Assessment of sea cucumber fisheries through targeted surveys of Lau Province, Fiji

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Executive Summary

This report details findings from a 24 day survey of sea cucumber resources and the status of the fishery from 10 islands (Cicia, Fulaga, Kabara, Mago, Matuku, Moala, Totoya, Tuvuca, Vanua Vatu, Vanuabalavu) in Lau Province, Fiji. The surveys were conducted by staff from the Fiji Department of Fisheries, the Institute of Applied Sciences and the Wildlife Conservation Society as part of the Khaled bin Sultan Living Oceans Foundation Global Reef Expedition between June 2 and 27, 2013. Direct in-water resource assessments were carried out using standardized protocols developed by the Secretariat of the Pacific Community (SPC) Regional Fisheries Observatory program. These data were combined with fisher perception surveys, measurements of dried bêche-de-mer processed in villages, and general observations from community discussions to assess the overall status of the fishery.

Within species densities of commercially important sea cucumber species across individual islands surveyed ranged from 0 – 132.81 individuals ha^{-1}. Densities were below SPC regional indicator values for all species except for *Pearsonothuria graeffei* (flowerfish). The highest densities were observed from Totoya and Vanuabalavu, however the values generally fell below suggested threshold densities of 10-50 individuals ha^{-1} required to avoid reproductive failure. Furthermore, with the exception of some well-managed and long-established community marine protected areas (*tabu*), individuals tended to be widely dispersed, which will also prevent successful fertilization. Sea cucumber densities were generally comparable to or lower than those measured from Kubulau and Bua districts, Bua Province, in 2012, and considerably lower than densities from four sites on Viti Levu and Vanua Levu surveyed in 2003 and 2009, suggesting that already depleted populations are likely further declining. The one optimistic finding was that community-based management does seem to be having a positive effect in preserving some remaining individuals, as total sea cucumber abundance was significantly higher in tabu areas than in areas open to fishing surveyed using belt transects.

Mean sizes of sea cucumber species measured underwater were generally above minimum recommended wet sizes, with the exception of *Holothuria atra* and *P. graeffei.* The general absence of very small sea cucumbers on the reef is of concern, and may be indicative of recruitment failure. Village measurements of dried samples indicate that many undersized individuals of *Actinopyga lecanora, Bohadschia vitiensis* and *H. atra* are being harvested, as well as almost all species harvested from Matuku Island reefs. As prices have increased due to reduction in supply, fishers have not yet been proactive about management measures given that they are still able to meet their daily needs with income derived from bêche-de-mer as they are using techniques (e.g. underwater breathing apparatus, free diving with 'bombs') to extract individuals from deep refuges.

Dive fatalities and injuries are regular features of the bêche-de-mer industry as individuals are exceeding depth and time limits in pursuit of valuable catch. Several companies appear to be undercutting local communities on prices, while other companies refused to pay out or failed to keep promises to assist with village development projects.

Given that populations are declining in tandem with increasing numbers of commercial operators, we strongly encourage the Fiji government to halt issuance of exemptions for harvest with underwater breathing apparatus.

In addition, other active management measures should be undertaken to preserve remaining stocks and encourage population recovery. Such measures can include:

- A complete ban on sea cucumber harvest for a set period of time (e.g. 5 years).
- A ban on the use of 'bombs' with free diving to allow for persistence of deeper populations to replenish stocks.
- Distribution of recommended minimum wet and dry size limits to enable individuals to reproduce.
- A harvesting ban that is triggered when monitoring of dried bêche-de-mer sizes by divisional fisheries officers indicates that stocks have fallen below minimum recommended sizes.
- Establishment of new no-take areas (*tabu*) in areas that are easily enforceable.
- Movement of wild-caught or hatchery-reared individuals into new or existing tabu areas.
- Development of alternative livelihood initiatives (e.g. copra farming, organic farming, honey, seaweed farming) to relieve pressure from sea cucumber harvesting.

Introduction

Across Fiji over the past few decades, increased demands for cash income and material goods, coupled with growing populations and access to markets, have led to substantially increased pressure on coastal and marine resources. Rural communities must meet annual payments for school fees and government levies, as well as support intermittent religious obligations and health care costs. As a consequence, coastal residents are increasing the frequency and intensity of harvesting fish and commercially valuable invertebrates as a main or supplemental source of income to meet these financial challenges (Jupiter et al. 2012). This commercialization of resources greatly endangers the ability of Fijian communities to meet their future food security needs from coral reef fisheries, which are already under threat from subsistence fishing alone (Bell et al. 2009).

Sea cucumbers are an important commercial resource in Fiji, listed at one time by FAO as the most important marine export in the dried form (*bêche-de-mer*) from the country (McElroy 1990). Sea cucumbers were initially traded and virtually depleted from Fiji in the early 1800s (Adams 1992). Although populations recovered, the market was not profitable until trade was re-initiated in the mid-1980s. Heavy demand from mainland China led to serial population decline of high value species in more proximate countries such as Indonesia, Philippines and Japan (Anderson et al. 2011), causing traders to look farther afield. Records of bêche-de-mer exports peaked in Fiji in 1988 at over 700 t and then quickly plummeted, despite efforts by Fiji government to control the trade with a 3 inch (7.6 cm) minimum (dried) size limit and ban on export of *Holothuria scabra* (dairo) approved by Cabinet in 1988 (Adams 1992,1993). The size limit was not well enforced and often broken by agents (Adams 1992; Friedman et al. 2011). Nonetheless, populations recovered and new markets became available. Export values rose through the mid-1990s with trade to Hong Kong and Singapore (Ferdouse 1998) and peaked nearly a decade later at 862 t recorded in 1997, followed by a precipitous decline from which the industry has yet to recover (SPC, unpublished data).

There is currently no fisheries management plan for sea cucumber in Fiji (although one is under development) and the number of licenses issued is uncontrolled. While the collection using any underwater breathing apparatus (UBA) has been banned under the Fisheries Act since 1997, the Fiji government routinely issues exemptions to licensed fishers who have agreements with foreign agents. The Secretariat of the Pacific Community (SPC) thus rates the Fiji sea cucumber fishery as poorly managed (SPC, unpublished data).

Several features of the biology of sea cucumbers make them vulnerable to local extirpation: (1) they are fairly sedentary and can therefore be harvested at rapid rates; (2) they have low and irregular recruitment rates; and (3) reproduction fails when species populations fall below critical density thresholds (known as the ‘Allee effect’ or ‘depensatory effect’) (Uthicke et al. 2004; Bell et al. 2008). Little is known to date regarding fertilization success as a function of species density and dispersion, with some notable exceptions. *Isostichopus fuscus* can achieve 50% fertilization success with approximately 1-2 individuals m^{-2} (Sheppard et al. 2004). Fertilization rates for *Bohadschia argus* are between 73 and 96% when mating pairs are within 1 m, but fall to less than 2% when mates are between 20 to 40 m apart (Babcock et al. 1992).

In addition to detrimental impacts to livelihoods through loss of potential revenue, mass exploitation of sea cucumber populations may substantially impact on coral reef ecosystem dynamics, thus reducing biological diversity and resilience to disturbance. As they feed, healthy sea cucumber populations can bioturbate the upper 5 millimeters of coral reef sediment annually, thus substantially reducing sediment nutrient loads and microalgal populations (Uthicke 1999,2001), while potentially keeping harmful algal and cyanobacteria populations in check. Meanwhile, large-scale sea cucumber removal has been associated with seafloor hardening, thus impacting habitat for other benthic organisms (Bruckner et al. 2003).

This study presents an opportunistic assessment of sea cucumber populations across 10 islands of the maritime Lau Province, Fiji. The survey was requested by the Lau Provincial Office based on reports of large-scale commercial extraction over the past 5 to 10 years, and increasing requests for exemptions for harvesting with UBA. We report on local fisher perceptions of the status of sea cucumber fisheries, underwater assessments and size structure of dried bêche-de-mer measured from village catches.

Methods

Study locations

From June 2 to 26, 2013, we conducted assessments of the status of the sea cucumber fisheries in 10 islands of Lau Province, Fiji: Totoya, Matuku, Moala, Fulaga, Kabara, Vanua Vatu, Tuvuca, Cicia, Mago, and Vanuabalavu (Figure 1). Our team undertook underwater surveys using manta tow and belt transects, conducted perception surveys, and measured dried bêche-de-mer stock during the Khaled bin Sultan Living Oceans Foundation Fiji leg of its Global Reef Expedition (GRE) aboard the M/Y Golden Shadow.

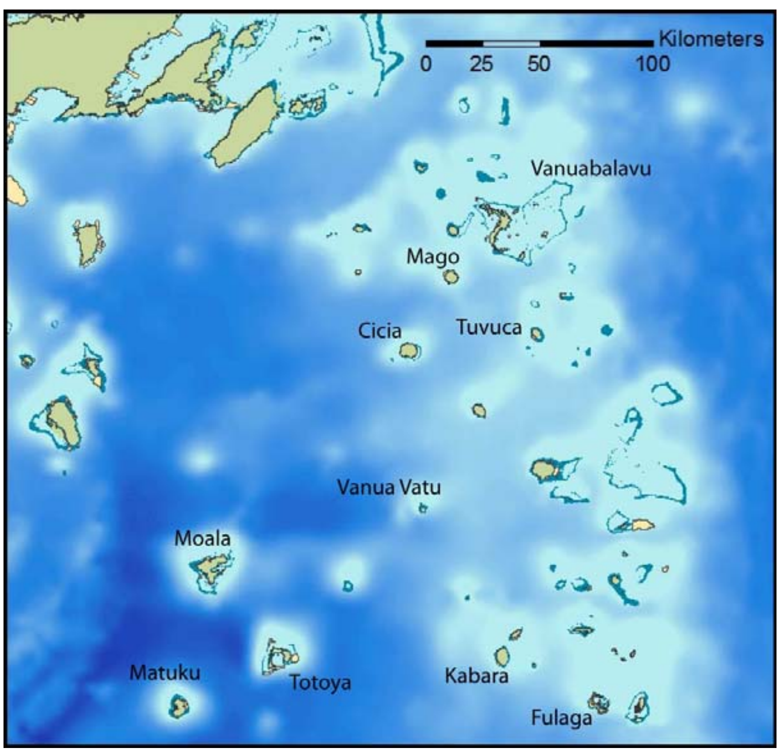

Figure 1. Map of survey island locations within Lau Province. Detailed GPS locations of sites surveyed are found in Annex 1.

Underwater surveys

We conducted underwater surveys of sea cucumber populations using a standardized protocol for direct in-water resource assessments developed by the SPC Regional Fisheries Observatory (RFO) program (Friedman 2008). In brief, we utilized manta (tow-board) stations, typically covering 3600 m^2 each with 6 replicate 2 m x 300 m transects, and snorkel or dive belt transect stations, covering between 120 and 480 m^2 with 3 to 12 replicate 1 m x 40 m transects across hard and soft bottom benthos. Annex 1 contains a table of the location and number of sites surveyed per island. We report data as occurrence (% of replicates) and mean density ha^{-1}, as per Friedman et al. (2011). Given the nature of the expedition, direct in-water resource assessments were performed opportunistically in coordination with other research objectives of the GRE, which precluded an experimental design that would robustly address differences in density across islands, habitats, bottom cover and depth. However, we performed PERMANOVA analyses of all manta stations combined and all belt transects combined to assess for differences in total sea cucumber abundance between areas that were protected and open to fishing. Data were pooled across all islands, habitats and reef areas. A sqrt(X+0.5) transformation was applied to the data to account for skew and the high number of zero counts. We calculated log10 Modified Gower dissimilarity matrices and performed PERMANOVA over 9999 permutations.

Perception surveys

We opportunistically surveyed 31 fishers who actively catch sea cucumbers from Totoya (4), Matuku (6), Moala (7), Kabara (7), Vanaua Vatu (1), Tuvuca (2), Cicia (1), and Vanuabalavu (3) regarding their perceptions of present status and trends in the fishery. Surveys were conducted in *iTaukei* (Fijian) language. The list of questions is shown in Table 1. While interviewing fishers, we also noted general observations about the nature of sea cucumber harvests from each island.

Table 1. Questions used in perception-based surveys of fishers active in the sea cucumber industry.

Question	**Response**
How do you rate the status of sea cucumber fisheries in your traditional fisheries management area (*qoliqoli*)?	Ranked on 5 point Likert scale, from 1 = very bad to 5 = very good
Has the abundance of sea cucumbers changed over time?	Ranked on 5 point Likert scale, from 1 = rapid decline to 5 = big increase
Has the size of sea cucumbers changed over time?	Ranked on 5 point Likert scale, from 1 = much smaller to 5 = much bigger
Has the price of sea cucumbers changed over time?	Ranked on 5 point Likert scale, from 1 = much lower to 5 = much higher
Are you happy with the price that you receive for sea cucmbers?	Yes or No. Asked to explain answer
How many different types of sea cucumbers do you usually catch?	# of types. [Note: many respondents also listed species]
Which kinds are most common?	Species
Which kinds are hardest to find?	Species
How many days a week do you fish for sea cucumber?	# days per week
What fishing method do you use?	Method

Dried bêche-de-mer measurements

Individudal fishers in Lau typically process sea cucumber into bêche-de-mer on shore and store catch dry until the arrival of one of the ferries that can transport the product for sale in Suva.

Alternatively, fishers work under the commercial license of a local individual with links to an export company, who transports the catch in bulk for export. When dried bêche-de-mer were available in villages, we measured a sub-sample of the catch or all of the catch if they were few in number.

Results

Underwater surveys

We surveyed 75 stations covering 143,280 m^2 of hard and soft-bottomed habitat. Mean total density of sea cucumbers ranged from 0 individuals ha^{-1} (at Fulaga, Matuku and Vanua Vatu islands using belt transects) and to 129.46 individuals ha^{-1} at Totoya Island using belt transects (Table 2). Total sea cucumber abundance was significantly higher in community-managed tabu areas than in fished areas surveyed with belt transects, however no significant differences were observed between protected and open stations surveyed by manta tow (Table 3). Species density is listed by island in Annex 2.

The species (average size in cm ± 1 SE) found on snorkel/dive transects included: *Actinopyga miliaris* (28.5 ± 1.5), *Bohadschia argus* (26.7 ± 8.7), *Holothura atra* (16.0 ± 0), *H. edulis* (26.2 ± 5.1), *H. fuscopunctata* (37), *H. whitmaei* (28.5 ± 3.5), *Pearsonothuria graeffei* (26.5 ± 0.8), and *Thelenota anax* (45). The species located on manta tows included: *B. argus*, *B. vitiensis*, *H. atra*, *H. edulis*, *H. fuscogilva*, *P. graeffei*, *Stichopus chloronutus*, *S. hermanni*, *T. ananas* and *T. anax*.

Table 2. Mean total density ha^{-1} of sea cucumbers sighted during in-water surveys

Island	Method	# stations	Mean density ha^{-1}	Standard error
Cicia	Manta	1	8.33	3.73
	Belt	5	19.74	11.22
Fulaga	Belt	2	0.00	0.00
Kabara	Manta	2	1.39	1.39
	Belt	4	26.79	14.88
Mago	Manta	2	1.39	1.39
	Belt	2	25.00	17.21
Matuku	Manta	5	0.67	0.73
	Belt	4	0	0
Moala	Manta	6	6.94	2.52
	Belt	1	25.00	25.00
Totoya	Manta	8	35.56	14.90
	Belt	2	20.83	20.83
Tuvuca	Manta	3	2.78	1.51
Vanua Vatu	Belt	3	0	0
Vanuabalavu	Manta	11	21.88	6.67
	Belt	12	129.46	29.91

In Table 4, we compare species specific occurrence rates and density ha^{-1} with data acquired by Fiji Department of Fisheries and NGO staff from Kubulau and Bua districts of Bua Province, Fiji, during RFO protocol training in August 2012. Compared with the 2012 surveys from Kubulau and Bua, the combined densities across Lau were slightly higher for *A. miliaris*, *P. graeffei*, *H. fuscopunctata*, and *H. whitmaei*, and similar for *B. argus*, *H. edulis*, *H. fuscogilva*, *T.*

ananas, and *T. anax*. Lau densities were lower than found in Kubulau and Bua for the following species: *A. lecanora, B. similis, B. vitiensis, H. atra, H. coluber, H. scabra, S. chloronutus, S. hermanni*. With the exception of *P. graeffei*, species occurrence rates and densities were far below values considered healthy and populations are considerably more sparse than reported in Friedman et al. (2011) for surveys of Viti Levu and Vanua Levu sites in 2003 and 2009 (Table 4).

Table 3. Results of PERMANOVA analyses to assess differences between total sea cucumber abundance between protected and fished areas across Lau islands surveyed. Data were pooled across all islands, habitats and reef areas. Values in bold indicate significance at $p < 0.05$ or below.

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Belt transects						
Status	1	0.0614	0.0614	14.459	**0.0012**	699
Residual	269	1.1433	0.00425			
Total	270	1.2047				
Manta tows						
Status	1	0.0365	0.0365	2.2816	0.1316	7616
Residual	215	3.441	0.0160			
Total	216	3.478				

Table 4. Comparison of sea cucumber survey occurrences and densities (ha^{-1}) between this survey in Lau (all islands combined), RFO surveys of Kubulau and Bua districts in 2012 (SPC, unpublished data), and surveys in 2003 and 2009 of 2 sites in Viti Levu and 2 sites in Vanua Levu combined from Friedman et al. (2011).

Species	Common name	2003[a]		2009[a]		2012 Kubulau[b]	2012 Bua[b]	2013 Lau combined		Healthy density[b]
		Occur.	Density	Occur.	Density	Density	Density	Occur.	Density	
Actinopyga echinites[1]	Deepwater redfish	1	0.1 (0.1)	0	0	0	0	0	0	
Actinopyga echinites[2]	Deepwater redfish	10	1131 (906.6)	0	0					
Actinopyga lecanora[1]	Stonefish	1	0.2 (0.1)	1	0.1 (0.1)	0.14	0.14	0	0	28
Actinopyga mauritiana	Surf redfish					0	0	0	0	27
Actinopyga miliaris[1]	Blackfish	0	0	1	0.1 (0.1)	0.14	1			50
Actinopyga miliaris[2]	Blackfish	10	9.9 (7)	0	0			1[3]	3.09 (2.18)[3]	50
Bohadschia argus[1]	Tigerfish	18	3.7 (0.6)	8	1.3 (0.4)	1	2	1[1] 1[3] 1[5]	0.38 (0.25)[1] 3.09 (3.09)[3] 2.29 (2.29)[5]	31
Bohadschia similis[3]	Chalkfish	43	343.5 (149.4)	0	0	1	6	0	0	828
Bohadschia vitiensis[4]	Brown sandfish	41	39.3 (10.2)	5	2 (2)	0.44	6	0.5[1]	0.08 (0.08)[1]	153
Pearsonothuria graeffei[1]	Flowerfish	10	3.8 (1.3)	7	1.4 (0.5)	3	19	4[1] 9[3] 7[5]	1.15 (0.39)[1] 55.56 (17.92)[3] 34.0 (14.0)[5]	36
Holothuria atra[1]	Lollyfish	52	36 (3.7)	55	106 (30.2)	28	46	6[1] 1[3] 1[5]	1.61 (0.51)[1] 1.54 (1.54)[3] 2.29 (2.29)[5]	2083
Holothuria atra[2]	Lollyfish	71	357.1 (76.1)	51	147.8 (46)					
Holothuria coluber[1]	Snakefish	5	2.2 (0.7)	0	0	2	0.14	0	0	485
Holothuria edulis[1]	Pinkfish	45	57.3 (14.2)	27	14.2 (2.9)	7	4	12[1] 1[3] 4[5]	10.32 (3.23)[1] 3.09 (2.18)[3] 9.17 (4.52)[5]	232

Holothuria fuscogilva[1]	White teatfish	2	0.4 (0.2)	1	0.1 (0.1)			0.05[1]	0.08 (0.08)[1]	28
Holothuria fuscogilva[3]	White teatfish	100	4.4 (0)	33	0.7 (0.5)	0.14	0.14			28
Holothuria fuscopunctata[1]	Elephant trunkfish	5	1.1 (0.3)	1	0.1 (0.1)	0.44	1	1[5]	2.29 (2.29)[5]	10
Holothuria leucospilota[1]	White threadsfish	1	0.1 (0.1)	0	0	0	0	0	0	
Holothuria scabra[4]	Sandfish	43	132.6 (43.9)	14	9.9 (6.4)	406	0	0	0	1200
Holothuria whitmaei[1]	Black teatfish	1	0.2 (0.1)	1	0.1 (0.1)	0	0			207
Holothuria whitmaei[2]	Black teatfish	14	7.9 (4.7)	4	2.4 (1.7)			1[3]	3.09 (2.18)[3]	207
Stichopus chloronutus[1]	Greenfish	13	3.3 (0.7)	13	5.7 (1.6)	1	3	4[1]	0.84 (0.31)[1]	878
Stichopus chloronutus[2]	Greenfish	67	69.4 (21)	28	79.4 (52.2)					
Stichopus hermanni						3	6	0.5[1]	0.23 (0.23)[1]	
Thelenota ananas[1]	Prickly redfish	4	0.6 (0.2)	2	0.5 (0.3)	0.14	0.27	1[1]	0.23 (0.13)[1]	27
Thelenota ananas[3]	Prickly redfish	0	0	33	1.5 (0.9)					
Thelenota anax[1]	Amberfish	2	0.3 (0.2)	0	0	0.29	1	2[1]	0.69 (0.33)[1]	
								1[3]	1.54 (1.54)[3]	12

[a] Data from Friedman et al. (2011) [b] SPC, unpublished data

[1] Measured from manta tow surveys [2] Measured from hard benthos belt snorkel transects [3] Measured from hard benthos deeper SCUBA surveys

[4] Measured from soft benthos snorkel [5] Measured from soft benthos with a combination of belt snorkel and deeper SCUBA surveys

Perception surveys

Fishers have differing perceptions of present status of the sea cucumber fishery, with 35% reporting that it is bad or very bad, 39% reporting that it is average, and 26% that it is good or very good. Despite this split, most (69%) of the respondents believe sea cucumber abundance is getting scarcer, while 31% reported no change. Most (64%) of the respondents believe that the size of encountered sea cucumbers is smaller, while 26% perceive no change and 10% perceive modest increases. The majority (67%) of respondents report an increase in sale price, and 68% of respondents are happy with the price they are receiving because the income supports family and additional needs (e.g. vanua, church, education), is lucrative, and in many cases is the only alternative for generating cash from the islands. The most commonly reported species being caught include the lower value *Bohadschia vitiensis*, *Holothuria atra*, and *Actinopyga mauritiana*. The hardest to find species include the high value *Holothuria fuscogilva* and *Holothuria whitmaei*. All fishers reported catching sea cucumbers by free diving, while 42% also claimed to use “bombs”, which are metal hooks on leaded weights that enable the fisher to catch deeper individuals.

Dried bêche-de-mer

In total, we measured 1006 dried sea cucumbers across 8 islands, which represent only a small fraction of the stock in the villages waiting to be sold. For example, in Muana-i-cake village, Fulaga Island, local divers collected 1506 individual sea cucumbers over 21 days with SCUBA prior to our arrival, operating with an exemption issued by Fiji government. Almost all of these individuals were collected from the adjacent uninhabited islands in the Yagasa Group.

Average sizes of the species sampled are shown in Annex 3 and they are compared with minimum sizes for harvesting recommended by SPC. In some cases, the mean size of certain species is well below the minimum recommended harvesting sizes, particularly for *Actinopyga lecanora* (stonefish), *Bohadschia vitiensis* (brown sandfish) and *Holothuria atra* (lollyfish), as well as almost all species harvested from Matuku Island reefs. In a few instances, we note that our sampling overestimates the mean size harvested: for example, in Matuku, we estimated that one fisher from Yaroi village, Matuku Island, had an additional 100 more undersized *Holothuria atra* and 150 more undersized *Pearsonothuria graeffei* that we did not have time to measure.

General observations

On most of the islands we visited in Lau, there has been a high level of commercial activity for bêche-de-mer over the past few years (Table 5). In no case has there been any regulation on the amount extracted, and only one individual with whom we spoke, who was running the local harvesting operation from Muana-i-cake village in Fulaga, expressed concern about leaving stock in the sea to enable population recovery. We recorded several instances of companies making promises to local communities for cash payouts or other compensation that they never received in exchange for mass harvesting of sea cucumber resources. During our expedition, a 16 year old boy from Dravuwalu, Totoya went missing while free diving for sea cucumber and fisher from Serua Province passed away from a UBA diving related accident near Oneata Island. We regularly encountered stories of local fishers who had passed away or suffered from permanent disabilities as a direct result of diving too deep or for too long on UBA. Families are receiving little to no compensation from local operators for these diving related injuries and deaths.

Table 5. General observations of the status of the sea cucumber industry in each island visited in Lau.

Village	General observations
Totoya	Roko Sau Josefa Cinavilakeba has banned use of SCUBA and will not give consent for exemptions. Harvests are being done on individual basis. One fisher using profits to build house in Suva. No commercial companies harvesting - individuals put dried catch on trading ships and product is sold in Suva. Recent deaths from diving accidents while searching for sea cucumbers
Matuku	Only found 1 sea cucumber in water. Fishers had 100s of small, low value species dried (too many to measure). Local agent in village was out of money, so sold product to postmaster.
Moala	$1.5M payout to Naroi Village in 2010 for sale of beche-de-mer. Reported death from SCUBA related accident in 2010. After company left in 2010, harvesting slowed way down as people found it harder to find sea cucumbers. Other villages on Moala did not seem as developed so likely not involved in the harvest in 2010
Fulaga	Company operating under local fisherman as village project. Village has earned $24K so far, but hoping for $3.5M. Villagers want to put earnings toward household needs. Harvested most of catch from islands in the uninhabited Yagasa cluster because couldn't find many in Fulaga. However, we casually observed many in seagrass areas and Living Oceans Foundation groundtruthing team saw some from drop camera footage in lagoon. Fisheries Department did not observe many on transect surveys.
Kabara	Company came through in April 2013. Harvested 1 week at Kabara, 1 day at Tuanasici, and 1 month Vuaqara. Community only made $24K - put all into church. Potentially not ideal habitat for sea cucumber on Kabara or had been previously seriously depleted. Company short-changed the community on price - for example, paid out only $40/piece for white teatfish, while fishers at Fulaga getting $170/dried kg. Company ripped out harvest records from Mata ni Tikina's notebook when he was away.
Vanua Vatu	No harvesting using SCUBA because under Roko Sau Josefa Cinavilakeba's domain, but commercial harvesting is active using free diving. Only recorded low value dried samples from catch. Youth (18-19 yrs) involved in individual harvesting.
Nayau	Low value species being harvested by communities. Planning to engage a company.
Tuvuca	Village got cheated by company in 2012 that harvested sea cucumber on mass scale and told community that they could not pay out because they were running at a loss. There were no written agreements with chief.
Cicia	Measured very small dried individuals of white teatfish, which indicate some recruitment fairly recently. Haven't had any commercial harvesting of late. Not many people haresting. Communities put motion to Bose ni Tikina to harvest with UBA, but Mata ni Vanua stopped this motion
Vanuabalavu	In Susui village, the FLMMA Lau representative came to the FLMMA Lau Provincial learning meeting in 2012 in Suva and then linked up with an Asian company which he brought back to harvest all of the sea cucumber from the village tabu area. This caused an uproar in the village. Mavana village tabu area, established in 2007, highest density of total sea cucumbers recorded. In Avea village, individuals harvest sea cucumber every day by free diving with bombs and they are reporting getting undersized specimens. Several residents paralyzed from diving with UBA when company was operating here and at least 4 deaths from

	Avea village. Previous Fisheries officer Babitu stationed here was instrumental in getting island-wide ban on UBA and was very vigilant about searching incoming vessels to make sure they were not going to harvest sea cucumber with UBA.
General	In all cases on islands, typically just a few people doing the harvesting. Many divers using "bombs" (weighted lines with hooks) so that they can access deeper individuals. A lot of catch is coming from adjacent, uninhabited islands.

Discussion

Our underwater surveys of sea cucumber populations suggest that the fishery is in severe decline to collapse on the 10 islands surveyed in Lau Province. Population densities in most cases were far below levels observed from sites on Viti Levu and Vanua Levu in Fiji in 2003 (Friedman et al. 2011) and were generally below the suggested threshold within-species density of 10-50 individuals ha^{-1} required to avoid depensation (Bell et al. 2008). The exceptions were from the low value species *Holothuria edulis* and *Pearsonothuria graeffei*, in particular on Totoya and Vanuabalavu islands where *P. graeffei* is within range of SPC recommended density for a healthy population (though not *H. edulis*). Otherwise, species density across the Lau islands surveyed was <1 individual ha^{-1} in many cases (Annex 2), far below the level required for successful reproduction though similar to levels reported from Milne Bay, Papua New Guinea, and Red Sea, Egypt, with high levels of exploitation (Skewes et al. 2002; Hasan 2005). While baseline densities are unknown for most species, there are reports of densities of blackfish (*Actinopyga miliaris* and an unknown *Actinopyga* sp.) from the northwest lagoon of Vanua Levu, Fiji, ranging between 250 – 78,900 individuals ha^{-1} from 1988 (Friedman et al. 2011).

Overall densities across all depths and habitats are likely slightly higher than we were able to measure with our survey techniques. Manta tows, in particular, may underestimate counts of species that are able to hide under reef ledges and within crevices (Figure 2). In addition, we restricted our diving on SCUBA generally to depths above 20 m. Given the high proportion of fishers using bombs to harvest sea cucumbers, it is likely that deeper depths are still providing a refuge. However, the spatial dispersion of individuals still may remain an issue. We tended to see solitary individuals, though Bell et al. (2008) suggest that there need to be groups of >10 sea cucumbers in which individuals are separated by no more than 5–10 m in order to achieve reproductive success.

Figure 2. *Actinopyga mauritiana* (surf redfish) wedged under a reef ledge in the shallow forereef area of Mago Island. Photo © Stacy Jupiter

Mean sizes of sea cucumber species measured underwater were generally above minimum recommended wet sizes, with the exception of *Holothuria atra* and *P. graeffei.* The general absence of very small sea cucumbers on the reef is of concern, however, and may be indicative of recruitment failure. Village measurements of dried samples indicate that many undersized individuals of *Actinopyga lecanora, Bohadschia vitiensis* and *H. atra* are being harvested, as well as almost all species harvested from Matuku Island reefs (Appendix 3). As prices have increased due to reduction in supply, fishers have not yet been proactive about management measures given that they are still able to meet their daily needs with income derived from bêche-de-mer. Fisher responses, however, suggest that income is being used to meet more than just household needs. For example, respondents reported using income to build houses in Suva and pay secondary and tertiary education expenses for their children. Such cash demands are driving exploitation to critical levels.

Conclusions and Recommendations

The sea cucumber fishery in Lau has declined in tandem with an increase in the number of exemptions for harvesting sea cucumbers using UBA. *We strongly encourage the Fiji government to halt issuance of exemptions for harvest with UBA.* In the interim, we encourage the following measures to improve dive safety and sustainability of harvests:

- Develop dive safety training and guidelines in *iTaukei* (Fijian) language to be distributed to all commercial operators harvesting sea cucumbers in Fiji.
- Produce an educational video showing the dangers and impacts of exceeding depth limits, using true stories from local fishers.
- Encourage communities to develop formalized, written agreements with companies that include bonds for payout of compensation to local fishers if they suffer a dive-related accident (and are not clearly at fault).
- Ensure that divisional fisheries officers are vigilant about checking boats for unlicensed UBA.

In addition, other active management measures should be undertaken to preserve remaining stocks and encourage population recovery. Such measures can include:

- A complete ban on sea cucumber harvest for a set period of time (e.g. 5 years).
- A ban on the use of 'bombs' with free diving to allow for persistence of deeper populations to replenish stocks.
- Distribution of recommended minimum wet and dry size limits to enable individuals to reproduce.
- A harvesting ban that is triggered when monitoring of dried bêche-de-mer sizes by divisional fisheries officers indicates that stocks have fallen below minimum recommended sizes.
- Establishment of new no-take areas (*tabu*) in areas that are easily enforceable. Our analyses indicate that tabu areas surveyed by belt transect contained significantly greater total abundance of sea cucumbers than in fished areas. In particular, the tabu area

established in 2007 in front of Mavana Village on Vanuabalavu Island stood out with densities of 97 total individuals ha^{-1}.

- Sea ranching though movement of wild-caught or hatchery-reared individuals into new or existing tabu areas (Bell et al. 2008; Purcell et al. 2012).
- Development of alternative livelihood initiatives (e.g. copra farming, organic farming, honey, seaweed farming) to relieve pressure from sea cucumber harvesting.

We recommend that different measures be carried out and assessed across different communities to determine which combination of measures is most suitable to the local context in terms of recovering populations to densities that can yield sustainable harvests.

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Annex 1. Location and characteristics of direct in-water resource assessments for sea cucumber populations. Geographic information for manta tow stations is given as the mid-point of the station.

Date	Island	Station	Lat	Lon	Method	Bottom	Mgmt Status	Reef Habitat	# transects	Area (m2)
3/06/2013	Totoya	TOYD01	-18.99603	-179.90331	Dive	Hard	Open	Backreef	6	240
3/06/2013	Totoya	TOYM01	-19.00221	-179.88438	Manta	Hard	Open	Fringing	6	3600
3/06/2013	Totoya	TOYM02	-18.99042	-179.86424	Manta	Hard	Open	Fringing	6	3600
4/06/2013	Totoya	TOYD02	-18.99808	-179.84731	Dive	Hard	Tabu	Backreef	6	240
4/06/2013	Totoya	TOYM03	-18.94777	-179.85947	Manta	Hard	Open	Fringing	6	3600
5/06/2013	Totoya	TOYM04	-18.97486	-179.78406	Manta	Hard	Tabu	Backreef	6	3600
5/06/2013	Totoya	TOYM05	-18.96466	-179.79494	Manta	Hard	Tabu	Fringing	6	3600
5/06/2013	Totoya	TOYM06	-18.91746	-179.86757	Manta	Hard	Open	Fringing	6	3600
5/06/2013	Totoya	TOYM07	-18.92721	-179.8291	Manta	Hard	Open	Fringing	6	3600
5/06/2013	Totoya	TOYM08	-18.89876	-179.88112	Manta	Hard	Open	Backreef	3	1800
6/06/2013	Matuku	MTKM01	-19.12299	179.78307	Manta	Hard	Open	Forereef	6	3600
6/06/2013	Matuku	MTKM02	-19.14639	179.7923	Manta	Hard	Open	Forereef	6	3600
6/06/2013	Matuku	MTKM03	-19.16072	179.73337	Manta	Hard	Open	Fringing	6	3600
6/06/2013	Matuku	MTKM04	-19.1449	179.74231	Manta	Hard	Open	Fringing	6	3600
7/6/2013	Matuku	MTKM05	-19.17217	179.7291	Manta	Soft	Open	Forereef	1	600
7/06/2013	Matuku	MTKD01	-19.17247	179.73183	Snorkel	Soft	Open	Seagrass/algae	6	240
7/06/2013	Matuku	MTKD02	-19.17185	179.73366	Snorkel	Soft	Open	Seagrass/algae	6	240
7/06/2013	Matuku	MTKD03	-19.16764	179.74004	Snorkel	Soft	Open	Seagrass/algae	6	240
7/06/2013	Matuku	MTKD04	-19.16655	179.74019	Snorkel	Soft	Open	Seagrass/algae	3	120
7/06/2013	Matuku	MTKD05	-19.16551	179.74036	Snorkel	Soft	Open	Seagrass/algae	5	200
8/06/2013	Moala	MOALD01			Snorkel	Hard		Fringing	6	240
8/06/2013	Moala	MOALM01	-18.55581	179.93556	Manta	Hard	Tabu	Fringing	6	3600
8/06/2013	Moala	MOALM02	-18.56819	179.88028	Manta	Hard	Open	Fringing	6	3600
8/06/2013	Moala	MOALM03	-18.5966	179.95146	Manta	Hard	Open	Backreef	6	3600
8/06/2013	Moala	MOALM04	-18.6091	179.93977	Manta	Hard	Tabu	Backreef	6	3600

10/06/2013	Moala	MOALM05	-18.64324	179.84418	Manta	Hard	Open	Backreef	6	3600
10/06/2013	Moala	MOALM06	-18.6332	179.91792	Manta	Hard	Open	Backreef	6	3600
10/06/2013	Moala	MOALD02	-18.55585	179.92607	Dive	Soft	Open	Coastal sediment	10	400
11/06/2013	Fulaga	FULD01	-19.1011	-178.6011	Dive	Hard	Open	Forereef	6	240
12/06/2013	Fulaga	FULD02	-19.1299	-178.6174	Dive	Hard	Open	Forereef	6	240
13/06/2013	Kabara	KABD01	-18.9414	-178.9847	Dive	Hard	Open	Forereef	6	240
13/06/2013	Kabara	KABD02	-18.9194	-178.9577	Dive	Hard	Open	Forereef	8	320
13/06/2013	Kabara	KABD03	-18.9136	-178.9455	Dive	Hard	Open	Forereef	8	320
14/06/2013	Kabara	KABM01	-18.92183	-178.95699	Manta	Hard	Open	Fringing	6	3600
14/06/2013	Kabara	KABM02	-18.92597	-178.97246	Manta	Hard	Open	Fringing	6	3600
14/06/2013	Kabara	KABD04	-18.9228	-178.9363	Dive	Hard	Open	Forereef	6	240
15/06/2013	Vanua Vatu	VAND01	-18.35836	-179.28477	Dive	Hard	Open	Forereef	6	240
15/06/2013	Vanua Vatu	VAND02	-18.36626	-179.28088	Snorkel	Soft	Open	Fringing	6	240
15/06/2013	Vanua Vatu	VAND03	-18.36351	-179.28044	Snorkel	Soft	Open	Fringing	6	240
17/06/2013	Tuvuca	TVCM01	-17.69088	-178.82195	Manta	Soft	Tabu	Seagrass/algae	6	3600
17/06/2013	Tuvuca	TVCM02	-17.69452	-178.79724	Manta	Soft	Tabu	Seagrass/algae	6	3600
17/06/2013	Tuvuca	TVCM03	-17.65435	-178.81456	Manta	Soft	Tabu	Seagrass/algae	6	3600
18/06/2013	Cicia	CICD01	-17.72433	-179.32991	Snorkel	Soft	Tabu	Seagrass/algae	6	240
18/06/2013	Cicia	CICD02	-17.72341	-179.32739	Snorkel	Soft	Tabu	Seagrass/algae	6	240
18/06/2013	Cicia	CICD03	-17.72634	-179.33247	Snorkel	Soft	Open	Seagrass/algae	6	240
19/06/2013	Cicia	CICD04	-17.72395	-179.33868	Dive	Hard	Open	Forereef	12	480
19/06/2013	Cicia	CICD05	-17.77107	-179.34439	Dive	Hard	Open	Forereef	8	320
19/06/2013	Cicia	CICM01	-17.71646	-179.32364	Manta	Hard	Open	Forereef	6	3600
20/6/2013	Mago	MAGD01	-17.45136	-179.19031	Dive	Hard	Open	Forereef	12	480
20/6/2013	Mago	MAGD02	-17.4231	-179.17303	Dive	Hard	Open	Forereef	8	320
20/6/2013	Mago	MAGM01	-17.44574	-179.18945	Manta	Hard	Open	Forereef	6	3600
20/6/2013	Mago	MAGM02	-17.41843	-179.13451	Manta	Hard	Open	Forereef	6	3600
21/6/2013	Vanuabalavu	VBLM01	-17.17945	-179.05447	Manta	Soft	Open	Backreef	6	3600
21/6/2013	Vanuabalavu	VBLD01	-17.2376	-179.0386	Dive	Hard	Open	Forereef	6	240

22/6/2013	Vanuabalavu	VBLM02	-17.16242	-179.04268	Manta	Soft	Open	Fringing	6	3600
22/6/2013	Vanuabalavu	VBLM03	-17.17009	-178.895	Manta	Soft	Open	Forereef	6	3600
22/6/2013	Vanuabalavu	VBLM04	-17.21187	-178.92796	Manta	Soft	Tabu	Fringing	6	3600
22/6/2013	Vanuabalavu	VBLD02	-17.16762	-178.89862	Dive	Soft	Open	Coastal sediment	12	480
22/6/2013	Vanuabalavu	VBLD03	-17.21139	-178.9287	Dive	Soft	Tabu	Fringing	12	480
23/6/2013	Vanuabalavu	VBLD04	-17.1206	-178.8265	Dive	Hard	Open	Forereef	6	240
23/6/2013	Vanuabalavu	VBLD05	-17.1518	-178.8512	Dive	Hard	Open	Forereef	6	240
24/6/2013	Vanuabalavu	VBLD06	-17.2824	-178.9267	Dive	Hard	Tabu	Patch reef	8	320
24/6/2013	Vanuabalavu	VBLD07	-17.28304	-178.96449	Dive	Hard	Open	Patch reef	8	320
24/6/2013	Vanuabalavu	VBLD08	-17.3364	-178.86	Dive	Hard	Open	Backreef	6	240
24/6/2013	Vanuabalavu	VBLM05	-17.25729	-178.94151	Manta	Hard	Tabu	Fringing	6	3600
24/6/2013	Vanuabalavu	VBLM06	-17.27106	-178.97137	Manta	Hard	Tabu	Fringing	6	3600
25/6/2013	Vanuabalavu	VBLD09	-17.36784	-178.8858	Dive	Soft	Open	Backreef	12	480
25/6/2013	Vanuabalavu	VBLD10	-17.34623	-178.87129	Dive	Soft	Open	Fringing	12	480
25/6/2013	Vanuabalavu	VBLM07	-17.37575	-178.89346	Manta	Soft	Open	Fringing	6	3600
25/6/2013	Vanuabalavu	VBLM08	-17.36305	-178.88419	Manta	Hard	Open	Fringing	6	3600
25/6/2013	Vanuabalavu	VBLM09	-17.27894	-178.79349	Manta	Hard	Open	Fringing	6	3600
26/6/2013	Vanuabalavu	VBLM10	-17.1052	-178.68365	Manta	Soft	Open	Backreef	6	3600
26/6/2013	Vanuabalavu	VBLM11	-17.10299	-178.77678	Manta	Hard	Open	Backreef	6	3600
26/6/2013	Vanuabalavu	VBLD11	-17.11999	-178.6987	Dive	Soft	Open	Backreef	12	480
26/6/2013	Vanuabalavu	VBLD12	-17.09547	-178.77438	Dive	Hard	Open	Forereef	12	480

Annex 2. Density (individuals ha^{-1}) of sea cucumber species by island. Values in parenthesis are 1 standard error. Dashes indicate that surveys using particular method indicated were not performed on the island.

Species	Cicia	Fulaga	Kabara	Mago	Matuku	Moala	Totoya	Tuvuca	Vanua Vatu	Vanua-balavu	Healthy density[a]
Actinopyga miliaris[2]	0	0	0	25.0 (17.2)	-	-	0	-	0	0	50
Bohadschia argus[1]	0		0	0	0	1.39 (1.47)	0	0.93 (0.93)		0.26 (0.26)	31
Bohadschia argus[2]	0	0	0	0	-	-	0	-	0	7.81 (7.81)	
Bohadschia argus[3]	13.89 (13.89)	-	-	-	0	0	-	-	0	0	
Bohadschia vitiensis[1]	0	-	0	0	0	0	0.37 (0.37)	0	-	0	153
Pearsonothuria graeffei[1]	0	-	0	0	0	0.46 (0.46)	0	0	-	3.65 (1.26)	36
Pearsonothuria graeffei[2]	0	0	8.93 (8.93)	0	-		20.83 (20.83)	-	0	132.81 (43.48)	
Pearsonothuria graeffei[3]	0	-	-	-	0	25	-	-	0	72.92 (31.92)	
Holothuria atra[1]	5.56 (3.51)	-	0	1.39 (1.39)	0	0	2.22 (1.01)	0	-	3.13 (1.52)	2083
Holothuria atra[2]	0	0	0	0	-	-	0	-	0	3.91 (3.91)	
Holothuria atra[3]	13.89 (13.89)	-	-	-	0	0	-	-	0	0	
Holothuria edulis[1]	0	-	0	0	0.67 (0.67)	1.39 (0.78)	27.41 (13.33)	1.85 (1.27)	-	14.32 (5.35)	232
Holothuria edulis[2]	0	0	17.86 (12.39)	0	-	-	0	-	0	0	
Holothuria edulis[3]	0	-	-	-	0	0	-	-	0	20.83 (10.08)	
Holothuria fuscogilva[1]	0	-	0	0	0	0.46 (0.46)	0	0	-	0	28
Holothuria fuscopunctata[3]	0	-	-	-	0	0	-	-	0	5.21 (5.21)	10

Holothuria whitmaei[2]	12.5 (12.5)	0	0	0	-	-	0	-	0	3.91 (3.91)	207
Stichopus chloronutus[1]	2.78 (2.78)	-	0	0	0	0.93 (0.65)	2.22 (1.25)	0	-	0.52 (0.37)	878
Stichopus hermanni[1]	0	-	0	0	0	1.39 (1.39)	0	0	-	0	
Thelenota ananas[1]	0	-	0	0	0	0.46 (0.46)	0.74 (0.52)	0	-	0	27
Thelenota anax[1]	0	-	1.39 (1.39)	0	0	0.46 (0.46)	2.59 (1.49)	0	-	0	
Thelenota anax[2]	0	0	0	0	-	-	0	-	0	3.91 (3.91)	12

[a] SPC, unpublished data
[1] Measured from manta tow surveys [2] Measured from hard benthos belt dive transects [3] Measured from soft benthos with a combination of belt snorkel and deeper SCUBA surveys

Annex 3. Mean size of dried sea cucumbers measured from villages on indicated islands in Lau Province. Red values indicate average size of dried individuals within a species is below minimum size limits recommended by SPC.

Species	Common name, *Fijian names*	SPC min dry size (cm)	Island	Mean size (cm)	#	% below min size
Actinopyga lecanora	Stonefish	15	Matuku	11.9	8	100
	Dritabua, Drivatu		Totoya	14.0	34	56
			Tuvuca	13.5	2	100
species total				13.6	44	72
Actinopyga mauritiana	Surf redfish	10	Cicia	15.0	1	0
	Tarasea		Kabara	10.6	26	23
			Matuku	7.4	72	88
			Totoya	10.3	40	45
			Tuvuca	10.5	40	23
species total				9.3	179	55
Actinopyga miliaris	Blackfish	10	Fulaga	16.0	1	0
	Dri, Driloa		Matuku	12.0	2	0
			Tuvuca	17.0	1	0
species total				14.3	4	0
Bohadschia argus	Tigerfish	15	Cicia	21.3	44	0
	Tiger, Vula ni cakau, Vula wadrawadra		Fulaga	18.0	48	13
			Kabara	26.0	2	0
			Matuku	14.9	33	48
			Totoya	22.0	1	0
			Tuvuca	18.0	61	10
			Vanua Vatu	16.0	6	17
species total				18.2	195	15
Bohadschia similis	Chalkfish	10	Totoya	20.0	1	0
	Mudra					
Bohadschia vitiensis	Brown sandfish	15	Cicia	20.2	36	0
	Vula		Fulaga	10.3	7	100
			Kabara	20.0	2	0
			Matuku	13.2	37	68
			Totoya	17.1	11	18
			Tuvuca	15.1	68	38
			Vanua Vatu	13.6	5	40
species total				15.7	166	37
Holothuria atra	Lollyfish	15	Cicia	21.1	5	0
	Loliloli, Loli ni cakau		Kabara	11.0	2	100
			Matuku	13.7	21	62

Holothuria atra	Lollyfish *Loliloli, Loli ni cakau*		Totoya Tuvuca	18.0 12.7	1 67	0 78
species total				13.3	96	70
Holothuria edulis	Pinkfish *Loli piqi*	10	Matuku Totoya	12.1 9.0	7 1	0 100
species total				11.8	8	13
Holothuria fuscogilva	White teatfish *Sucuwalu*	15	Cicia Fulaga Kabara Matuku Moala Totoya Tuvuca Vanua Vatu	19.4 22.3 23.0 16.8 21.5 21.3 23.0 15.0	4 85 2 11 2 49 3 1	0 0 0 45 0 0 0 0
species total				21.5	157	3
Holothuria fuscopunctata	Elephant trunkfish *Tinani dairo, Dairo ni Toba*	15	Fulaga	22.4	10	0
Holothuria whitmaei	Black teatfish *Loaloa*	15	Cicia Fulaga Kabara Matuku Totoya Vanua Vatu	23.1 20.0 21.5 20.7 16.0 10.0	6 3 2 3 2 1	0 0 0 0 0 100
species total				20.3	17	6
Pearsonothuria graeffei	Flowerfish *Senikau*	20	Matuku	12.6	37	100
Stichopus chloronotus	Greenfish *Barasi*	10	Matuku	12.6	43	12
Thelenota ananas	Prickly redfish *Sucudrau*	15	Fulaga Totoya	22.8 17.6	12 10	0 10
species total				20.5	22	5
Thelenota anax	Amberfish *Basi*	15	Matuku Totoya	24.0 19.8	1 25	0 8
species total				20.0	26	8