of high quality. If these steps are not followed appropriately, the quality and value of the final product will be affected (Conand, 1994; Ram *et al*., 2010).

Sea cucumbers are benthic marine organisms and broadcast spawners that release their gametes into the water column (Hamel *et al*., 2001; Battaglene and Bell, 2004). After fertilization, early development proceeds through series of planktonic larval stages (Battaglene and Bell, 2004; Bell and Nash, 2004; Hair *et al*., 2011; Jimmy *et al*., 2011) before recruitment to an appropriate substrate and development into early juveniles. Sea cucumbers play an essential role in their shallow water benthic habitats through bioturbation (Conand, 1989, 1990, 2004a, b; Purcell *et al*., 2012b). But their readily accessible habitat, relatively high value compared to other marine commodities and strong demand by South-East Asian markets, exerts significant fishing pressure on sea cucumber populations in Fiji and other Pacific island countries (Carleton *et al*., 2013b). However, despite numerous studies addressing sea cucumber stock management (Bell and Nash, 2004; Lovatelli *et al*., 2004; Conand, 2004a; Bruckner, 2006; Purcell *et al*., 2009a, b, 2013; Friedman *et al*., 2011; Jimmy *et al*., 2011; Carleton *et al*., 2013a, b; Pakoa *et al*., 2013) there has been little to no implementation of management recommendations for sea cucumber fisheries in South Pacific countries (Bell and Nash, 2004; Conand, 2004a; Kinch *et al*., 2008b; Purcell *et al*., 2010, 2012a, 2014; Carleton *et al*., 2013a; Pakoa *et al*., 2013). Fiji has been the focus of a number of these studies, including, Carleton *et al*. (2013a), who recommended seasonal closure of the fishery during the spawning season and an effective ban on the use of SCUBA to harvest sea cucumbers from deeper water. But neither of these recommendations has been implemented.

In Papua New Guinea (PNG), a national management plan was established in 2001 that included minimum size limits for fresh and dried products, a ban on the use of SCUBA for sea cucumber collection, seasonal closures of the fishery, prohibitions on collection from marine reserves, bans on the use of surface and underwater lights to aid collection, establishment of a Total Allowable Catch (TAC) and limited entry to the fishery for PNG citizens (Kinch *et al*., 2008a). Prior to this PNG was noted as the largest bêche-de-mer producer from the South Pacific. A similar ten year ban on harvesting sea cucumbers and processing bêche-de-mer was imposed in Tonga in 1997. But this was lifted in 2009 when revenue earned from bêche-de-mer exports peaked at US$ 6.5 millions (Carleton *et al*., 2013a). A further ban was imposed in 2012 for another three years but again this was lifted in April, 2014 (Anonymous, 2014). In the Solomon Islands, efforts to manage the sea cucumber fishery were initially through minimum size legislation, but a ban on sea cucumber fishing was imposed in 2005. The ban was lifted two years later when sea cucumber harvests were allowed as part of relief efforts following the impacts of a tsunami in the Western province and Choisuel province of the country. A sea cucumber fishing ban was re-imposed in 2009 but illegal harvest and export continued because of lack of monitoring and enforcement (Pakoa, 2012).

Within the context of the various sea cucumber fisheries management strategies used in South Pacific countries, this study provides an overview of sea cucumber fishery management in the Fiji Islands based on past research and new information obtained from stakeholders. It makes recommendations for changes to current fisheries practices that will help bring resilience and sustainability to this important fijian fishery that is a vital component of coastal livelihoods.

MATERIALS AND METHODS

Data were collected from online databases and from the records of the Fisheries Division in the Republic of the Fiji Islands. A structured questionnaire was also formulated to capture data on knowledge of the sea cucumber management plan from Fiji Fisheries personnel, from sea cucumber fishers (n = 86); Fijian bêche-de-mer exporters (n = 5); industry middlemen who purchase sea cucumbers and process them for a higher return from the exporters (n = 8) and officials of the Ministry of Fisheries and Forests (n = 3) of Fiji Islands who were involved with sea cucumber research. At the study sites (Fig. 1) direct field observations were undertaken to record the species of sea cucumber harvested, the numbers of each and their sizes (to the nearest 0.1 cm) and weights (to the nearest 0.1 g).

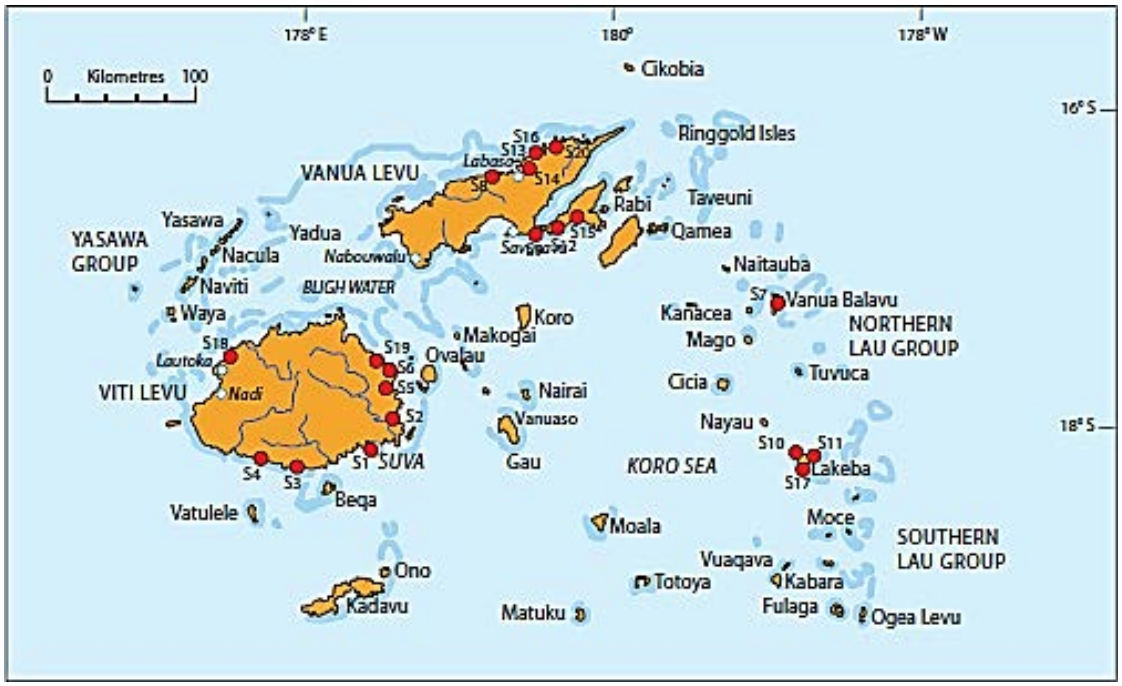

Fig. 1: Sites visited in Fiji for collection of data (source: Ram, 2008)

RESULTS

A brief history of Fiji's bêche-de-mer trade: Fiji's sea cucumber fishery is part of one of the country's oldest export trades. With development of the sandalwood trade in the early 1800's, traders came to Fiji for both sandalwood and bêche-de-mer. The rise of the bêche-de-mer trade in Polynesia and Melanesia was closely linked to that of sandalwood, often providing an alternative income for traders faced with depletion of sandalwood (Ward, 1972). Many records from early sandalwood traders noted the existence of sea cucumbers in Fiji (Dough, 1973) but it appears that sea cucumbers were not actually collected and cured in Fiji until 1813 (Ward, 1972), in the closing years of the sandalwood boom, when Peter Dillion led a party to gather bêche-de-mer (Dough, 1973) to supplement a cargo of sandalwood that the Fijians were proving slow to supply. There is no firm evidence that any bêche-de-mer was collected and cured in Fiji before 1813 (Ward, 1972) although shipments were likely to have occurred. In that year Captain Robson of the East India Company ship "Hunter", had difficulty obtaining a full cargo of sandalwood and therefore established a bêche-de-mer camp at Kampa point in the Southeast of Viti Levu (Dough, 1973). Following the re-entry of American ships after the Jeffersonian embargo[1] and the British blockade of New England in 1812-1815, trading of bêche-de-mer in Fiji was resumed by the American ship Roscoe in 1822 (Putnam, 1930).

Bêche-de-mer, in addition to tortoiseshell, pearls and pearl shells were among the products traded after sandalwood declined (Dough, 1973) in Fiji. Bêche-de-mer was considered a delicacy in Asian markets and Fiji was regarded as a lucrative source of bêche-de-mer. As with sandalwood, the bêche-de-mer trade was short-lived due to over-exploitation with a major boom period from 1830-1835. Three to four cargoes, each between 35-70 t of sea cucumbers were collected annually causing sea cucumber populations on the reefs of western and northern Vanua Levu and Southeast Viti Levu, to be considerably depleted. With a decrease in stock, traders began to employ tender vessels built in Fiji, or brought from Salem, to establish a number of shore drying stations at more remote sites where resident Europeans were hired as interpreters and supervisors of drying-houses establish for bêche-de-mer processing (Dough, 1973). By 1834, stocks of sea cucumbers on the reefs to the west and north of Fiji's main island of Vanua Levu were depleted.

Following this period, reduced collection of sea cucumbers took place in Fiji for a period of seven years, from 1835-1842, when an annual average of 20-50 t of bêche-de-mer was exported (Ward, 1972). This was enough, however, to exhaust stocks (Adams, 1993) and by 1850, trade

[1]The Embargo Act of 1807, sponsored by President Thomas Jefferson, placed an embargo on all ships and vessels under U.S. jurisdiction and prohibited American vessels were from landing in foreign ports.

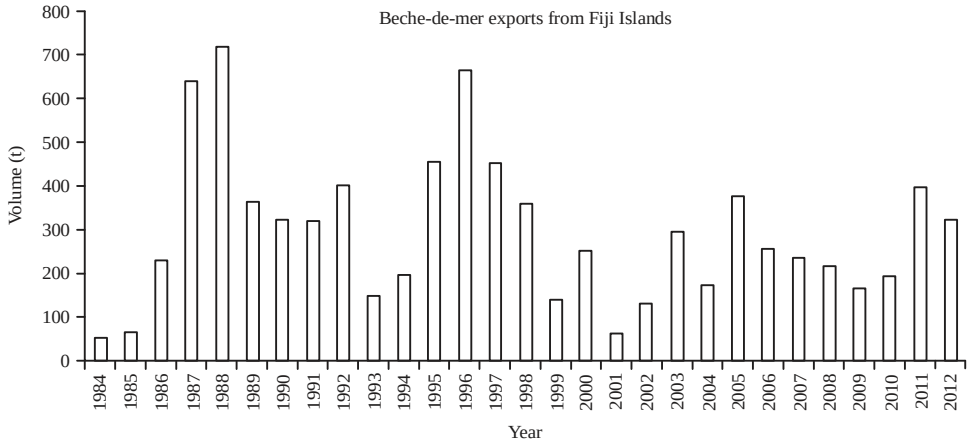

Fig. 2: Bêche-de-mer exports (tonnes) from the Fiji Islands between 1984-2012 (Source: Ministry of Fisheries and Forests: Fiji)

had deteriorated to relative inconsequence (Dough, 1973). After 1850, the number of ships coming to Fiji for bêche-de-mer decreased because of reduced sea cucumber stocks and the unstable political state in Fiji at that time (Ward, 1972). However, some vessels continued to visit Fiji for bêche-de-mer, but export of other items, such as cotton wool, copra, sandalwood and sugar, took precedence, and bêche-de-mer did not dominate Fiji's export trade. In 1865, bêche-de-mer accounted for only 6% of exports by value and in 1869 less than 1% (Dough, 1973). Primary export commodities from Fiji at this time included coconut oil that accounted for 47% of export value in 1865, and cotton that accounted for 29% of export value in 1869. Towards the end of the 19th century, changes to the sea cucumber species composition in Fiji following over-exploitation of the more valuable species, led to the exploitation of other fishery and agricultural products such as fish, crabs, clams, sugar, cotton wool and sandalwood. However, Fijians continued to sell bêche-de-mer to residents or to visiting traders at a time when sandalwood and bêche-de-mer traders were active over a wide area of the Pacific. Sea cucumbers were even more widely distributed through the Fiji Islands than sandalwood, with the number of species decreasing in an easterly direction (Ward, 1972). As a result, the bêche-de-mer trade was far more enduring and intensive than that of the earlier sandalwood trading and due to over harvesting, Pacific bêche-de-mer supplies were eventually depleted (Ward, 1972; Dough, 1973).

Bêche-de-mer remained a minor export of several territories of Fiji in the early 20th century, generally being gathered and processed by islanders and then sold to Chinese marine product agents. In 1931; 143 t (valued at £16,045) were exported from Fiji but since the mid 1930's bêche-de-mer exports decreased because of the closing of the Chinese market during World War II (Dough, 1973). In the late 1930's the Chinese and the Japanese markets for bêche-de-mer were closed and trade did not regain its pre-war importance until a number of decades later (Ward, 1972). The trade was at a minimum of 30 t until the 1970's when it again began to increase and in 1984, a total of 600 t of bêche-de-mer was exported from Fiji (Vuki and Viala, 1989) (Fig. 2). However, the harvesting of small sized sea cucumbers in large quantities was an indicator that stocks were being overfished. Reports reached the Ministry of Fisheries and Forests division in Fiji regarding reefs being fished out and stakeholders complained about large volume of small sized sea cucumber being brought for processing. In 1984, Fiji's Cabinet prohibited the use of underwater breathing apparatus (SCUBA and Hookah apparatus) for collecting sea cucumbers. The basis for this was not to manage the fishery, but to prevent underwater accidents relating to untrained divers. It was also decided that the provisions for regulations for the fortification of any fishery resource be made to secure aspects of Fiji's heritage from abuse. A major reef fishery survey was conducted by the Ministry of Fisheries and Forests in 1988 in northern Vanua Levu (Adams, 1993). The major recommendations that were made from this research were documented by Adams (1993) and included:

- Harvesting and processing of sea cucumbers be restricted to Fiji nationals only
- Implementing a seasonal closure of sea cucumber fishery in Fiji Islands
- Tighter management measures to prevent over-fishing of sea cucumbers such as establishment of a catch quota for individual fishermen
- harvesting and processing of sea cucumbers to be carried out on a small scale basis to maximise returns

Preston (1990) reported that annual bêche-de-mer production from Fiji rose dramatically in 1984 and again in 1988 when a total of 665 t of bêche-de-mer was produced (Fig. 2). In 1988, 95% of bêche-de-mer exported from Fiji consisted of *Actinopyga miliaris* (blackfish), a species that rarely appeared in the export market prior to 1984. This resulted from the establishment of centralised processing facilities in coastal areas that enabled processing to be carried out economically and with greater cost effectiveness (Preston, 1990, 1993). Processing was done in large batches with each of the processing facilities producing about 1-2 t of bêche-de-mer per day. However, establishment of centralised processing areas encouraged over-fishing, and species that occurred in low densities such as the sandfish, *Holothuria scabra* and are used locally as a food source, became depleted in some areas (Preston, 1990). As a result, a ban on exports of *H. scabra* was imposed by the Fijian government in January, 1989 and sandfish landings declined from 34-14 t from 1986-1991 as a result of the ban (Pakoa *et al*., 2013).

Current status of the bêche-de-mer trade in the Fiji Islands: From 1984-2012, a total of 8,620 t of bêche-de-mer were exported from Fiji (Fig. 2). Particularly large volumes of bêche-de-mer were exported in 1987 (>600 t), 1988 (>700 t) and 1996 (>600 t). Declines in export volumes are notable following these peaks and these could be due to over-fishing (Preston, 1990) (Fig. 2). Subsequent peaks in export volumes of around 400 t in 2005, and again in 2011, are considerably lower than those in the 1980s and 1990s. After 2005, bêche-de-mer exports levelled-off to average around 243 t per year (Pakoa *et al*., 2013). Sea cucumber harvests over recent years have generally declined for the high value species and as a result, fishing yield has now shifted from high value species to either medium or low value species (Friedman *et al*., 2011; Pakoa *et al*., 2013).

Between 2003 and 2012 there was a decline in export volume of high value species (e.g., white teatfish, black teatfish and sandfish) from 14-8%, while the export volume of medium value species (e.g., curryfish, chalkfish and hairy blackfish) increased from 50-59% of total exports. Sandfish is regarded as a very high value species (Table 1) and appeared on export lists in 2003 and 2004 despite a moratorium on the export of this species. For export value, there was a decline over the same period from 40-31% for very high value species, while the proportion of medium value species exported increased from 31-44% (Pakoa *et al*., 2013). This information indicates a decline in high value species and a shift in the market from high value species towards medium and low value species. Of current concern is that continued fishing pressure on high value species will result in over-exploitation of the resource through collection of juveniles including those of sandfish that is still collected in Fiji for processing (Adams, 1992; Kinch, 2002; Ram *et al*., 2010; Pakoa *et al*., 2013) despite a fishing ban on this species.

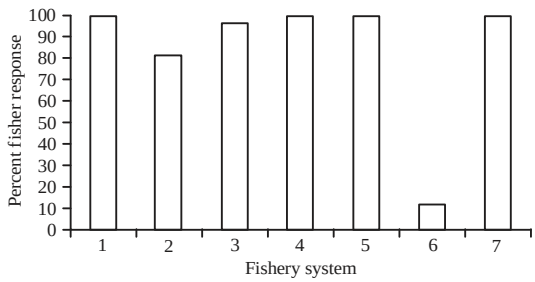

Fig. 3: Sea cucumber management response from fishers in Fiji Islands. The numbers in the fishery system are as follows; 1: Processing method improvements, 2: Establishment of harvest quotas, 3: Sustainable harvesting, 4: Value addition to BDM products, 5: Seasonal closure on harvesting sea cucumbers, 6: Complete ban for 10 years for recovery purpose, 7: Sea ranching of sea cucumbers

From the surveys conducted as part of this study, almost all respondents (Fig. 3) wanted improvements to processing techniques that would generate better income, 100% of respondents wanted some sort of sustainable harvesting or controlled harvesting to be introduced, while 97% supported seasonal closure of sea cucumber harvesting to allow stocks to recover prior to the next harvesting season. Furthermore, 70% of respondent fishers supported establishment of harvesting quotas for sea cucumbers in Fiji. One of the reasons for this is that there is an observed decline in sea cucumber catches for fishers in Fiji from 16 to 5 individuals per hectare (Teh *et al*., 2009; Ram *et al*., 2014c) and fishers are only able to harvest medium to low value species because stocks of high value species have been exhausted. On this basis, respondents reasoned that if a quota was established, it might affect their income. In addition to the quota, 12% of the respondents surveyed supported a long-term ban on harvesting sea cucumbers. These respondents were mainly the heads of the villages (turaga-ni-koro) that own large marine protected areas supporting daily fishing activity. All respondents supported development of sea cucumber aquaculture to supplement and possibly revive sea cucumber population in the wild (Hair *et al*., 2012). Harvesting and processing of sea cucumbers in Fiji was documented by Ram *et al*. (2014c) who reported that an annual average of 100-200 kg fresh weight of sea cucumbers were harvested per fishermen and sold to bêche-de-mer exporters.

Over-collection of sea cucumbers can also lead to ecosystem problems such as loss of marine life including fish, corals and sea grass (Purcell *et al*., 2014). Surveys conducted with the heads of villages indicated that around 15 years ago, when large sea cucumber populations still existed within their traditional fishing areas[2], the sea water was clearer and other marine life flourished. However, with increased harvesting of sea cucumbers, fishers have noticed changes to these fishing areas that are now considered to be less diverse. Sea cucumbers play an important role in the ecosystem through bioturbation; they are filter feeders and mix the sand to benefit other benthic marine life and infauna (Purcell *et al*., 2010).

Sustainability and management of the sea cucumber resource

Sea cucumber fishery management in the South Pacific: Previous studies have emphasized that Fiji's sea cucumber fishery has not upgraded its management status since the 1820's. Other countries in the Pacific, such as Tonga, have introduced periodic closure of their sea cucumber fishery to facilitate stock recovery and a five-year moratorium on sea cucumber fishing was recently enforced in Papua New Guinea (PNG). However, Fiji has not closed the sea cucumber fishery since the trade began. Despite 'boom and bust' cycles observed for the Fijian sea cucumber fishery in the early 1990's (Fig. 2), the fishery remained open all year round and throughout this period (Carleton *et al*., 2013a). Carleton *et al*. (2013a) reported that Fijian stocks of the high value species have been fished-out and this has forced fishers and processors to shift their focus to medium and low value species (Ram *et al*., 2010, 2014c; Friedman *et al*., 2011; Pakoa *et al*., 2012). Greater concerns have been expressed about the continued harvesting of juvenile sea cucumbers that are harvested before reaching sexual maturity (Conand, 1990, 2004a; Kinch *et al*., 2008b; Ram *et al*., 2010, 2014c; Friedman *et al*., 2011; Pakoa *et al*., 2012).

Sea cucumber fisheries issues are similar to other marine resource sustainability issues (Bruckner, 2006; Conand *et al*., 2006) where fisheries are over-exploited and poorly managed due to poverty and lack of adequate extension, education and enforcement. Over-harvesting of sea cucumbers can have major consequences on stock recovery and reproduction (Conand and Tuwo, 1996) because individuals within sea cucumber populations need to be close together during spawning to effectively reproduce (Conand, 1994). Instead, in heavily fished populations, the remaining population may decline as a result of subsequent fishing effort (Conand, 1989, 1994) and natural mortality, the so called 'Allee effect' (Stephens *et al*., 1999). Mmbaga and Mgaya (2004) commented that over-fished sea cucumber stocks require decades to recovery from over-fishing and Lokani *et al*. (1996) proposed a number of prospective measures to protect the resource. These included establishment of minimum size limits for capture (Baine and Poh-Sze, 1999; Stutterd and Williams, 2003; Carleton *et al*., 2013a) strict quotas, limiting the numbers of fishers, closed seasons, banning the use of SCUBA by sea cucumber fishers, establishing reserves and promoting stock enhancement (Purcell and Pomeroy, 2015). Australia has set a Total Allowable Catch b (TAC) quota for each fishing season (of 80 t per fishing group) and minimum size limits that apply to most of the commercially valuable species (Belhadjali, 1997). Fishing groups may harvest at any time during the season until their quotas are reached (Stutterd and Williams, 2003; Carleton *et al*., 2013a; Pakoa *et al*., 2012). By adopting similar measures coastal communities in the Pacific islands would have the prospect of surmounting the problems related to over-exploitation within sea cucumber fisheries (D'Silva, 2001; Purcell and Pomeroy, 2015). Effective management measures that are likely to have positive impacts on bêche-de-mer fisheries in the Pacific include:

- Sea cucumber collection limited to hand collection or the use of non-mechanical devices (Sachithananthan *et al*., 1985; Ram *et al*., 2014c) such as, dri-bomb (Fig. 4)
- Imposing bans on underwater breathing devices as an aid to sea cucumber collection (Carleton *et al*., 2013a; Pakoa *et al*., 2013; Purcell *et al*., 2014)

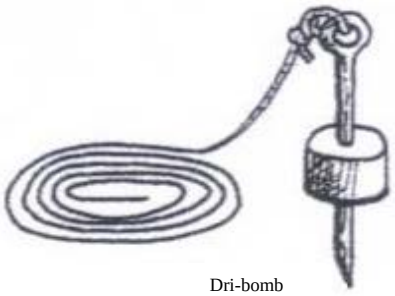

Fig. 4: Dri-bomb composed of rope, weight and metal spike for harvesting sea cucumbers in the deep

[2]Any area of seabed or soil under the sea, sand, reef, mangrove swamp, river, stream or wetland, or any other area, recognised and determined within customary fishing grounds

- Limiting the size of sea cucumber fisher's dinghies to <7 m in length
- Imposing a competitive total allowable catch (TAC) for commercial species
- Minimal size limits (Strehlow, 2004) on all commercial species and temporal and spatial closures
- Improving post-harvest quality, so that bêche-de-mer and the sea cucumbers they were derived from acquire higher value (Ram *et al*., 2010; Purcell *et al*., 2012a)

Numerous illegitimate fisheries and fisheries practices are still being conducted in the South Pacific region (Jenkins and Mulliken, 1999; Ram *et al*., 2014c). Spalding (2006) reported that illegal fisheries in many countries resulted in collection of sea cucumbers that are not accounted for in official fisheries statistics. A study of the Galapagos Islands sea cucumber fishery, for example, reported that over-fishing, illegitimate fishing and harvesting of under-sized individuals lead to the development of a participatory management process for conservation and resource management in the marine reserve (Capozza, 1999; Martinez, 2001). Sustainable management of sea cucumber fisheries requires production models that combine data on fishery activity, population dynamics and socio-economic aspects that are particularly important for these small artisan activities (Purcell and Pomeroy, 2015).

Sea cucumber stocks are over-exploited in most parts of Fiji and further unrestrained harvesting without limits or quotas will continue to see the decline of this resource. This can lead to closure of the fishery (Adams, 1992, 1993) or local extinctions of some species. This has already occurred in some Pacific island countries such as Papua New Guinea (PNG), Solomon Islands, Vanuatu, Kiribati, Tuvalu, Tonga and French Polynesia, as well as Fiji. The PNG, Vanuatu, Fiji, Tuvalu and French Polynesia have declared that high and low value species of sea cucumbers in their region have been over-fished, while the Solomon Islands, Kiribati and Tonga have declared that their sea cucumber stocks are depleted and require stricter management practice such as minimum harvest sizes, gear restrictions, limited sizes of fishing boats and harvest quotas (Purcell *et al*., 2010).

The sea cucumber fishery and sales of bêche-de-mer is an important income source for coastal communities in the Solomon Islands. Bêche-de-mer export figures from the Solomon Islands indicated a decline in bêche-de-mer stocks in 2004 due to unsustainable fishing practices (Nash and Ramofafia, 2006). The authors recommended that sea cucumber fishers sustain their catch rates by employing rotational harvesting of the fishing grounds. After survey and awareness programs conducted by the Solomon Island Department of Fisheries and Marine Resources (SDFMR), a ban was placed on harvesting and exporting all species of sea cucumber from 1 December, 2005. Such a strategy may be an effective management measures for the sea cucumber fishery in Fiji for example, a fishing ban for a short period of time (e.g., five years) could be imposed and the fishery reopened for a few months each year to allow harvesting and processing (Carleton *et al*., 2013a; Pakoa *et al*., 2012).

Sea cucumber fishery management in the Fiji Islands: Legislation relating to management of the Fijian sea cucumber fishery is contained within the 'Bêche-de-mer fisheries act of Fiji'. It states that no person shall export, either in a natural or processed form, holothurians (bêche-de-mer) of the species *Metriatyla scabra* (*Holothuria scabra*) (dairo) (sandfish) or shall take, be in possession of sell, offer or expose for sale or export holothurians, either in a natural or processed form of any other species whatsoever of a length less than 7.6 cm (3 inches). Thus, Fiji's only management mechanism for the sea cucumber fishery is a size limit of 7.62 cm that applies to all commercial species. However, different commercial species have different shrinkage rates during processing and previous studies have suggested that the harvest size limit should be revised (Vuki and Viala, 1989; Seeto, 1999; Skewes *et al*., 2004; Purcell *et al*., 2009b). There is an immediate need for research into the processing yield and reproductive biology of all species of sea cucumbers commercially utilized in Fiji, to determine conversion ratios for each and their size of reproductive maturation. Such information would provide a reasonable basis for adjustment of harvest size restrictions that are species-specific and assist fisheries in obtaining an estimate of the fresh weight of sea cucumbers processed by fishers and exporters. Information on the size at sexual maturity is particularly important because a large proportion of processed species currently fall into a category made up of 100-171 individuals per killograms (Battaglene and Bell, 2004; Conand, 2004b), resulting from sea cucumbers with an approximate length of 120-155 mm (Conand, 1990), that may have only just reached maturity or else spawned only once (Conand, 1990; Battaglene and Bell, 2004).

Customary closure of sea cucumber fishing areas in Fiji or non-fishing seasons stipulated by the heads of villages (Turaga-ni-koro) or any outside organization, often has no impact because collection of reef organisms continues to occur but is confined to times when collecting can be done more covertly e.g., during the night (100% of survey respondents). Continuing decline of sea cucumber stocks in

Table 2: List of red listed IUCN sea cucumbers species

Scientific name	Common name	IUCN status	Population trend
Endangered or at a high risk of extinction			
Apostichopus japonicus	Japanese spiky sea cucumber	Endangered A2bd ver 3.1	Decreasing
Holothuria lessoni	Golden sandfish	Endangered A2bd ver 3.1	Decreasing
Holothurian nobilis	Black teatfish [Indian Ocean]	Endangered A2bd ver 3.1	Decreasing
Holothurian scabra	Sandfish	Endangered A2bd ver 3.1	Decreasing
Holothuria whitmaei	Black teatfish [Pacific, South-East Asia]	Endangered A2bd ver 3.1	Decreasing
Isostichopus fuscus	Brown sea cucumber	Endangered A2bd ver 3.1	Decreasing
Thelenota ananas	Prickly redfish	Endangered A2bd ver 3.1	Decreasing
Vulnerable, or at risk of extinction			
Actinopyga echinites	Deepwater redfish	Vulnerable A2bd ver 3.1	Decreasing
Actinopyga mauritiana	Surf redfish	Vulnerable A2bd ver 3.1	Decreasing
Actinopyga miliaris	Hairy blackfish	Vulnerable A2bd ver 3.1	Decreasing
Apostichopus parvimensis	Warty sea cucumber	Vulnerable A2bd ver 3.1	Stable
Bohadschia maculisparsa	Unknown	Vulnerable D2bd ver 3.1	Unknown
Holothuria arenacava	Unknown	Vulnerable D2bd ver 3.1	Unknown
Holothuria fuscogilva	White teatfish	Vulnerable A2bd ver 3.1	Decreasing
Holothuria platei	Unknown	Vulnerable D2bd ver 3.1	Unknown
Stichopus hermanni	Curryfish	Vulnerable A2bd ver 3.1	Decreasing

Source: Conand *et al.* (2014)

Fiji exerts pressure on remaining stocks that are largely composed of juveniles. High value species and some medium value species (Table 2) have been 'Red-listed' by the International Union for Conservation of Nature (IUCN) indicating heavy exploitation of those species that will be unavailable to the next generation of fishers. Marine product agents in Fiji have urged the Ministry of Fisheries and Forests to control the number of agents in Fiji and to enforce stricter rules that address the harvest of under-sized sea cucumbers. Juveniles are becoming a significant target of fishers because of the over-collection of larger individuals. But under-sized processed bêche-de-mer brought to marine product agents are either rejected or given lower grade for export (Ram *et al.*, 2014a-c) with considerably reduced value in international markets. Surveys conducted during this study indicated that marine product agents in Fiji are critical of the Ministry of Fisheries and Forests of Fiji for not holding community awareness programs relating to harvesting and processing of bêche-de-mer. Extension visits by the Ministry of Fisheries and Forests (MFF) officers to villages regarding the harvesting and processing of seafood are irregular or non-existent. Published information on value of this type of seafood hardly ever reaches villages and therefore fishers, the general community do not know the actual value of the product and are guided by what is offered by the marine product agents, which is considered to be true value (Ram *et al.*, 2014b, c).

Mariculture of sea cucumbers: A number of management strategies aimed at replenishing sea cucumber stocks for future utilization have begun in various countries (Purcell *et al.*, 2010). Preston (1990) considered the possibility of restocking populations of commercially important species of sea cucumbers based on hatchery production. The program involved stock enhancement by seeding and rearing juveniles and farming of these individuals to improve the Fijian economy (Conand, 2004a; Purcell *et al.*, 2010, 2014). However, juveniles that are released can only benefit restocking efforts if there is strong and effective management of stocks in the wild (Battaglene and Bell, 2004; Bell and Nash, 2004; Conand, 2004a). Although hatchery and nursery production of juvenile sandfish would benefit fishers, the cost of producing a juvenile sandfish to a size of 10 g was estimated to be around $US 7.57 which is too high considering the variable survival that has been experienced (Battaglene and Bell, 2004). Nevertheless, some successes have been reported with improvements to hatchery and nursery culture of sandfish as well as advances in field-based culture (Chen, 2003; Friedman *et al.*, 2011; Hair *et al.*, 2011; Mills *et al.*, 2011; Duy *et al.*, 2015).

Continued research is likely to result in more effective and cheaper mariculture methods for sea cucumbers (Pitt, 2001) that will increase the importance of mariculture as a source of sea cucumbers for the bêche-de-mer industry in the Pacific islands and as a source of juveniles for rejuvenating wild stocks. Sea cucumber mariculture programs should be developed in Fiji to resolve the problem of dwindling sea cucumber stocks (Conand, 1989, 1990; Carleton *et al.*, 2013a; Pakoa *et al.*, 2013) and to provide employment for sea cucumber fishers that might be impacted by restrictions that might be applied to the bêche-de-mer fishery. If restrictions

were applied to the fishery, cultured sea cucumbers (including Sandfish) could be grown in marine protected areas, processed and exported since they would not be harvested from the 'Wild'. Such a scenario could improve income for existing sea cucumber fishers while providing an opportunity for recovery of wild stocks. The heads of villages could play an important management role in such programs by placing and enforcing a harvest quota for each marine protected area depending on the species present. One potential problem with this relates to our ability to distinguish cultured sea cucumbers from wild collected individuals (Conand, 1991; Kirshenbaum *et al*., 2006; Fitzpatrick *et al*., 2010; Gianasi *et al*., 2015).

Major recommendations for sea cucumber management in Fiji Islands: The current status of the sea cucumber fishery in Fiji clearly illustrates the inadequacies of current legislation, enforcement as well as extension and education activities. Current fishing pressures are unsustainable and new management measures are needed to support resilience within the fishery. Declining yields from the fishery and an increasing proportion of lower-value species within those landed, negatively impact the livelihoods of coastal communities as well as the country's export potential. This study has highlighted some important issues for future management of sea cucumber population in the Fiji Islands and a number of recommendations are suggested on this basis:

- Further research should be done on harvest yields of sea cucumbers in the Fiji Islands and based on the results obtained, group quotas, fisher's quota and industry quotas should be allocated to protect the current stock from further depletion (Carleton *et al*., 2013a)
- Seasonal closures or rotation of fishing areas should be put in place for sea cucumber fishers. This would be an imperative decision taken by the Ministry of Fisheries and Forests and would allow spawning at least once prior to harvest. Changes in the fishing grounds would reduce pressure on sea cucumber stocks and would be effective in controlling fishing of all species from given area to improve sustainable yield (Carleton *et al*., 2013a; Pakoa *et al*., 2012; Purcell and Pomeroy, 2015)
- Development of aquaculture of high value sea cucumber species in Fiji could also reduce pressure on sea cucumber stocks and would offer alternative livelihood options for those engaged in the program (Battaglene and Bell, 2004; Purcell *et al*., 2010; Hair *et al*., 2011; Jimmy *et al*., 2011)
- Bêche-de-mer fishery laws should be enforced properly since current regulations are flouted by sea cucumber fishers and marine product agents in Fiji. Illegal sales of sandfish still occur with no monitoring. Furthermore, undersized sea cucumbers are harvested and sold
- There is a need for a strong, sustainable management plan that has to be implemented and enforced properly to support a sustainable future for Fiji's bêche-de-mer fishery (Carleton *et al*., 2013a)
- Further research into the reproductive biology of all commercially harvested holothurians in Fiji should determine a recommended species-specific harvest length that would allow individuals to reach sexual maturity before harvest
- In addition to the reproductive biology, studies relating to the potential impacts of climate change on fishery stocks of sea cucumbers (Hair *et al*., 2011; Carleton *et al*., 2013a) in the South Pacific (Pickering *et al*., 2011) should be carried out and the risks from possible emergence of diseases be assessed
- Total Export Limits (TEL) by species should also be instituted for each buyer in Fiji, or applied to the fijian export that could be in a range of 200-300 t per annum. Once this limit is reached the export should cease until the next harvesting season
- There should be restrictions on issuing SCUBA licenses to sea cucumber fishers and a complete restriction on the use of hookah. Issuing of SCUBA operator's exemption certificates in Fiji has increased from 9 in 2010 to 25 in 2013. The use of SCUBA has to be completely banned to avoid the risk of over-exploitation of sea cucumbers (Pakoa *et al*., 2013)
- Elimination of middlemen in the bêche-de-mer industry in Fiji and the linking of sea cucumber fishers directly to the marine product agents would earn the fishers more money since middlemen buy product from fishers for much less than they sell it to marine product agents (Ram *et al*., 2010)
- Sea cucumber fishers should be educated about the ecological importance of holothurians through non-formal extension activities. Hands-on training programs on processing and handling techniques for holothurians should be given to fishers to help improve the quality and value of their bêche-de-mer product (Ram *et al*., 2010; Carleton *et al*., 2013a; Purcell *et al*., 2012a)

DISCUSSION

Fiji has a total of 28 sea cucumber species that are exported. White teatfish is currently regarded as the premium species and is preferentially targeted by the fishery, while export of sandfish is prohibited (Carleton *et al*., 2013b; Pakoa *et al*., 2013). As demand for bêche-de-mer increases in South East Asia, fishing activity also increases with little to no control over the quantity of sea cumbers being harvested (Eriksson and Clarke, 2015). Fiji has so far not established an effective management plan to control harvest or bêche-de-mer export quotas (Carleton *et al*., 2013b; Purcell *et al*., 2013). Although a number of studies have focussed on sea cucumber management in Fiji, implementation of recommendations from such studies has not occurred (Pakoa *et al*., 2013; Purcell *et al*., 2014). Such studies have indicated that most of Fiji's sea cucumber species, especially high value species are at a risk of extinction in Fiji waters (Conand *et al*., 2014). With the high value species nearly fished out, the fishery has shifted towards medium and low values species that now dominate Fijian bêche-de-mer exports (Friedman *et al*., 2011). This puts the bêche-de-mer industry at further risk because most of the medium and low value species of sea cucumber inhabit the intertidal zone and face significant risk of overfishing (Purcell *et al*., 2012a; Friedman *et al*., 2011; Pakoa *et al*., 2012; Ram *et al*., 2014c; Purcell and Pomeroy, 2015). This shift towards medium and low values species indicates overfishing of sea cucumbers in Fiji (Carleton *et al*., 2013b) and this is a key component of the "Boom and bust" pattern of the Fijian bêche-de-mer export industry. Since the early 1980s, the industry recorded export booms in 1987-1988 and again in 1995-1997 before declining. Subsequent export peaks in 2005 and 2011 resulted from an increase in the proportions of medium and low value species that were part of shipments that included undersized bêche-de-mer of all species (Carleton *et al*., 2013b; Ram *et al*., 2014a-c). It is notable that these export peaks in 2005 and 2011 were considerably lower in volume than the export peaks in the 1980s and 1990s.

For the past 25 years Fiji has not revised its minimum export size for bêche-de-mer of 7.62 cm, despite a number of studies suggesting further research work into the reproductive biology (i.e., knowledge of minimum reproductive size for targeted species) and differences between species in yield after processing (i.e., knowledge of physical changes to the length and weight of sea cucumber after processing and variation between species) (Skewes *et al*., 2004; Purcell *et al*., 2009b; Carleton *et al*., 2013b; Pakoa *et al*., 2013; Ram *et al*., 2014a-c). For example, lollyfish shrinks to more than 50% of its initial size after processing and resulting bêche-de-mer are below the minimum legal size for export. It would be appropriate to revise the current 'Catch-all' export size limit to species-specific size limits that consider the minimum reproductive size of target species. This action would support better management and sustainability of both the sea cucumber fishery and the bêche-de-mer export industry in Fiji.

Our results indicate that all survey respondents supported seasonal closures of the sea cucumber fishery to allow recovery of fished populations. Seasonal restrictions on sea cucumber harvesting and stricter implementation of regulations have been recommended in prior studies (Carleton *et al*., 2013b; Pakoa *et al*., 2013). However, spawning seasons of the sea cucumber species harvested in Fiji vary and more research into the reproductive biology of target species is essential before meaningful seasonal closures could be implemented. Survey respondents also supported improvements to bêche-de-mer processing techniques that will improve product quality and value. The effects of processing methods on quality and value of resulting bêche-de-mer in Fiji has been reported in prior studies (Ram *et al*., 2014a, b) that recommended improvements to both sea cucumber handling by fishers and bêche-de-mer processing methods.

Unless changes are implemented immediately, Fiji will continue to lose millions of dollars of potential revenue from the bêche-de-mer export trade because of: (1) Diminishing stocks of sea cucumbers (Carleton *et al*., 2013b; Pakoa *et al*., 2013; Purcell *et al*., 2013; Vincent and Morrison-Saunders, 2013), (2) An increasing proportion of lower value species contributing to the fishery (Ram, 2008; Pakoa *et al*., 2013; Ram *et al*., 2014a-c), (3) Significant harvests of undersized sea cucumbers for processing (Ram *et al*., 2014a-c) and (4) Poorly processed bêche-de-mer (Ram *et al*., 2014a, c). Many of these issues could be address by improved fishery management and oversight. However, there may be opportunities for the Fijian sea cucumber fishery through development of new value adding products. For example, low value species such as amberfish, elephant trunkfish and brown spotted sandfish are traded for below US$ 10 kg^{-1} dried (Ram *et al*., 2014b), but such species can also be used to produce medicinal products, and products such as 'Konowata' (cured sea cucumber entrails). Furthermore, the fishery and bêche-de-mer export industry could be supplemented by mariculture programs (Rasolofonirina *et al*., 2004; Hair *et al*., 2011; Jimmy *et al*., 2011; Purcell *et al*., 2014) that would not only contribute to production of high value species for processing, but could also reduce stress on wild fished sea cucumber stocks.

CONCLUSION

A number of major issues need to be addressed if sustainability is to be brought to Fiji's bêche-de-mer industry. The major problems identified in this study were that the Sea Cucumber Fishery Act in Fiji has not been revised since it was implemented in 1984 and in contrast to other South Pacific countries, the Fijian sea cucumber fishery has not been closed either temporarily or longer-term in response to over-harvesting. Because of the depletion of high value sea cucumber species, the fishery has now shifted focus to medium and low value species resulting in a decline in the value of the industry and in export earnings. Improvements to processing techniques development of methods for sea cucumber mariculture bans on the use of SCUBA for diving sea cucumbers and proper enforcement of the regulations are huge tasks for the Fiji Fisheries Department.

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