FIJI LIVE ROCK HARVESTING ASSESSMENT
Findings and recommendations

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Introduction

In 2002, Fiji's Department of Environment (DoE) responded to Cabinet's concerns about coral and live rock harvesting and entered into an agreement with IMA, an international and locally based NGO, to undertake a study of aquarium coral and live rock harvesting in Fiji looking at whether or not this export trade was being carried out sustainably and without serious environmental impacts.

To support the study, IMA secured phase 1 funding in the US from the Oak Foundation enabling IMA, Hawaii's Bishop Museum and Fijian marine scientists to start field studies in September and December 2002. IMA-Fiji local staff and consultants from the University of the South Pacific (USP) also worked throughout 2002 on the assessment holding a National Coral Trade Workshop at Votualailai village on the Coral Coast in July 2002.

IMA applied in 2003 to the US National Oceanographic and Atmospheric Administration (NOAA) for funding to complete the study given US and CITES interest in Fiji managing this trade along sustainable lines. In October 2004 NOAA entered into an agreement with IMA and released funds for the live rock study enabling IMA staff to complete the field work in November and December 2004. Fiji's DoE also entered into an agreement with IMA in December 2004 to expedite completion of this study, providing matching funds for the assessment.

During this same two year period, TRAFFIC Oceania South Pacific Programme and World Wildlife Fund (WWF) in association with the CITES Secretariat started a process to assist Fiji with non-detriment finding methodology for the extraction of and trade in marine aquarium species, also helping Fiji enact the Endangered and Protected Species Act (2002) and Regulations (2003), establishing quotas for the export of aquarium fish, live corals and live rock. In addition, over the last few years, the Marine Aquarium Council (MAC) introduced certification for companies involved in Fiji in the collection and handling of marine ornamental (aquarium) organisms. The Foundation of the People of the South Pacific International (FSPI) secured SPREP funding to assess the socio economic value of the trade, in the latter part of 2004.

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Under its agreements with Fiji's DoE and NOAA, IMA presented interim findings and draft recommendations for live rock harvesting and culture in December 2004 at the end of the field work period. This is the final report presenting findings and recommendations from the live rock study, with supporting documents, data analyses and digital images.

Commercial environment in Fiji

At this time[3] within the aquarium trade in Fiji five companies are involved in harvesting live coral, cultured coral, live aquarium fish, live rock and cultured live rock for export:

Aquarium Fish Fiji	established 1984
Waterlife Exporters	1984
Ocean 2000	1995
Walt Smith International	1995
REL Fisheries	2001

Four of these companies mine live rock from the reef (Aquarium Fish Fiji does not[4]). Previously, there were three additional companies involved in harvesting live rock, fish and corals for one to three years but are no longer in business; known as: Tropical Fish Fiji (formerly South Seas Export Ltd.), Viti Mari Ornamentals and Marisearch.

Coral and live rock harvesting for sale in the aquarium trade can be usefully distinguished from coral harvesting for the curio or decorative trade. When IMA initiated this study in 2002 there were two companies in Fiji harvesting live corals for bleaching and export (by the container-load) as dead or curio corals and for medicinal purposes - Seaking Trading and Acropora International. Now, Seaking no longer harvests corals in Fiji but imports and re-exports these products. Acropora International went out of business. Observations made by Coles in this report (appendix one) suggest that the collection of curio corals as it was being conducted up to 2002 for example in the Nadogoloa area was damaging to the reef environment and unsustainable in the long term.

[3] December 2004 – the completion of the field studies.
[4] Widely understood as not harvesting live rock, although Lal and Cerelala (2005) show recent live rock exports.

Project Scope

For much of the past decade concerns have been voiced in Fiji (and internationally) about the sustainability of aquarium trade harvesting of corals, fish and live rock from the coral reefs of Viti Levu and neighboring islands. This report assesses environmental impacts and questions of sustainability for live rock harvesting with additional discussion and recommendations about the sustainability of live coral harvesting in Fiji, together with cultured coral and live rock alternatives.

As mentioned above, curio coral harvesting was a major concern at the time the study was being initiated in 2000-2. Recommendations are therefore included in this report about the curio coral trade. People were alarmed about the curio coral trade in Fiji being lumped in with the aquarium trade for management purposes since it had depended explicitly for years upon destructive harvesting of large quantities of live *Acropora* and other corals which were dried, bleached and shipped overseas by the container load (accompanied by huge wastages). Fortunately, harvesting stopped following disputes between the communities involved. However, national policies permanently banning the highly destructive practices associated with the curio trade are still needed.

In addition to improved national policies outlawing destructive practices, one of the critical challenges for management in Fiji has always been to assemble and compare enough objective data or information about all of these coral and live rock trades and their environmental impacts, to be able to make improved and consistent decisions about their sustainability and desirability. Another coral trade of concern which this study also evaluated is the domestic trade in *Porites lutea* or brain coral often seen cleaved, stacked in cairns and for sale on the side of the road in the Suva-Lami area and harvested from the surrounding reefs for use in septic systems. Coles in this report (appendix 2) estimates that 150,000 brain corals have been extracted by this trade over the past ten years and that this is non sustainable as demonstrated by expansion of the collection area from Suva Harbour to Nukalau island. Recommendations are to curtail this activity which is having a serious impact on a major component of coral communities in the Suva area; when at the same time alternative more modern materials could be substituted for use in septic systems.

The purpose of the study team, then, has been to objectively question the sustainability of such trades where they appear destructive. Our main focus is live rock and cultured live rock.

Live Rock

The following live rock data sets were made available to IMA during this study; each is discussed:

- 2000-4 export data for each company, from Fiji Ministry of Fisheries & Forests (MFF)
- 1997-2002 US import data provided by NOAA
- 1998-2004 village production data provided by Walt Smith International (WSI)
- 2001-2004 cultured live rock export data provided by WSI

Assembling these data sets was an achievement for everyone involved. It was also quite recent; less than a year ago there was no complete and reliable data set available in Fiji about live rock exports. When IMA started the study only ball-park estimates of Fiji's national export quantities of live rock were available since the data had been tallied from CITES permits. It turned out that a CITES permit pertained to a coming month's worth of shipments; the shipper naturally overestimated the quantity to avoid over-running what the CITES permit would allow. The actual export data from customs and freight forms did not get included in the data set, at first, leading to a significant over-estimate of Fiji's live rock exports and an early national data-set virtually unusable for management purposes. The lack of accurate data caused uncertainty and in 2003-4 under pressure from CITES, MFF started the long task of re-entering the actual export data, completing the data set for 2003 such that CITES had something on which to base quotas. More hard work by MFF staff led to a complete dataset being released recently in March 2005 for live rock exports for each company from 2000 to 2004. Table 1 below gives the MFF annual data and Appendix 3 the monthly data.

As a result of the data constraints, when IMA submitted its interim report at the end of the field work period in December 2004 only the export data for 2003 was available for analysis. However, with the data constraint mostly solved, table one and the graph below (figure 1) show the most complete 2000-2004 data set available for the four companies currently exporting live rock[5]. A fifth company (Aquarium Fish Fiji, previously South Seas Export Ltd.) stopped exporting live rock in 2001 and went out of business. Also in 2001 for some reason only an annual total is given for WSI (in appendix 1), there is no monthly data for WSI in 2001 in the MFF dataset.

[5] There has been limited QA/QC of the data - quality assurance or quality control – i.e. validation and double checking of the data. This analysis identified a few small gaps that are discussed below.

In table 1, the MFF data shows that Fiji exported a total of over 5,000 tonnes (5,054,852 kg.) of live rock from 2000-2004. During these five years the annual export quantities of live rock increased steadily from 790 tonnes in 2000 to 1,360 tonnes in 2004 (figure 1) - a seventy percent increase.

	WSI	Waterlife Exporters	Tropical Fish Fiji	REL	Ocean 2000	Total (kg)
2000	540,965	156,915	96,049	0	0	793,929
2001	605,620	178,500	128,085	0	0	912,205
2002	625,131	234,000	0	0	0	859,131
2003	592,277	58,588	0	317,978	156,689	1,125,532
2004	715,351	129,209	0	200,238	319,257	1,364,055
Total	**3,079,344**	**757,212**	**224,134**	**518,216**[6]	**475,946**[7]	**5,054,852**

Table 1: Fiji's live rock exports from 2000-2005, for each company (MFF data, in kg.)

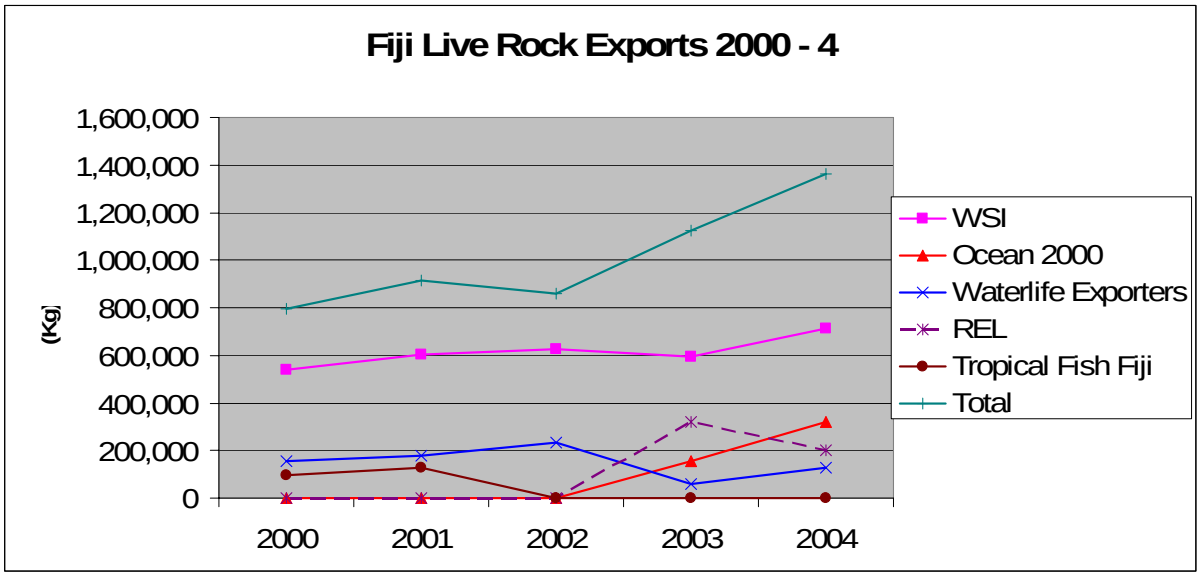


Figure 1: National and individual company exports of Fiji live rock 2000-4 (MFF dada)

According to the MFF data much of the increase in the last 2 years (2003-4) can be attributed to the apparent increased production by Ocean 2000 and REL. However, Ocean 2000 and REL are known to have mined live rock earlier than 2002 so there may be some gaps in the MFF data.

[6] REL stopped selling to WSI in 2001 (table 4), so MFF data for REL in 2002 may be missing.
[7] In 2001, Lovell reported that Ocean 2000 mined live rock in Malomalo for 4 years; so MFF data for Ocean 2000 before 2003 may be missing.

Over 5 years WSI shipped some 3,080 tonnes or 61% of the total. Waterlife Exporters sold 760 tonnes over 5 years or 15% of the national MFF total. REL and Ocean 2000 shipped 520 and >480 tonnes (10% and >9%) respectively. In 2003/2 REL's production split-off from WSI; their production combined for 2003 and 2004 was 910 tonnes (81%) and 916 tonnes (67%) respectively.

This MFF data has only recently become available supporting an industry wide view of the extent of live rock harvesting in Fiji. Prior to this, given the uncertainty surrounding CITES export figures, the only data sets available for enumerating the size and structure of Fiji's live rock industry were preliminary NOAA/USFWS live rock import data for 1997-2002 (table 2) and company data such as WSI village production data for 1998-2004, discussed below. Both data sets were made available in November 2004 and used in IMA's interim report to provide rough estimates of live rock production for Fiji. However, with the more complete MFF data for 2000-4, on comparing Fiji's live rock export data in table 1 with the NOAA/USFWS data in table 2, for the three overlapping years 2000-2, the US import data seems to *overestimate the quantities of live rock* from Fiji[8]. Nevertheless in the US import records a doubling in live rock exports was evident from 1997 to 2000. The MFF export data shows a doubling between 2000 and 2004 to nearly 1,400 tonnes/year.

	wt. of live rock	# permits
1997	551,000 kg	275
1998	791,737 kg	360
1999	904,534 kg	412
2000	1,119,000 kg	473
2001	1,197,020 kg	569
2002	1,149,947 kg	463

Table 2 – US import data for Fiji

Commercial live rock mining was taking place on the Coral Coast (Vatukarasa) in 1992-5 having started in 1990-1 following Fiji Fisheries surveys (Vatukarasa CAMP[9]). An important question in the assessment – of what is essentially a non renewable resource - is whether we can calculate how much live rock has been mined since it started in Fiji. MFF's dataset for 2000 to 2004 indicates that Fiji exported over 5,050 tonnes of live rock during these five years. Prior to that, data is less reliable. The 1997 to 1999 NOAA/USFWS import data (table 2) shows over 2,000 tonnes[10] of live rock imported to the US, which when combined with the MFF data suggests Fiji exported at least 7,000 tonnes of live rock over eight years from 1997-2004. This figure is developed further below.

[8] imported to the US. 85% of Fiji's live rock exports are to the US (Bruckner, pers.com)
[9] Vatukarasa Collection Area Management Plan (CAMP) for WSI with Marine Aquarium Council (MAC), 2003.
[10] Comparison of tables 1 and 2 shows for 2000-2 the US import data was consistently higher than the Fiji MFF export data. There's uncertainty if NOAA/USFWS data is exclusively live rock. Or, is the MFF dataset missing data? We have to assume either a) 1997-99 was overestimated also, so 2,247.3 tonnes imported is around 1,700 tonnes; or b) the MFF dataset is missing data, such as Ocean 2000 pre-2003 possibly as far back as 1996 or 97, and REL 2002.

Live rock mining areas and production intensity

Table three and figure 2 show the main villages in Fiji where live rock has been mined from reefs by communities and sold to the aquarium companies. Each village has a company agreement[11].

Company (founded)	Mining villages	Coastal area	Map Area
WSI (1995)	Vatukarasa - see map ref.(i)	Coral Coast, East of Sigatoka	1
	Namada - (ii)	Coral Coast, East of Sigatoka	1
	Nakelo	East of Suva and Nausori	2
	Sanasana - (iii)	West of Sigatoka	3
	Nabukavesi	Between Navua[12] and Suva	4
Waterlife Exporters ('84)	Navunisoco, Nabukavesi to Namuka Harbor	Between Navua and Suva	4
REL (2000)	Nakelo	East of Suva	2
	Navunisoco, Nabukavesi to Namuka Harbor	Between Navua and Suva	4
Ocean 2000 (1995)	Nabukavesi, Nabukebuke	Between Navua and Suva	4
	Kaba and Malomalo	West of Sigatoka	3
No longer in operation:			
Tropical Fish Fiji (? - 2002) formerly S.Seas Exporters('92-)	Komave Vatukarasa	Coral Coast, East of Sigatoka	1
Viti-Mari Ornamentals(2001-2)	Lautoka	North of Nadi	n/a

Table 3 Live rock collection areas for each company

Figure 2 – Map showing live rock mining areas in Fiji
From west of Sigatoka near Nadi, along the Coral Coast towards Nausori east of Suva

[11] Supposedly a Fiji Fisheries one-area-one-company policy, which has worked for a while until companies started concentrating recently from Navua to Suva (area 4). Mining has ended in area 3 and almost stopped in area 1.
[12] East of Pacific Harbour

Four distinct live rock mining regions can be described (moving west to east) along the Coral Coast:

- the fringing reefs of **Malomalo**, **Sanasana** and **Kaba** villages west of Sigatoka and just to the south of Nadi (map area 3);
- the fringing reefs of **Vatukarasa**, **Namada** and **Komave** villages east of Sigatoka (map area 1);
- the fringing lagoonal and barrier reefs of **Nabukavesi**, **Navunisoco**, **Namuku** and **Muaivuso** west of Suva (map area 4); and
- the **Nakelo** area off Nausori, east of Suva (map area 2).

The history of live rock in Fiji may be as follows. Live rock mining started after a Fiji Fisheries reef survey in 1990-91 in the Vatukarasa area (map area 1). From 1992 to 1995, South Seas Exporters purchased live rock from Vatukarasa. WSI then started buying live rock from Vatukarasa in 1996. Around the same time, Ocean 2000 began collecting in Malomalo (map area 3; too early or data missing from 2000-4 MFF data). Waterlife Exporters started closer to Suva (map area 4) in 1998. REL supplied WSI from the Nakelo reefs east of Suva (map area 2) and areas west of Suva (map area 4). Tropical Fish Fiji (formerly S.Seas Exporters) got going in Komave village (map area 1) around 1997 (went out of business in 2002). In 1999, WSI expanded to include neighboring Namada village reefs (map area 1) and four years later in 2002 (table 4 below) WSI started buying from Sanasana near Malomalo (map area 3). REL continued collecting (from map areas 2 and 4) but stopped selling to WSI in 2002, exporting independently, apparently using the same market chain.

In 2002/3, the paramount chief for the Malomalo-Sanasana area passed away and communities decided to discontinue mining live rock (map area 3). This affected WSI and Ocean 2000. By 2003-4, all four companies were buying from villages along the Navua to Suva coast (map area 4). In late 2004, the Namada community stopped except for a small area of reef (and asked Vatukarasa if they could mine their reef); and Vatukarasa was down to re-mining one reef (refused access to Malevu). By 2004 then most of the collection pressure was shifting from “historically” mined reefs west and east of Sigatoka on the Coral Coast, to reefs and communities along the Navua to Suva coastline.

This shift indicates the demand for live rock has exceeded what communities were able to mine or were *prepared* to mine (the quality of live rock also deteriorated and wastage increased) requiring companies to move to new areas. Live rock mining is not a renewable resource (see Coles, this report) and the shift away from Vatukarasa and Namada, as well as Malomalo, shows that it is non-sustainable for individual communities and reefs. Community awareness has been growing together with intolerance for the destructive impacts of live rock mining on their coral reefs.

Live rock resources in Fiji are not as unlimited, or the impacts of mining as benign, as first proposed with four companies recently moving into the same section of coastline (map area 4).

More detailed quantification of mining intensity and evaluation of sustainability were made possible by Walt Smith International (WSI) kindly making available data showing WSI's weekly live rock purchases from villages, from 1998 to present, summarized in table 4.

	Area 1	Area 1	Area 2/4	Area 3	Area 4	
Year	**Vatukarasa**	**Namada**	**Lote Rasiga**[13]	**Sanasana**	**Nabukavesi**	**Total tonnes**
1998	499.3		96.5			595.7
1999	412.7	197.9	250.0			860.5
2000	406.6	172.2	405.5			984.3
2001	397.5	195.3	255.5			848.3
2002	445.3	170.4		140.0		755.7
2003	476.4	154.4		42.1		672.9
2004[14]	173.9	82.3			91.0[15]	349.1
Total	**2,811.6**	**974.5**	**1,007.4**	**182.2**	**91.0**	**5,066.6**

Table 4: WSI live rock purchases from 1998 – 2004[6 months] **(in metric tonnes)**

WSI purchased over five thousand tonnes of live rock since 1998 (7 years) from at least 5 village collection areas along Fiji's south coast (table 4 and figure 2). The MFF data for 2000-4 showed WSI *exported* 3,080 tonnes or 61% of the total national production for this 5 year period, which tallies fairly well with WSI's figures of 3,600 tonnes *purchased* for 2000 to 2004 in table 4 above.

However, we saw above that live rock mining started in the early 90's and has involved more companies so in order to arrive at a figure of total exported live rock and to better assess impacts in the mining areas, we need to estimate missing data. In addition, there has to be a calculation of wastage, which is applied to the total exported live rock figure to calculate the *actual* quantities of live rock mined from the reef in the different areas. From this we might better evaluate impacts.

[13] Lote Rasiga = REL probably the Nakelo area and possibly Nabukavesi
[14] Until June 2004
[15] September – November 2004

The following table combines MMF (M) and WSI (W) data in tonnes from tables 1 and 4, and estimates missing data (E) based on survey information and tables 1, 2, 3 and 4. The missing data estimates (Est.) are combined with MFF and WSI data (from tables 1 and 4) to provide estimates of total live rock purchased from each of the map areas 1 through 4.

																Map area			
Co.	**Village**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**Est.**	**1**	**2/4**	**3**	
WSI	Vatukarasa					?	E	W	W	W	W	W	W	W	400	3212			
	Namada							W	W	W	W	W	W	W		975			
	LoteResega							W	W	W	W						1007		
	Nabukavesi													W			91		
	Sanasana											W	W					182	
WLE	NavuaSuva							E	E	M	M	M	M	M	300		1057		
SSE	Vatukarasa	E	E	E	E										400	400			
TFF	Komave						E	E	E	M	M				285	509			
REL	NavuaSuva											E	M	M	254		772		
O2000	NavuaSuva											E	M	M	150		626		
	Malomalo						E	E	E	E	E				750			750	
Total															2539	5095	3554	932	9581

Table 5 – Estimated Fiji live rock purchases by company in 4 areas, from 1992-2004 (tonnes)

MFF data for 2000-2004 showed Fiji exported at least 5,055 tonnes of live rock over 5 years (table 1). Further analysis suggested that REL and Ocean 2000 data was missing from this MFF data set and could be estimated (table 5). WSI data was complete back to 1998 (table 4), but has been estimated for 1997 (96?); as has data for the other companies prior to 2000.

As a result we can estimate that 9,580 tonnes of 'marketable' live rock has been purchased within Fiji from 1992 through 2004 (over 13 years). Of this total, the village reefs of Vatukarasa, Namada and Komave (map area 1) supplied an estimated 5,095 tonnes or 53% of Fiji's total exports. Most of this area's production was purchased by WSI over the last nine years and before that South Seas Exporters (SSE), plus Tropical Fish Fiji (TFF). Many of these reefs now no longer supply live rock.

The Nakelo/Navua-Suva reefs (map areas 2 and 4) have supplied an estimated 3,550 tonnes of live rock over eight years since 1997 (37% of the total exports) and continue to supply the four companies in 2004 and 2005 (with emerging conflicts, competition and disregard for the one-area-one-operator policy). For almost a seven year period, until 2003 when production stopped, the reefs adjacent to Malomalo, Sanasana and Kaba (map area 3) supplied WSI (182 tonnes) and Ocean 2000 (estimated 750 tonnes) totaling an estimated 930 tonnes of live rock (10% of the total).

In addition to calculating the production per region, we can use these estimates to calculate annual export quantities of Fiji live rock in table 6 in tonnes. These are derived from table 5, a combination of all of WSI's data (table 4), and MFF data (table 1) and estimates for the other companies.

Interestingly, if we then apply a factor of 0.85 which would be the proportion imported to the US and compare these figures with the NOAA/USFWS data for 97-02 in table 2, they are of similar proportions. This suggests the estimates may be fairly robust.

'92	**'93**	**'94**	**'95**	**'96**	**'97**	**'98**	**'99**	**'00**	**'01**	**'02**	**'03**	**'04**	**TOTAL**
100	100	100	100	?	645	991	1256	1388	1306	1393	1206	995	9580
85	85	85	85	?	548	842	1068	1180	1110	1184	1025	846	8143
NOAA/USFWS import data:					551	792	905	1119	1197	1149			
MFF data								794	912	859	1126	1364	

Table 6: Estimated annual exports and US imports (85%) of Fiji live rock (in tonnes) compared with 97-02 US import and 00-04 MFF data

Wastage and total production estimated

During discussions with communities and companies, live rock wastage or rejected proportions were assessed. This is important for determining the actual quantities of live rock mined from the reef and assessing the extent of impact. The MFF export figures discussed are for marketable rock – the end product - and WSI's for final purchase. The companies explained that the reject factor was 10 to 20% - not paid for because of poor quality - one of the criteria being that marketable rock must have more than 60% of the rock surface covered with the target purple coralline algae.

In addition, during the survey, community members mining the live rock on the reef from Namada and Vatukarasa also estimated that when breaking the reef with a crowbar about 25% of the target material is too small or immediately rejected and left to roll around on the reef. Also, of the material brought ashore on the *bilibili* or bamboo raft, the team loading the 60kg. plastic tubs said they used axes to knock off or discard an additional 25% of the rock. And, once the product was hauled to the factory (>3000 kg per truck) a further 25% of the rock was rejected by the buyer. (Inspection of one company's purchasing form for rock purchased from Namada on the 18 October 2004 showed that 29% of the rock had been rejected at the processing plant).

Multiplying these factors together[16] yields a wastage factor of 58% (lost) such that an estimated 42% of the material crowbarred from the reef makes it to the factory - purchased ("exported") by the company. Proportionally then, wastage equals 1.38 times what is purchased. Added together they equal the total quantity mined from the reef. This figure for the total mined is calculated in the last column of table 7, for each area; it is 2.38 times bigger than the estimated purchased production.

Area	Villages or coastal area	Collecting reefs[17]	Actual WSI and MFF data	Actual, plus estimated[18]	Total, including wastage
1	Vatukarasa Namada Komave	Oria & Navoto reefs Vunisese reef	2,811.6 974.5 224.1 **4,010.2**	3,611.6 974.5 509.1 **5,095.2**	8,595.6 2,319.3 1,211.7 **12,126.6**
3	Malomalo Sanasana	Koroniuniu reef Matanatoga reef	 182.2 **182.2**	750.0 182.2 **932.2**	1,785.0 433.6 **2,218.6**
2	Nakelo (E.Suva)		**2,849.8**	**3,553.8**	**8,458.0**
4	Navua to W.Suva				
	TOTAL (tonnes)		**7,042.2**	**9,581.2**	**22,803.3**

Table 7: Estimated total live rock production including wastage from 4 areas and reefs from 1992-2004 (in tonnes)

In summary then, if we apply a wastage factor of 58% (the cumulative wastage from each step between the reef and the factory-curing) then the estimated total quantity of live rock mined by communities between 1992 and 2004 increases from 9,580 tonnes to 22,800 tonnes.

The companies have acknowledged a 20% reject factor at the factory. However, this does not account for the losses on the reef at the time of crowbarring the material off the reef (estimated as 25%[19]), or at the time of sorting before putting in the truck (also estimated as 25%). More conservatively, if instead we assumed the factor was 20% for each of the three steps then it still adds up and the wastage is about equal to production sold (i.e. the total quantity mined is double). At 15% the ratio is down to 40:60 (the total quantity mined is 1.64 times).

[16] 0.75 cubed (what remains each time, cubed)
[17] Reef names: accurate for Vatukarasa/Namada; taken from map for Malomalo and Sanasana; and n/a from elsewhere
[18] From table 5
[19] Estimated by live rock mining communities

This enables us to conclude that between 15,000 and 23,000 tonnes of live rock and discarded reef rock were mined from the reefs in Fiji between 1992 and 2004. An estimated 9,580 tonnes of this live rock was exported (which is between 40 and 60% of what was mined, depending upon the wastage). We appear to have reliable data for over 7,000 tonnes of the exported live rock; about 75% of the estimated exports.

Table 7 above shows this analysis broken down for each of the four live rock mining areas (areas 2 and 4 are combined). Half of the mining total (53%) was from the Vatukarasa-Namada-Komave area; forty percent (37%) from the Nakelo/Navua-Suva reefs; and ten percent from Malomalo-Sanasana.

Calculating the impact

Given the level of detail provided by WSI's data (table 4) we can take a closer look at the mining in the Vatukarasa area. The Vatukarasa community mined its two reefs Oria and Navoto reefs either side of Sovi Bay between 1990/2 and 2004 (12-14 years). Recently Oria reef was placed off limits to live rock mining by their own community during this last year since the landowner and village decided to subdivide the adjacent coastal land for development purposes and felt the mining of the reef depreciated the value of the area.

Vatukarasa continued to mine Navoto reef and in late 2004 the reef was being re-mined again and was producing increasingly inferior quality rock. As rock ran out, the live rock miners from Vatukarasa had even asked their neighboring Malevu villagers if they could start to mine their reef (just beyond Navoto) but the answer had been "no".

Namada village in the other direction had also scaled back its live rock operation and limited it to the western end of their Vunisese reef. The tura ni koro (village headman) said in December 2004 this was soon to stop and the Namada live rock miners had been asking the Vatukarasa boys if they could mine over there.

All of which indicates that Vatukarasa's two reefs have been pretty-well mined out, which corresponds with the assessment of the study team that visited Oria and Navoto reefs periodically throughout the study.

Figure three shows a 1994 aerial photo of Vatukarasa's Oria and Navoto reefs. The fringing reefs along this stretch of Fiji's coastline are about 400 m. wide. Navoto reef is 1550m.long and Oria reef is 1000m.long; measuring (respectively) 62 and 40 hectares in area. The outer half of the reef is targeted for live rock, staying inside of the surf zone. Mining takes place closer inshore as the better live rock gets used up.

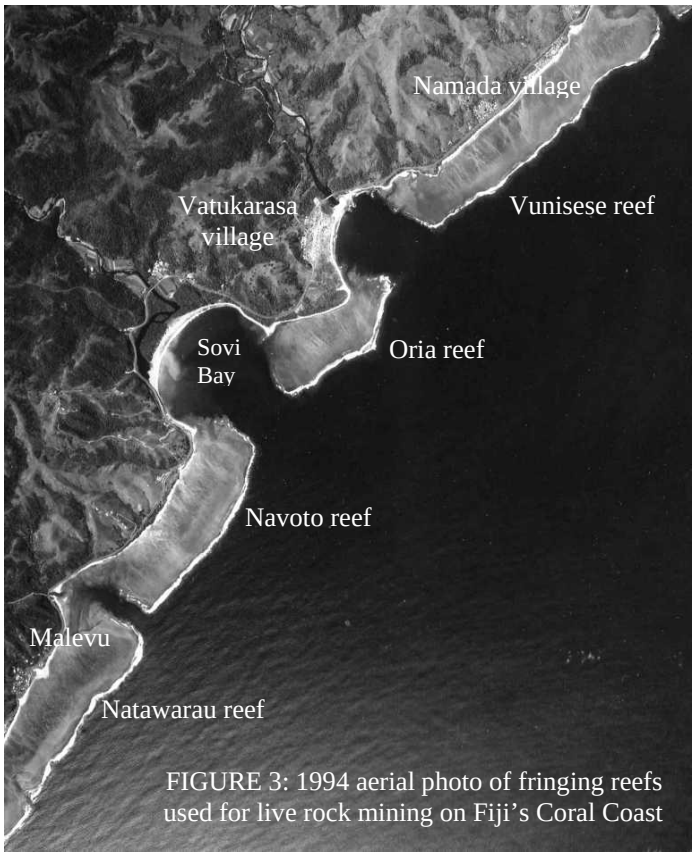


FIGURE 3: 1994 aerial photo of fringing reefs used for live rock mining on Fiji's Coral Coast

The estimated total live rock and discarded rock mined at Vatukarasa village (from Oria and Navoto reefs) from 1992 to 2004 was 8,600 tonnes.

If we assume that just half the area of the fringing reef provides suitable live rock (until it is used up) since the outer half of the reef is initially favored then Vatukarasa produced 8,600 tonnes of live and discarded rock from half of its reef area at Oria and Navoto reefs or approximately 51 hectares. This is equivalent to 169 tonnes per hectare (an area 100m x 100 m). If we also assume that after 12-13 years Vatukarasa has now been mined out of marketable live rock[20], then the Vatukarasa figures can provide a basis for estimating the total area of reef impacted by live rock mining in Fiji as well as how much live and discarded rock Fiji's reefs can be expected to produce.

The figure of 169 tonnes of live rock per hectare applies to the outer portion of the reef or more intensively targeted mining area. Once this part of the reef is used up, the collectors and their crow bars move inshore, but this doesn't last for long since the quality is poor. If we now include the area inshore – the other half of the reef – in the calculation so that we can apply the figure to reefs in general, then the production rate for live and discarded rock (from Vatukarasa data[21]) is 84 tonnes per hectare (of which 42% is estimated as marketable equivalent to 35 tonnes per hectare).

[20] Given the movement of the buyer out of this area, and the reported drop in quality, plus villagers' attempts to shift mining to neighboring reefs, and this study's observations that these reefs have been mined out of live rock.
[21] 8,600 tonnes of live and discarded rock mined from 100 hectares of Novato and Oria reefs over 13 years, 1992-2004.

Using this production rate of 84 tonnes per hectare, the 22,800 tonnes of live and discarded rock estimated as having been mined from Fiji's reefs since 1992 were extracted from some 272 hectares of fringing reef. This represents a total reef area equivalent in size to over 500 American football fields or 400 rugby pitches[22].

In each of the seven years therefore since 1998 when estimated live rock exports averaged 1,200 tonnes per year[23], when we include wastage, reef areas of 35 hectares equivalent to 50 rugby pitches or 65 Am. football fields has been mined each year to supply this live rock, and is still going on.

Figure 4: Map of Fiji's main island (grid length 50 km.)

Fiji's live rock mining has been taking place along Viti Levu's south or Coral Coast - approximately 150 km. in length (figure 4). All companies are however now concentrating on reefs in the eastern sector between Navua and Suva. Some of these reefs are further offshore.

[22] American football field w/end zones is 109.1m x 48.5m or 0.53 hectares; Rugby pitch is 100m x 70m or 0.7 hectares.
[23] Table 5 estimates/uses data not appearing in either the MFF or WSI data, and table 6 shows the estimated annual exports.

With significant conflicts occurring with tourism and many villages along the Coral Coast having preferred not to be involved in live rock mining it is reasonable to observe that within a few years most of the reefs on the south coast accessible to live rock companies will be exhausted. The Navua-Suva reefs although extensive have already supplied an estimated 8,500 tonnes of live and discarded rock (table 7). By comparison, Vatukarasa and Namada reefs supplied 12,000 tonnes of live and discarded rock before production wound down. It seems quite likely then that the Navua-Suva reefs will not supply much more.

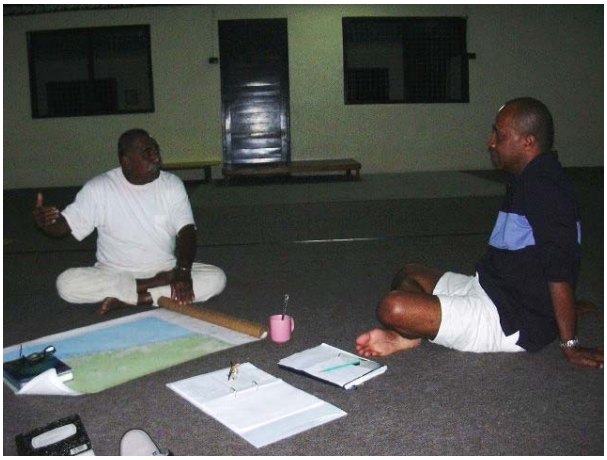
Reefs on the Coral Coast occupy a third of Viti Levu's 450 km. circumference (figure 4). Since mining first started, nearly all of Fiji's live rock has been extracted from only the Coral Coast. It seems reasonable to assume then that reefs elsewhere in Viti Levu are less suitable, even perhaps unsuitable, based on factors such as ease of access (cost) and conditions necessary for a high quality of coralline algae growth.

From a production and area perspective, then, live rock mining in Fiji as a whole is well past its prime and clearly non sustainable at both the local and national levels.

Underwater assessment of the impacts of live rock mining

During field studies throughout Viti Levu in September and December 2002, and November to December 2004, IMA scientists (including coral and marine biologists from the Bishop Museum in Hawaii and USP in Suva) spent a number of days and weeks underwater at Vatukarasa's two reefs, and at reefs opposite Namada and Malomalo studying the impact of live rock mining activity and making comparisons with areas that had not been harvested. Access was made possible through the support and participation of communities, village headmen and provincial government in all these areas visited. As discussed above the Coral Coast has been the center of Fiji's live rock industry.

Meetings were enjoyed with the people from Namada, Malomalo and Sanasana and others along the way especially on the Coral Coast. (A company closer to Suva said villagers were unfortunately "secretive" about where they harvested so access to the IMA team could not be easily granted). Elsewhere this wasn't the case and people were open and happy to discuss and show how they did things.



When live rock mining takes place, generally on a daily basis, teams of men with crowbars from each village typically wade out across the 3-400 metre wide fringing reefs at mid to low tides, initially targeting the shallow reef flats in an outer band 100 to 200 metre wide near the surf zone.

Namada - live rock mining - September 2002

Before mining, this part of the fringing reef flat or algal ridge would have been exposed at extreme low tides and originally consisted of consolidated coral rock and rubble derived from erosion of corals offshore and further inshore. Various types of algae including red coralline algae cement this rubble together forming the reef flat; also giving the live rock mined from this area its high qualities. Where the water is deeper, live corals and tropical seaweeds are found. On some of the reefs, the sections closer to the shoreline are knee and waist deep at low tide, creating shallow lagoons with an abundance of coral heads, seaweeds and fish, the latter often targeted by communities for subsistence purposes (in some cases using the fish poison duva, a type of vine).

The coralline algae covered rock targeted by the aquarium companies has to be broken from the reef using a crow bar, with the densest growth of coralline being on the underside and on shady sides of the rock. Mining of the best material takes place up to 50 metres from the surf line and was initially confined to the algal ridge impacting 50% of the total fringing reef but in recent years has extended back in to the shallow lagoons now directly impacting 80% of the reef area. Lovell (2001) also pointed out this movement inshore. Direct measurements by the IMA team of scars in the reefs in 2002 showed depths of 20 to 28 cm of live rock mined from the surface of the reef, and in 2004 at the same reefs scars as deep as 40 cm were observed. Intensive measurements and sampling of scar depths and densities of scars during the 2002 survey showed that between 58 and 83% of the reef flat in the harvested areas had been chipped away (see Coles, appendix one, this report).

Namada - fresh reef scars and waste from live rock mining – September 2002

Namada – unloading, discarding and sorting live rock – September 2002

In 2004, (as the data above has confirmed) it was apparent that virtually all of the reef areas suitable for live rock collection in Namada (Vunisese reef), Vatukarasa (Oria and Navoto reefs) and off Malomalo have been mined-out. Under the so called "area rotation scheme" at Vatukarasa harvesters were digging deeper into the reefs and going back over previously harvested areas thoroughly destroying what was left of elevated sections of low grade live rock including corals of the *Porites lutea* variety. Companies were still placing orders with collectors in these areas in December 2004 daily sending at least two container trucks down the Coral Coast aiming to haul away over a 100 tonnes of live rock during the Christmas period for curing and export. Wastage factors were higher and one company reported complaints from buyers in the US about a reduction in quality.

Live rock curing for export

There was considerable evidence in December 2004 of a lower quality of live rock being mined from harvest areas that have been repeatedly targeted over the past few years. Village collectors complained they now worked in deeper water and, as quantified above, companies such as WSI and (earlier) Ocean 2000 were shifting to new areas (nearer Suva).

Vatukarasa's Navoto reef – widening, deepening decade-old scars and impacts - December 2005

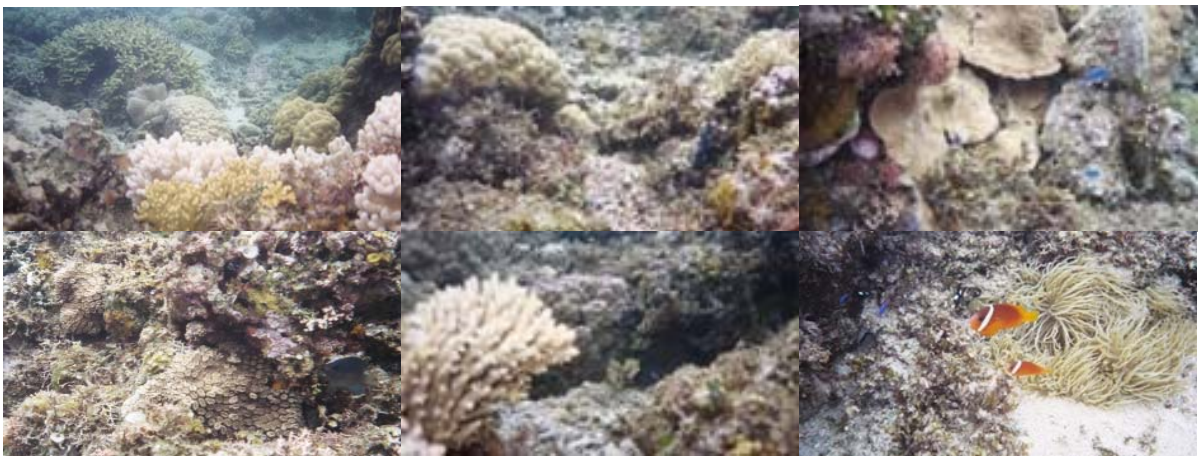
Underwater, the appalling impact of live rock mining activity is clearly visible. Digital pictures taken underwater and reproduced here show this. Mined areas are virtually barren except for thick growths of brown seaweeds (*Sargassum, Padina*) and black colored blue-green algae. Many of the scars remain as bare rock or with a few centimeters of rubble and sand accumulating in the hollows. There has been very little consolidation of this rubble material. These impacts and the barren appearance extend well inshore of the mined areas suggesting that suspended sediment and rubble from the mining activity have had a more extensive negative impact.

Malomalo - live rock mining: the community stopped it - September 2002

Shoreline erosion, inshore pollution from septic leachate, fertilizer run off, and changes in the watersheds are also believed to be having an impact. However, in areas that have never been mined or that were mined more than five years ago, the growth of corals inshore, diversity of algae and presence of numerous small fish including juvenile groupers is stunningly different.

Such areas are also stressed by the same terrestrial impacts, which places more of the blame on live rock mining for creating barren reefs than previously acknowledged. Places that were mined more than one, three and five years ago have not recovered their topographic features, although corals and habitat value are clearly increasing with time.

Companies and earlier environmental impact assessments claimed that live rock harvesting was only carried out on the ends of the reefs where seasonal discharge of rivers, freshwater and suspended sediments caused newly recruited corals to die anyway. This seemed logical when first considered, but field observations under this study in neighboring inshore areas, that have not been targeted for live rock, directly below or adjacent to river outlets show that diversity and longevity of corals are both high, while habitat, algae and fish populations are richer, contrasting significantly with mined areas which are barren inshore[24] (see pictures below and compare with those above).



Baseline reef-flat pools east of Tabua Sands and Namada, protected from and untouched by live rock mining, biologically diverse, yet also experiencing run off from impacted watersheds

There is no information available about the impact of live rock harvesting on a community's subsistent fisheries. However, fish numbers and diversity were significantly higher in areas that had not been mined for live rock.

In less scientific terms, team members repeatedly agreed that these live rock mining areas have been "trashed" where mining has taken place. This is an especially significant concern given the importance of the tourism industry on the Coral Coast (and to the whole of Fiji) and also given the importance of reef flats in continuing to supply the subsistence needs of future generations.

[24] At Navoto reef, Vatukarasa mined the whole reef flat demonstrating the extent to which people and companies will go.

An important question is how long will it take reefs such as those mined in Vatukarasa to restore themselves? This study found no evidence that live rock is a renewable resource, at least within anyone's life time. So the question of renewal concerns more the recovery of reef flat ecosystems and restoration of biological diversity. Steve Coles with the Bishop Museum under this study was able to analyze the question of the length of time for recovery (from appendix 1, part 2):

> "Concerning the question of the time that may be required for regrowth of reef material in the live rock extraction scars to a normal reef surface, no specific studies have been made which would provide a direct answer. However, an estimate may be made using published information on coral reef vertical growth and accretion. In contrast to the vertical growth rates of hard corals, which range from about 1-2 cm per year for massive species to as high as over 20 cm per year for some branching *Acropora*, accretion rates of the reef substratum are comparatively low. Estimates reviewed by Smith and Kinsey (1976) and Buddemeier and Smith (1988) for vertical reef growth rates range from 0.6 to 15 mm per year, with more common rates below 10 mm per year, which was considered the best overall estimate for sustained maximum reef growth. It should be noted that these values were all estimated for the growth of intact reef surfaces, and that the broken reef substratum that results from live rock mining is very like to regrow at a much lower rate.
>
> Using an average extraction depth indicated for the live rock scars of 28 cm at Namada and 20 cm at Vatukarasa[25], and the best estimate of 1 cm per year for reef growth rate, it is apparent that reef recovery for the extraction scar areas will require at least 20 years[26]. This recovery rate will only take place in the unlikely event that regrowth can occur at the rate of published estimates. How long the process will actually require for the broken and disturbed reef substratum is conjectural, but it is highly likely that the process will take at least twice as long, or will not occur at all in some cases. As described above there is little indication the regrowth process has even started for the extraction scars observed off Namada villages where live rock mining has been underway for three years[27], and some indication of channelization is occurring from the extraction scars."

A minimum of 50 to 100 years may be required for mined reefs to return to their natural state, if they do at all.

[25] Later in 2004 scars in Namada and Vatukarasa's repeatedly harvested areas were measured at 40 cm.
[26] Closer to 40 years following scar measurements in 2004.
[27] "…*at least* three years" see table 5: Namada was mined 98-04; Vatukarasa mined 92-04 with no recovery, either.

Clearly, live rock extraction is a having a significant and negative impact. In addition, it should have been categorically considered a mining activity, since it is non renewable and can hardly be described as a sustainable activity.

In 2003, Wesson, a masters student from Newcastle University in the UK also assessed the impacts and management of the live rock trade in Fiji concluding there was no apparent recovery of the sites previously harvested, questioning the sustainability of the trade.

Early, Fiji-based studies commissioned by the harvesting companies proposed that live rock harvesting was sustainable. However, under this study all available information indicates the opposite, that live rock mining is not sustainable. Steve Coles presents additional evidence:

> "Fiji's reefs are vast, and it might be argued that live rock mining on about 3000 m^2 is a trivial impact on the total reef system[28]. It has also been proposed that live rock extraction can be used to increase the three dimensional diversity of reef to create shallow pools and habitat relief which would promote greater reef coral settlement and fish diversity (Lovell and Tamuri 1999; Lovell 2001). On the other hand the present analysis indicates that the activity is not sustainable where it is being conducted, and that it can only be done in the long term by extending the activity to other reefs in Fiji as the resource on presently mined reefs is used up. A minimum of 50 years may be required for mined reefs to return to their natural state, if they do at all. As for the contention that live rock extraction creates habitat diversity that may promote coral settlement and growth and attract fish and other organisms, it is quite likely that this may occur. On the other hand, the same shallow pool creation from removing live rock from the reef may result in channelization that may allow increased wave penetration to the shoreline and resulting shoreline erosion[29]. This is particularly problematic at a time when sea level rise is occurring which already exceeds the vertical growth rates of corals reefs (Buddemeier and Smith 1988). The total costs and benefits of these two opposing results of live rock mining have not been evaluated".

[28] When we add in wastage and - from a slightly different perspective - look at how long entire reefs such as Navoto and Oria reef were able to support live rock mining at Vatukarasa, overall the area of reef impacted annually is about 100 times what Coles estimates (equivalent to "50 rugby pitches" a year and discussed above following table7).
[29] Erosion is undoubtedly occurring along the live rock mining sections of the Coral Coast.

Steve Coles helps us conclude this section on the assessment of the impacts of live rock mining:

> "In conclusion, the present available information indicates that live rock extraction is not sustainable in the long term, that it produces localized damage impacts of various levels on Fijian reefs where it is being conducted, and that the long term impacts of the practice have not been evaluated nor are being monitored. The economic value of this enterprise to villages where it is being conducted is recognized[30], but an alternative exists by their participation in the seasoning of cultured live rock, which will produce long term economic benefits with minimal environmental impact. A transition from mining of live rock from Fiji's reefs to production of cultured live rock to supply the total market demand should be a goal for completion within five years or the shortest time within which this transition can be effected."

Given the non-sustainability of live rock mining and the destructive impacts to the reefs where it is practiced it is recommended that the Fiji government ban the practice of live rock mining outright. As currently implemented, the live rock industry's continuity or "sustainability" depends entirely upon the practice of mining the reef and being able to expand to new extraction areas and reefs. The destructive and environmental impacts are automatically transferred to these new areas. There is no way to avoid the environmental damages; they come with the practice of crow barring the reef.

Live rock mining in Fiji over much of the last decade has been consuming new areas of reef at rates equivalent to 40 to 50 rugby pitches each year (28-34 hectares/year). Since 1992 some 270 hectares of reef area equivalent to 400 rugby pitches have been dug up and destroyed. A minimum of 50 to 100 years may be required for mined reefs to return to their natural state, if they do at all.

Shifting over to cultured live rock in the shortest time possible is the second recommendation. Transitioning as soon as possible to a cultured product is from an environment perspective the best thing for Fiji. However, environmental criteria can hardly be used as guidance on how long it should take to transition over to cultured live rock. Crow barring the reef is a destructive practice that by definition should be banned immediately and never allowed again. Similarly, under any principal of eradicating destructive practices it seems there is little environmental justification for allowing any crow barring of live rock to continue. Hence the recommendation for the Fiji Government to ban this practice outright.

[30] But are not at all "long term" as marketable live rock becomes harder to find in areas such as Vatukarasa and companies move on.

Criteria for deciding how long it should take to transition might come instead from social or business sectors since banning live rock harvesting will undoubtedly have a financial impact on the aquarium trade exporting companies, their employees and the communities involved, necessitating a transition phase. The duration of the transition phase needs to be determined responsibly.

The financial and economic underpinnings of live rock mining and alternative live rock culture are discussed by Lal and Cerelala (2005).

Companies hardly seem likely to support a short transition phase and have argued for a longer phase-out. However, government decisiveness and leadership is required in implementing a ban and a sufficiently rapid[31] phase-out of destructive live rock mining if there is to be any incentive for companies to bring in cultured live rock. So far there has been very little incentive or pressure to make this change.

How long can it take companies to transition to cultured live rock? What is the minimum time required; what is reasonable? To what extent and how quickly can this alternative become a viable substitute for the current level of live rock export production from Fiji?

It does not seem reasonable to allow companies to introduce new communities to live rock harvesting for only a short time given that things are being scale down. The decision by government is made that much harder as new areas and communities are added. At this point environmental damages need to be contained. New areas for live rock mining should therefore not be allowed to be opened up.

Another concern echoed by live rock companies in Fiji is if Fiji cuts back its live rock mining production to both protect its environment and provide an incentive to companies to shift over to culturing live rock, it does not seem reasonable if other Pacific Islands step in to supply the mined live rock. This would effectively be shifting the environmental impacts overseas. A coordinated and concerted effort between the US government, Fiji and other Pacific Islands to control the spread of destructive practices associated with the live rock trade is therefore called for.

[31] responsibly determined

Live rock culturing

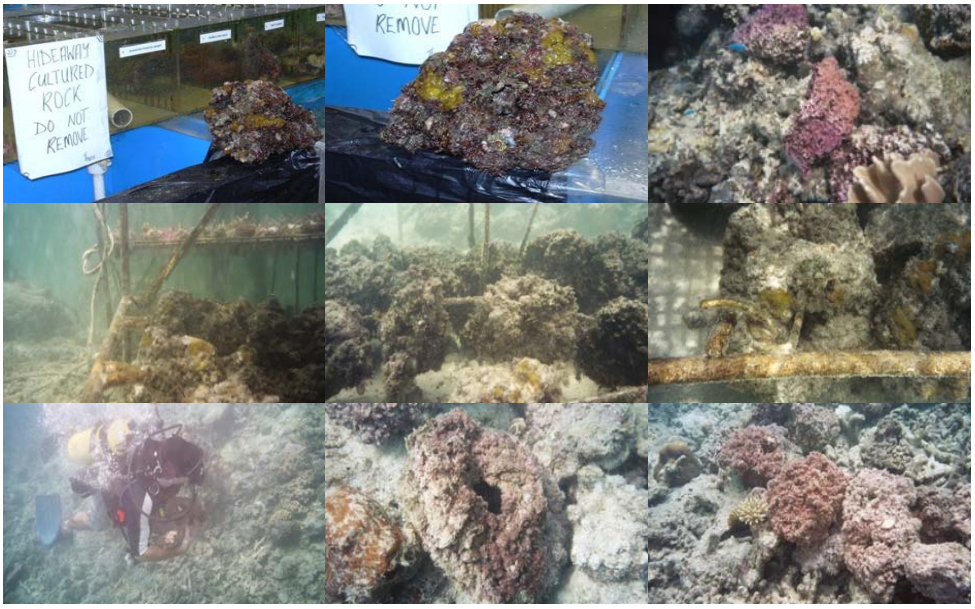
WSI has pioneered the development of live rock culturing in Fiji. At the time of the field studies in November and December 2004, WSI reported that although they could sell twice as much, 16% of their total exported live rock production was cultured live rock, or 400 boxes per month (each holding 22.2 kg. with approximately 10 pieces of cultured rock per box). Two years earlier WSI suggested to Steve Coles (appendix one) that in five years time they were aiming for 50% of their live rock exports to be cultured live rock – by 2007.

WSI cultured live rock production at Lautoka. Iron oxide pigment imparts pink-purple colour further developed by coralline algae during seasoning on the reef

The composition of the artificial live rock was reported as 40% pumice (imported from New Zealand) and 20% aragonite (coral fragments), with the remainder cement and sand; the aragonite reportedly coming from cyclone smashed Acropora mined (commercially?) from beach locations.

WSI preparing and positioning cultured live rock for seasoning in reef flat farms, strung on wires attached to reef with metal bars - near Hideaway Resort, east of Namada

In November 2004, WSI had 41,000 pieces of cultured live rock in the water at seven farming locations. Four types of live rock farming practice were observed: (i) wire strings - 100 pieces per string - seasoning on the reef flat at Hideaway; (ii) wires strung underneath coral farming racks at Hideaway; (iii) cultured live rock pieces scattered over lagoon reefs 20-40’ deep in Lautoka Bay near coral farm areas; and (iv) cultured live rock pieces piled onto lagoonal patch reefs 2-5’ deep adjacent to deeper lagoon water. In common with mined live rock it is the shady side of the artificial live rock that gets more coralline algae growth.



WSI cultured live rock from wires strung under coral farming racks and also broadcast over deeper lagoonal patch reefs

Other companies such as Waterlife Exporters consider live rock culturing to be achievable, and say it would take 12-36 months to reduce wild rock and increase cultured rock.

Looking at how much reef would be occupied by live rock culture. If a piece of cultured live rock 20 cm. in diameter occupies 25 cm. diameter of farm space and weighs 2.2 kg, then 1000 tonnes of cultured live rock (one rock thick; a total of 454,400 pieces) would occupy 2.84 hectares – 4 rugby pitches. Packed in at this density, live rock is being produced at 352 tonnes per hectare. If we take a less dense scenario and allow for more access between rows and a more heterogeneous reef surface we might increase the area of the farm by 25% and then 1000 tonnes of cultured live rock would occupy 3.55 hectares of reef (5 rugby pitches; at 282 tonnes/hectare).

If the rock was seasoned in the water for 12 months and we had storm losses to contend with then for a regular monthly production we'd probably need twice this area to sustain 1000 tonnes per year or about 7 hectares.

Seven hectares is thus a reasonable estimate of the area of reef flat occupied by a national Fiji production level of 1000 tonnes of cultured live rock a year. This same area of reef would be used over and over again (theoretically!).

In contrast, the analysis of live rock mining in Fiji indicates that some 270 hectares of reef have been used for live rock mining since 1992[32], at the rate of around 30 hectares of new reef currently being targeted for live rock mining each year. The impact on Fiji's reefs of culturing live rock would therefore be considerably less: compare 7 hectares in total, with 30 hectares being added per year to some 270 hectares already mined.

Conclusions and recommendations for live rock mining in Fiji:

Given the non-sustainability of live rock mining and the destructive impacts to the reefs where it is practiced it is recommended that the Fiji government ban the practice of live rock mining outright.

As currently implemented, the live rock industry's continuity or "sustainability" depends entirely upon the practice of mining the reef and being able to expand to new extraction areas and reefs. The destructive and environmental impacts are automatically transferred to these new areas. There is no way to avoid the environmental damages; they come with the practice of crow barring the reef.

Live rock mining in Fiji over much of the last decade has been consuming new areas of reef at rates equivalent to 40 to 50 rugby pitches each year (28-34 hectares/year). Since 1992 some 270 hectares of reef area equivalent to 400 rugby pitches have been dug up and destroyed. A minimum of 50 to 100 years may be required for mined reefs to return to their natural state, if they do at all.

[32] Producing an estimated 22,800 tonnes of live and discarded rock or around 9,580 tonnes of marketable live rock, equivalent to production rates of 84 and 35 tonnes per hectare (respectively), compared with 282 t/ha estimated production rate for cultured live rock. Derived from independent figures, this live rock culture production rate of 282 t/ha compares favorably with roughly estimated production rates of up to 169 t/ha from Vatukarasa's Navoto and Oria reefs for the best live rock mined on the outer half of the reef.

Shifting over to 100% cultured live rock in the shortest time possible is recommended. Transitioning as soon as possible to a cultured product is from an environmental perspective best for Fiji. However, a responsible transition time needs to consider social and economic consequences for companies, their employees and community producers.

At least two companies are prepared to make a switch to live rock culturing in one to three years. One company is already supplying 16% of its live rock exports from cultured live rock production.

Government decisiveness and leadership is required in implementing a ban and a sufficiently rapid phase-out of destructive live rock mining if there is to be any incentive for companies to bring in cultured live rock. So far there has been very little incentive or pressure to make this change.

Such a decision by government is made that much harder as new areas and communities are added. It therefore does not make sense to allow companies to introduce new communities to live rock harvesting for only a short time given that things are being scale down. Environmental damages need to be contained. New areas for live rock mining should therefore not be allowed to open up.

Another concern echoed by live rock companies in Fiji is if Fiji cuts back its live rock mining production to both protect its environment and provide an incentive to companies to shift over to culturing live rock, it does not seem reasonable if other Pacific Islands step in to supply mined live rock to the US and others. This would effectively be shifting the environmental impacts overseas. A coordinated and concerted effort between the US government, Fiji and other Pacific Islands to control the spread of destructive practices associated with the live rock trade is therefore called for.

If Fiji can do it, then all countries should be required to produce live rock from cultured sources. This requires recognition and cooperative action by US, European and other importing countries, and also CITES.

Other destructively obtained alternatives to watch out for include a product being called “yard rock” by Fijian exporters, being substituted for live rock following the establishment of CITES quotas. This is supposedly dead coral, harvested from lagoonal patch reef tops or pinnacles. However, as with live rock mining, environmental impacts associated with yard rock mining would be expected.

Yard rock: one company's substitute for live rock; the method of extraction from lagoon reef pinnacles is likely to be equally destructive.

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APPENDIX ONE

Fiji Coral Trade Project – Phase 2
Trip Report and Observations December 12-17, 2002
S. L. Coles, Bishop Museum

1. Phase 2 Activities

The purpose of this second trip to Fiji was to further visit companies and villages involved in coral and live rock extraction and to obtain quantitative data to evaluate the impacts of live rock mining on Fiji's reefs for a determination of the sustainability of this operation.

On December 12, 2002 visits were made to the processing facilities of Ocean 2000 in Nadi and Walt Smith International in Lautoka, and on December 13 a site visit was made to reefs off Lautoka where live hard and soft corals were being collected.

Ocean 2000 Operation

A tour of the Nadi facility was conducted by Mr. Norman Turagaivu, operations manager, who provided the following information. Ocean 2000 has been in operation under its present name for over six years and ships live rock and fishes collected off the Nadi area, as well as live corals collected from Motoriki, near the island of Ovalau. These are processed at the company's facility in Nausori and are brought to Nadi by truck for final shipment to international markets. The Nadi facility employs 15 employees and the Nausori facility 12, with 12 divers working from the Nadi facility collecting fish, five of which are from Sri Lanka or the Philippines. Mr Turagaivu estimated the quantities of live rock, which is mined from reefs at Malomolo and Nabukavasi villages, as "thousands of tons" per year, with a rejection and return rate of only "10-20%." He stated that the company plans to downsize or phase out live rock operations because of the price drop from formerly about US$4/lb to present $1.50/lb. The live rock is processed by washing with seawater for 2-3 days, then shipped in 20 kg quantities in Styrofoam-lined cardboard boxes. At the time of the visit a pile of live rock about 5 X 1.5 X 1 m weighing an estimated 2 tons was being processed (Fig. 1), and this was the second such quantity to be shipped this week.

In addition to the live rock on hand the Ocean 2000 Nadi facility had three tanks each about 1.5 X 8 m with about 500 pieces of live hard and soft corals awaiting shipment (Fig. 2) that had been transhipped from the company's Nausori facility. A brief visit was made to the Nausori operation on December 16, but no useful information was obtained, since the manager was not available. The facility is small and limited to three relatively small tanks that at the time contained mostly *Sinularia* soft corals. We were informed that Ocean 2000 was derived from the first company to collect and market coral from Fiji, beginning in 1985 under another name.

Walt Smith International (WSI) Operation

Tim McCleod, operations manager of the WSI Fiji operation gave a tour of the Lautoka processing facility and provided the following information. WSI has operated in Fiji for six years after moving from Tonga and is the major exporter for live rock from Fiji. It's primary product is live rock, which is supplied by the villages of Namada, Vatukarasa and ? on the Coral Coast of Viti Levu. Live fish and live coral are shipped in quantity, but these have higher costs of collection and processing and are less profitable than live rock. WSI employs about 100 people, all Fijian citizens, in specimen collection, processing, shipping and administration. Presently WSI

and all other Fiji companies can only ship to the U.S. because of the CITES ban which is being upheld by European countries, but even with this limited market there is no indication of market saturation for Fiji live rock.

During the visit we were shown live corals and live fish being acclimated to aquarium conditions and prepared for shipment, with the aquaria for these occupying two large warehouse rooms (Fig 3). A large variety of soft and hard corals were present, all taken from the large collecting area controlled by WSI from Lautoka offshore to the Mamanuca and Yasawa Islands. All corals appeared in excellent condition and WSI claims a mortality rate in shipment of only 1-2%. Less space was occupied by the live rock being processed for shipment (Fig 4), some of which was under a seawater sprayer to reduce the invertebrate content, or awaiting removal of fleshy macroalgae by Fijian women employees (Fig. 5). Tim estimated that WSI shipped about 700,000 kg of live rock in 2002, of which about 10-15% was cultured or manufactured from cement and aggregate, a process which WSI has been developing the past four years. At the time of our visit, WSI had on hand about 25 piles of manufactured live rock (Fig. 6), each with 50 pieces ready to be placed in the ocean for "seasoning" i.e. acquiring a coating of pink-purple coralline algae. This process requires about 18 months and gives the live rock the characteristics sought by aquarists in their belief that the coralline algae imparts a capacity for reduction of nitrogen and other toxic components in their aquaria. Tim aims for 25% of the WSI live rock total shipment to be composed of cultured material in 2003 and 50% within five years, and would like to phase out live rock mining along the Coral Coast altogether. The cultured live rock can be manufactured in any desired shape that will make an attractive reefscape (Fig. 7) and is virtually identical to that which is extracted from the reef (Fig. 8). It also has the advantage to the manufacturer in that it can be made less dense than the natural material, thereby saving on airfreight costs. A significant transition to cultured live rock will require changes in the perception of the market to the point of view that cultured live rock is as attractive and functional as that mined directly from the reef, and that it represents a substantial decrease in impact on the reef environment. Fijians and villages presently involved in live rock mining will also need to make a shift to the delayed but steady income that can result from being custodians of cultured live rock during its seasoning process, instead of the short term income presently associated with live rock mining.

On December 13 site visits were made to two sites where live corals are collected by WSI, to one site where an pilot project is underway for "culturing" live coral pieces broken from larger heads and growing to marketable size, and to one area which underwent heavy coral bleaching in 2000 and is undergoing recovery. The first stop was at a site where collectors were at work on our arrival collecting "show pieces" i.e. corals larger than the normal size which are usually collected for aquarium sale. The operation consists of selecting the coral, breaking it from the reef using a small hammer and chisel (Fig. 9), and transferring it to a holding area on the reef or sand where corals are placed until all have been collected and are ready to be loaded into the boat for transport (Fig 10). Even though these pieces were approximately one-third larger than those which are usually collected, little or no damage was noted from the process and it would be very difficult to determine that corals have been removed from the reef or that there were any gaps in the size distributions of the corals population, even at the time of collection (Fig. 11). The general appearance of the corals throughout this reef suggests that the reef underwent bleaching and substantial mortality from the 2000 event . Most of the acroporid and pocilloporid corals on the reef are in the <25 cm diameter range, and many table *Acropora* showed dead bases and tops with grow-back areas in this size range. Larger corals, mostly *Diploastrea heliopora* are restricted to the reef edge or deeper. Besides the extensive bleaching event of 2000, bleaching also occurred in shallow water <1 m depths this year. Despite these recent disturbances and the collecting that has been done on this reef, coral growth appears abundant and vigorous with a diverse set of species, with no long-term damage apparent.

Another stop was made at a reef which is being used as a grow-out area for coral nubbins held in small concrete bases (Fig. 12) held on racks which are cemented to the reef to hold them upright when disturbed by waves (Fig. 13). There were ca. 200 corals per rack and ca. 10 racks for a total of ca. 2000 corals (Fig. 14). Growth to marketable size requires about nine months through the winter season, but there is a loss or rejection rate of about 25%. The initial batch was entirely lost during the 2000-bleaching event, but during this year's shallow water bleaching WSI staff were able to move the racks to deeper and cooler water, saving the corals. Tim would like to utilize this approach to "culture" live corals in a shore-based grow-out facility, but this is prohibited by the quality of the available seawater. Alternatively, the present approach of placing grow-out racks on reefs could be expanded to phase out collecting of naturally settled corals. Based on a present demand of ca. 1000 coral pieces per week estimated by time, a rejection/loss rate of 25% and a grow-out time of nine months, I estimate that continuously supplying the demand would require racks to accommodate a total of 45,000 corals, or 225 racks, each about 3 X 5 m in dimension. The placing of this many structures on the reef would impart its own not insignificant impact. Also, it should be recognized that until the life cycle is closed for marketable species that would enable true culturing of adults from eggs, sperm and larvae, the present approach utilizes adult corals that are broken into pieces to supply the nubbins that are grown to marketable size. Therefore, it is quite likely that this approach might exert a greater impact on the reef than a collecting program that is sufficiently dispersed, and the grow-out approach needs to be rigorously evaluated before proceeding on a large scale.

The final stop of the day was at a reef further inshore that has been utilized continuously as a source of soft corals, in contrast to hard corals, for which collection sites are rotated. Growth rates of the soft corals are fast enough that a single collection area has been sufficient to supply demand without diminishing the resource. WSI collectors were observed removing spaghetti corals (*Sinularia* sp.) (Fig. 15). I observed abundant soft as well as hard corals at the site and a quite pristine reef under somewhat turbid conditions. The only negative observation was that the large bases of the soft corals result in a much larger breakage scar occurring when the coral is chiseled from the reef (Fig. 16). However, the newly exposed reef would probably not be detectable after a few days of weathering and micro-algal overgrowth.

My overall impression of the WSI live coral collection operation was that it is well run and managed with a concern for the environment. Despite collection and shipment of an estimated ca. 55,000 coral pieces a year, the size of the collection area, abundance of the resource, rapid coral growth rates and care in collection methods indicate that the impact to the coral populations and their resident reefs has been below measurability in terms of the natural variability of coral assemblages. All indications are that the operation is sustainable in the long term, and a rigorous analysis of sustainability is being conducted as part of a Fisheries Management Plan (Lovell, draft ms.). By contrast, the impact to reefs where live rock is being mined is substantial (see analysis below) and a shift to supplying live rock demand with cultured live rock over the next five years should be supported.

On December 14 we drove to Nadogoloa village to see a site where corals have been collected for marketing as ornamental curios and to discuss this operation with villagers. Nadogoloa village is very remote and requires a two hour drive over a rough and winding road from the highway near Rakiraki. We were accompanied by an assistant Roko for District Council, who informed us that this activity had been conducted without Council approval, which had authorized only harvesting of food fish in this area. Despite this lack of approval a license for curio coral collection was issued by the Ministry of Fisheries to Acropora International Ltd., which operated in

the area approximately nine months until August of 2002. Formerly, curio collection in the area was done for Seaking Trading Co. for about five years. Collection of corals and the revenue obtained was shared among the four local villages which have ownership of the offshore reefs, each village collecting and sending corals one week at a time. Corals were collected and sent in truckloads two to three times per week to fill one twenty-foot container, for a fee to the villages of F$1200. Therefore four containers per month are estimated to have been sent from this area to the market by Acropora International. This is close to the 40-50 containers per year reported by the company to the Ministry of Fisheries, totaling just under 100,000 coral pieces per year (IMA data). Fisheries reports also indicate that Seaking Trading shipped at least 20,000 pieces per year when it was operating in the area. It should be noted that these corals were substantially larger than the small 10 cm pieces that are shipped by companies supplying live corals for marine aquaria. Curio corals would range up to 35 m in height or diameter and therefore each represent years of post-settlement growth.

Snorkeling observations were made on reefs directly offshore of Nadogoloa village. The first area observed was a medium size reef about six km offshore which had been a collection site until operations ceased in August, according to the boat driver, who was one of the collectors. He said that corals had been abundant but none were left, and observations confirmed this. Virtually no intact branching *Acropora* corals were found in the size range up to 30 cm diameter, and the only corals of this type were broken or damaged, usually with only the bases remaining (Fig. 17). Otherwise broken but still alive fragments and branches were on the reef pavement (Fig. 18), and there was a large field of coral rubble on the reef top (Fig. 19). Other species, mostly massive *Porites* and *Diploastrea*, were present along with extensive colonies of *Pocillopora* cf. *verrucosa*, and a very few small *Acropora* colonies present suggested the reef was in the earliest stages of recolonization.

Sea conditions at the time of the observations were very turbulent, with wind driven waves of 3-4 feet on the reef top, indicating that this reef is routinely exposed to mechanical disturbance that may account for much of the observed coral breakage or lack of branching corals. Therefore I inquired if there were reefs where collecting had not been done which could be used as comparison for control conditions. I was taken to two smaller reefs about one km toward the shore, one of which where collecting had been done and the other which had not. Despite the somewhat calmer conditions than at the offshore reef, on the collected reef I observed similar, although not as extensive, damage and indications of collection impact. Abundant rubble, both live and dead, occurred on the reef pavement (Fig. 20) and numerous partly broken dead or mostly dead branching colonies were still standing (Fig. 21). Live branching colonies on the <30 cm diameter range were still rare and *Acropora* generally in low abundance. There was some suggestion of a “phase shift” to an algal or soft coral dominated reef indicated by relatively abundant macroalgae (Fig. 22) or *Sinularia/Sarcophyton*. By contrast the similar size reef only about 100 m away from the collected site where no corals had been removed showed none of these symptoms of stress. There was no indication of coral breakage, missing *Acropora* size class or community phase shift, and the overall appearance of the reef was pristine (Fig. 23), dominated by small-medium size table and arborescent *Acropora* and a high coral diversity and total coverage of about 50% (Fig. 24).

<u>These observations indicate that the collection of curio coral as it has been conducted in the Nadogoloa area is damaging to the reef environment and unsustainable in the long term</u>. The monetary incentive to an area with little alternative sources of income has apparently resulted in collecting analogous to “clear cutting” with little regard to the capacity of the reef community for recovery. This situation has probably been aggravated by the resource being shared among four villages, and by a departure from the policy of “one area, one company” that is supposed to be a primary determinant of issuing licenses for coral collection in Fiji. The resulting competition

for the resource has created a classical “Tragedy of the Commons” situation where all users with access to the resource have the benefit to remove as much as possible before other users do the same. It is possible that curio coral collection can be done in a environmentally acceptable and sustainable way in Fiji, but the necessary safeguards have not been established or adhered to. These include establishing the extent of the resource and the portion of the resource composed of collectible corals, determining recruitment and growth rates of the corals collected and comparing this information to the portion of the total corals collected, and monitoring to determine the impact of collection on the total coral population and size distributions of collectibles, as well as the impact of collection on the total reef community. Until these safeguards are implemented as part of a management plan, curio coral collection should be suspended in Fiji.

On December 16 a brief visit was made to Ocean 2000’s Nausori facility, and a visit was attempted to Acropora International’s Nasinu warehouse, but the latter was empty and the company apparently out of business for some time. On December 17 surveys were made of the impact of live rock mining at Namada and Vatukarasa villages (described below). On December 18 a brief interview was made with Mr. Mike Thoms, owner and founder of Seaking Traders, which he said he started in 1983, and also a director of Aquarium Fish which he founded with Tony Nahaky in 1985. Seaking was the major exporter of curio coral from Fiji until recently but is no longer collecting coral, which he blames on Acropora International having moved into his former collection areas and offering a better price. Years ago Mr. Thoms converted his operation from unprocessed to value-added, processed (i.e. cleaned) curio coral, which he proposes provides local employment, gives a higher selling price and therefore gives greater monetary return and less collection impact per unit of income. He complained that collection of unprocessed coral by Acropora International in his negotiated areas violated the agreement control and assessment concepts that are part of the one area-one company concept and created far more reef disturbance impact. He supports the requirements of CITES to assure sustainability of collecting the resource on a long-term basis.

On December 29, out of curiosity of what the end result of Fiji live rock and live coral collection represents to the consumer, I visited a marine aquarium shop in Nashua, New Hampshire, a small town in the southern part of New England. The shop’s name is Inland Reef and it is owned and operated by Tom O’Toole, who has been interested in live coral aquaria for about ten years and had the shop for about five years. According to the owner, Inland Reef is a medium-size operation and one of five that he knows of in operation in the New Hampshire area. The shop had about eight medium size aquaria set up with reefscapes containing live corals and reef fish, and four tanks with live rock for sale from Fiji, Tonga and Brazil. The source of the Fiji material, according to Mr. O’Toole’s supplier, is a totally Fijian owned company named REL Fisheries. Shop records indicated a sale of about 3000 lbs. of live rock in 2002 at a price of about US$ 4.50 per lb., which would represent about a 20 fold increase above the price of F$ 0.80 per kg going to the villages in Fiji at the source of the live rock collection. We briefly discussed the use of and market for cultured live rock, and Mr. O’Toole expressed some skepticism and concern that it was being made from material taken from the reef and therefore as or more damaging to the environment as mining of natural material. I replied that this was not my perception and that I believed that the aggregate in culture live rock was from land quarried material, but that this needs to be verified. I believe that the owner's perception was based on some material that he showed me he gets from the Caribbean, which appeared to me to be just quarried limestone of very low quality. He said that from our conversation that he would look into the virtues of cultured rock further. My impression from our discussion was that, like most tropical marine aquarium owners and suppliers, Mr. O’Toole desires that collecting for this industry be done in an environmentally safe and sustainable manner and will support safeguards to assure these objectives at the source areas.

2. Live Rock Mining

This activity is conducted at a number of villages under agreement with exporters, who provide basic equipment for removing portions of the coral reef substratum and transport the material from the collection site to the company's processing facilities. The "live rock" is evaluated for its quality and processed to remove unwanted organisms that may die in aquaria, adding to oxygen demand and toxic components. The primary characteristic of the live rock for export is a surface layer of pink to purple coralline algae, which is reputed to reduce levels of nitrogen and other toxic components released by aquarium organisms, and adds to the coral reef appearance of the aquarium seascape. The exporters prefer that this material be collected on the offshore areas of reef flats near the surf zone where coralline algae is likely to make up a greater portion of the live rock collected. Rock that is deemed unsuitable for export is returned to the village with no payment. Villagers have reported the return rates to be as high as 50% of the material collected, but Tim McCleod reported that WSI has reduced this to an average of about 10-20% for more recent collections by working with the villages.

Discussions and observations of live rock extraction activities were conducted at two villages, Malomalo and Namada, in the week of September 22-29 during Phase 1. Malomalo village has conducted this activity for about the last eight years from throughout the reef flat rather than near the outer edge. Namada village has collected from the outer reef flat for about the last three years and was engaged in this activity at the time of our September observations(Figs 25-28). In both cases preliminary observations indicated that rock extraction is having a substantial and non-sustainable impact on the reef substratum. Gouged and broken areas in the reef surface marked the locations where rock has been removed using crowbars (Fig. 29), and no indication of regrowth of these broken reef surfaces was observed on older areas of extraction (Fig. 30). These areas remain barren and mostly without even colonization of fleshy macroalgae that is generally the first step in recolonization of reef surfaces where corals are absent (Fig. 31). The only corals observed in extraction areas were microatolls of *Porites lutea* on the reef that has been utilized for eight years, and unfortunately these are sometimes directly impacted by rock extraction for the coralline algae that may occur within the ring of the microatoll. Virtually no corals were found in the area of extraction of the reef where this activity has been underway for three years, but corals are moderately abundant on this reef further toward shore. The main problem at this extraction site appears to be potential erosion of the gouged areas marking rock extraction that are in or near the active surf zone (Fig. 32). Bare edges of the gouged reef could be easily broken by hand, in contrast to the very hard surfaces of intact reef. This suggests that waves may continue to erode and degrade the reef in these broken areas and contribute to coastline erosion reported to be occurring by villagers.

According to sources at both villages, approximately 50% of the material that is not suitable for the live rock trade and is returned to the villages for replacement on the reef. However these loose pieces are subject to disturbance by the next large wave event, and the beach at one site was littered with reef rock apparently from this source. Other indications of disturbance on the reef was a high density of the macroalgae *Padina* sp. found only on areas of both sites which had been subject to previous live rock extraction.

Considerable attention which has been given to the environmental impacts and sustainability of harvesting live coral in Fiji (Lovell and Tamuri 1999; Lovell 2000, Lovell draft mss.) and internationally (Bruckner 2001), and studies have been conducted to estimate the size of the resource and potential impact of both live coral and curio collection in Fiji (Lovell draft mss.). By contrast, the impacts of mining live rock from Fiji's reefs have received little attention, and no information is available that would permit a rigorous evaluation of the long-term impacts of this activity, despite the fact that the quantities of live rock material taken far exceed those from

commercial coral collection. The Fiji Ministry of Fisheries reports (IMA data) that 1,345,188 kg of live rock was exported in 2001. By contrast the same source reported that 158, 618 pieces of live coral and 119, 464 curio corals were exported in the same year. Because the latter are not reported by weight a strict comparison to live rock quantities cannot be made, but assuming the average piece of live coral to have weighed ca. 0.1 kg and the average curio coral 1 kg, approximately 135, 325 kg of live or dead coral were exported, or less that 10% of the total mass of live rock. Moreover, the coral exports represent the removal of material that colonizes and grows rapidly in comparison to slow rates of reef accretion, which are discussed below.

In order to obtain preliminary information on the quantities and impact of live rock mining on reef in Fiji, surveys were conducted on two reefs where live rock has been extracted for about the last three years. The first site was on Vunisese reef, off Namada village, had been observed in September and was briefly described in the Phase 1 report. The second site was on Oria reef, off Vatukarasa village, only about 5km west of Namada village. Despite their proximity the characteristics of these two reefs contrast strongly. In the area of the Vunisese reef where live rock is being taken, the reef surface is relatively smooth and flat, with few live corals and abundant fleshy macroalgae. Corals and channels on this reef occur shoreward of the collecting area that is on the outer reef flat near the active surf zone. By comparison, Oria reef has numerous small channels in the coral extraction area which provide habitat for moderately abundant corals on the sides of the channels.

In contrast to the substantial impact from live rock mining described above for the mined zone of the Namada village, there are far fewer indications at the Vatukarasa reef of negative effects from live rock mining, despite the fact that this activity has been going on for as long on this reef as at Namada. This may have as much to do with the physical characteristics of the reef at Vatukarasa as well as to the manner in which live rock is extracted there. At Vatukarasa live rook is primarily taken from the edges of existing channels, and it is difficult to detect the scars from these extractions, since they are in already in existing depressions. Where reef surface extraction scars are visible at Vatukarasa, the sizes of the pieces taken appear to be substantially smaller and shallower than at Namada, where the dimensions of the scars often exceed 1 m, indicating that multiple pieces are taken from a given extraction site.

Surveys using a plotless method of sampling using random pairs (Cottam and Curtis 1949, 1955) was used to determine the density of live rock extraction areas per along a 50 m line at the two sites. The 50 m line was deployed parallel to the reef front through a zone and where live rock was being extracted in September and showed extraction scars. Random points along the line were used as a starting point for each measurement, which consisted of measuring the distance from the center of the extraction scar nearest the random point to the center of the extraction scar that was nearest the first scar but located in a different quadrant than the first scar. Density (D) of the extraction scars was determined by the formula:

$$D = \text{unit area (m)} / [0.8 \times \text{mean scar to scar distance (m)}]^2$$

The long and short axes of each extraction scar were also measured along with the depth of the scars penetration into the reef, and these data were used to estimate the area (A) and volume (V) of each scar by the formulae:

$$A = \frac{(L_1 * L_2)^2}{2} \times \pi$$

and

$$V = d \times \left(\frac{L_1 * L_2}{2}\right)^2 \times \pi$$

where L_1 and L_2 are the long and short axes and d is the depth of the extraction scar.

Conditions during the survey were very difficult, with waves up to three feet high impacting the study areas and producing strong currents, so measurements are roughly approximate. Sixteen pairs of observations were made at the Namada site, compared with only six pairs of observations at Vatukarasa because a falling tide and rising wind and waves prevented further measurements.

The results indicate that live rock extraction at the Namada site has resulted in a substantially greater impact than at Vatukarasa. Although the density of extraction scars was lower at Namada with an average of 0.61 scars per m^2 compared to 2.0 per m^2 at Vatukarasa, the dimensions and depths of the scars at Namada were substantially larger. The average L and D for Namada scars were 122 and 28 cm compared to 57 and 20 cm at Vatukarasa, resulting in an average area and volume per scar of 1.35 m^2 and 0.39 m^3 at Namada compared with 0.29 m^2 and 0.06 m^3 at Vatukarasa. Multiplied by the density of scars, this would mean an average scar area of 0.83 m^2 per m^2 of reef substratum at Namada and 0.58 m^2 per m^2 at Vatukarasa. In terms of volume of material removed per area, the mean Namada value of 0.24 m^3 per m^2 was more than double the Vatukarasa value of 0.11 m^3 per m^2.

The area of reef impacted by live rock mining at each can be roughly estimated from these results and information on the annual quantities of live rock exported by WSI. Given an estimated 2002 total export by WSI of 700,000 kg/year, a total of about 233,300 kg of live rock can be estimated to be extracted from the reefs of three villages annually, assuming that one third of the total is mined by each of the three villages. Given an estimated density of 2.35 kg/ liter for the live rock, each village would be extracting a total of about 99,290 liters or about 100 m^3 of live rock annually. For Namada village where the mean quantity of live rock taken per m^2 was 0.24 m^3 the total extraction represents the disturbance of 417 m^2 of reef per year, or a belt of reef about 4 m wide by 100 m long. Comparable calculations for Vatukarasa result in the same total annual extraction suggest that the area of reef impacted there to be 909 $m^{2,}$ or a belt of 4.5 X 200 m.

The total amount of reef impacted by live rook mining in Fiji can also be very roughly estimated from these results and total annual export data from the Ministry of Fisheries. Using the 2001 export figure of 1,345, 1888 kg of live rock from all companies (IMA data) and averaging the values estimated from Namada and Vatukarasa surveys for the m^3 removed per m^2 of reef, approximately 572 m^3 were removed from Fiji's reef in 2001, directly impacting approximately 3270 m^2 of reef at an average density of 0.18 m^3 of live rock removed per m^2.

Concerning the question of the time that may be required for regrowth of reef material in the live rock extraction scars to a normal reef surface, no specific studies have been made which would provide a direct answer. However, an estimate may be made using published information on coral reef vertical growth and accretion. In contrast to the vertical growth rates of hard corals, which range from about 1-2 cm per year for massive species to as high as over 20 cm per year for some branching *Acropora*, accretion rates of the reef substratum are comparatively low. Estimates reviewed by Smith and Kinsey (1976) and Buddemeier and Smith (1988) for vertical reef growth rates range from 0.6 to 15 mm per year, with more common rates below 10 mm per year,

which was considered the best overall estimate for sustained maximum reef growth. It should be noted that these values were all estimated for the growth of intact reef surfaces, and that the broken reef substratum that results from live rock mining is very likely to regrow at a much lower rate.

Using an average extraction depth indicated for the live rock scars of 28 cm at Namada and 20 cm at Vatukarasa, and the best estimate of 1 cm per year for reef growth rate, it is apparent that reef recovery for the extraction scar areas will require at least 20 years. This recovery rate will only take place in the unlikely event that regrowth can occur at the rate of published estimates. How long the process will actually require for the broken and disturbed reef substratum is conjectural, but it is highly likely that the process will take at least twice as long, or will not occur at all in some cases. As described above there is little indication the regrowth process has even started for the extraction scars observed off Namada village where live rock mining has been underway for three years, and some indication of channelization is occurring from the extraction scars.

Fiji's reefs are vast, and it might be argued that live rock mining on about 3000 m^2 is a trivial impact on the total reef system. It has also been proposed that live rock extraction can be used to increase the three dimensional diversity of reef to create shallow pools and habitat relief which promotes greater reef coral settlement and fish diversity (Lovell and Tamuri 1999; Lovell 2000, draft ms.). On the other hand the present analysis indicates that the activity is not sustainable where it is being conducted, and that it can only be done in the long term by extending the activity to other reefs in Fiji as the resource on presently mined reefs is used up. A minimum of 50 years may be required for mined reefs to return to their natural state, if they do at all. As for the contention that live rock extraction creates habitat diversity that may promote coral settlement and growth and attract fish and other organisms, it is quite likely that this may occur. On the other hand, the same shallow pool creation from removing live rock from the reef may result in channelization that may allow increased wave penetration to the shoreline and resulting shoreline erosion. This is particularly problematic during a time when sea level rise is occurring which already exceed the vertical growth rates of corals reefs (Buddemeier and Smith 1988). The total costs and benefits of these two opposing possible results of live rock mining have not been evaluated.

In conclusion, the present available information indicates that live rock extraction is not sustainable in the long term, that it produces localized damage impacts of various levels on Fijian reefs where it is being conducted, and that the long term impacts of the practice have not been evaluated nor are being monitored. The economic value of this enterprise to villages where it is being conducted is recognized, but an alternative exists by their participation in the seasoning of cultured live rock, which will produce long term economic benefits with minimal environmental impact. A transition from mining of live rock from Fiji's reefs to production of cultured live rock to supply the total market demand should be a goal for completion within five years or the shortest time within which this transition can be effected.

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Figures (in attached CD)

Figure 1. Pile of live rock undergoing seawater was in preparation for shipment at Ocean 2000 warehouse in Nadi.
Figure 2. Tank of live corals awaiting shipment from at Ocean 2000 warehouse.
Figure 3. Tanks of live coral in Walt Smith International (WSI) at Lautoka.
Figure 4. Live rock awaiting processing and shipment at WSI Lautoka warehouse.
Figure 5. WSI staff cleaning fleshy macroalgae from live rock at WSI warehouse.
Figure 6. Cultured “live” rock stock piled in WSI warehouse yard ready for placing in ocean.
Figure 7. Example of unusual shape in which cultured live rock can be formed.
Figure 8. Cultured live rock after 18 months in seawater and ready for shipment.
Figure 9. Diver collecting live hard coral in WSI collecting area on reef off Lautoka.
Figure 10. Staging area for collected corals for holding prior to transport to WSI facility.
Figure 11. Reef off Lautoka from which live corals have recently been collected.
Figure 12. Coral nubbin on concrete holder to be placed on grow-out frame
Figure 13 and 14. Frames used to hold “cultured’ live corals during grow-out period.
Figure 15. Diver collecting soft coral from nearshore reef off Lautoka.
Figure 16. *Sinularia* soft coral and collection scar from recent removal of one colony.
Figure 17. Damaged *Pocillopora eydouxi* coral on Nadogoloa offshore reef where curio corals were extensively collecting in 2002.
Figure 18. Damaged live coral fragments on collection-disturbed offshore reef.
Figure 19. Large coral rubble field on collection-disturbed offshore reef.
Figure 20. Broken coral small reef further inshore where curio corals have been collected.
Figure 21. Dead coral colony on inshore collected reef.
Figure 22. Coral fragment and macro-algal bloom on inshore collected reef.
Figure 23. Wide view of small inshore reef undisturbed by curio coral collection.
Figure 24. Closer view of corals on undisturbed inshore reef.
Figure 25-28. Extraction of live rock at reef off Namada village
Figure 29-31. Extraction scars from previous live rock mining off Namada village.
Figure 32. Reef channel apparently formed by live rock mining off Namada village

APPENDIX TWO

Fiji Coral Trade Project – Phase 1
Trip Report and Observations September 22-29, 2002
S. L. Coles
Bishop Museum

Phase 1 Activities

As a member of the IMA project team I participated in Phase 1 of an assessment on various aspects of harvesting of reef corals and coral reef material in the country of Fiji. Seven days were spent in on-site observations and discussions with local participants in the industry, which included diving or snorkeling observations made on four sites. The following remarks are preliminary in nature and subject to revision with further visits and observations to be made in Phase 2 of the project.

The commercial exploitation of reef corals or reef material in Fiji consists of the following activities: 1) Mining of live colonies of massive species of the genus *Porites* or of reef substratum for local use in cesspools, 2) Extraction of calcareous reef substratum, termed "live rock", for sale to the international marine aquarium industry, 3) Harvesting of live corals to be maintained alive and shipped internationally for sale to the marine aquarium industry, 4) Extraction of "curio" corals that are dried and sold internationally for decorative purposes. During Phase 1, we had the opportunity to have discussions and make observations on activities 1 to 3.

1. Corals and reef material for cesspool use.

Although assessment of this usage was not part of the project Terms of Agreement, observations indicate that this practice is having a serious impact on a major component of coral communities in the Suva area. Neatly stacked piles, or cairns, of cleaved, recently alive colonies of *Porites lutea* are for sale along Queen's Road just outside of Suva in Lami, and more cairns of similar size blocks of reef substratum are for sale about 10 km further along the road. Extrapolation of information derived from a discussion with one of the collectors suggests that the quantity of live corals taken amounts to approximately 1500 m^3, or about 15,000 corals, per year with an average radius size of approximately 25 cm for corals presently collected. This suggests that approximately 150,000 corals have been extracted over the ten years that this activity has gone on, with each coral representing at least 10 years of growth at estimated growth rates for this species. That this activity has not been sustainable is indicated by the fact that collection, which originally began nearby at sites in Suva Harbor, is now being done as far away as near Nukalau Island. No systematic evaluation or assessment of this activity has been undertaken, nor is it done under any permit or government ministry authorization. Also, it is unlikely that the purpose for which these corals are being used is unique or valid, since the use of conventional gravel or pebbles in cesspools would provide a greater surface or volume ratio for bacterial growth to reduce sewage waste levels in cesspool drain fields. A sanitary engineer should be consulted for a professional assessment of this conclusion.

2. Live Rock Extraction

This activity is conducted at a number of villages under agreement with exporters, who provide basic equipment for removing portions of the coral reef substratum and transport the material from the collection site to the company's processing facilities. The "live rock" is evaluated for its quality and processed to remove unwanted organisms that may die in aquaria, adding to oxygen demand and toxic components. The primary characteristic of the live rock for export is a surface layer of pink to purple coralline algae, which is reputed to reduce levels of nitrogen and other toxic components released by aquarium organisms., and adds to the coral reef appearance of the aquarium seascape. The exporters prefer that this material be collected on the offshore areas of reef flats near the surf zone where coralline algae is likely to make up a greater portion of the live rock collected. Rock that is deemed unsuitable for export is returned to the village with no payment.

Discussions and observations of live rock extraction activities were conducted at two villages during Phase 1. One village has conducted this activity for about the last eight years from throughout the reef flat rather than near the outer edge. The other village has collected from the outer reef flat for about the last three years and was engaged in this activity at the time of our observations. In both cases preliminary observations indicated that rock extraction is having a substantial and non-sustainable impact on the reef substratum. Gouged and broken areas in the reef surface mark the locations where rock has been removed using crowbars, and no indication of regrowth of these broken reef surfaces was observed on older areas of extraction. These areas remain barren and mostly without even colonization of fleshy macroalgae that is generally the first step in

recolonization of reef surfaces where corals are absent. The only corals observed in extraction areas were microatolls of *Porites lutea* on the reef that has been utilized for eight years, and unfortunately these are sometimes directly impacted by rock extraction for the coralline algae that may occur within the ring of the microatoll. Virtually no corals were found in the area of extraction of the reef where has been this activity has been underway for three years, but corals are moderately abundant on this reef further toward shore. The main problem at this extradition site appears to be potential erosion of the gouged areas marking rock extraction that are in or near the active surf zone. Bare edges of the gouged reef could be easily broken by hand, in contrast to the very hard surfaces of intact reef. This suggests that waves continue to erode and degrade the reef in these broken areas and contribute to coastline erosion reported to be occurring by villagers.

According to sources at both villages, approximately half of the material extracted is not suitable for the live rock trade and is returned to the villages for replacement on the reef. However these loose piece are subject to disturbance by the next large wave event, and the beach at one site was littered with reef rock apparently from this source. Other indications of disturbance on the reef was a high density of the macroalgae *Padina* sp. found only on areas of both sites which had been subject to previous live rock extraction.

Preliminary conclusions are that this activity is destructive to the reefs of Fiji, especially if it continues to move from village to village in response to demand, that it is unsustainable and that it is wasteful of the resource being extracted. No information is available that would permit a rigorous evaluation of the long-term impacts and no management plan has been developed or implemented.

3) Live Coral Harvesting.

Pieces of live coral are harvested from the reef, maintained under carefully controlled conditions to promote their viability and shipped internationally to brokers internationally for sale and use in marine aquaria. Three companies in Fiji are involved in this activity, the longest having been operating for seven years. I had discussions and made observations of collection and processing at the smallest of these companies, Aquarium Fish, working from Pacific Harbor, which has been harvesting coral for about three years. The following discussion is based on that information and may or may not apply to the other companies.

Aquarium Fish collects and ships about 300 coral pieces per week in sizes up to approximately 100 g weight and 10 cm in height for branching corals. A variety of species are harvested, but most are of the fast growing acroporids, pocilloporids and poritids. Corals are returned to the companies facilities in Pacific harbor, held for a week to assure viability and shipped to the U. S. (the European market is presently closed due to CITES restriction). Time enroute is 48 hours or less, during which a target mortality of <1% is achieved unless there is a cargo delay. Collection is made by the company owner or six trained Fijians using company boats and diving gear, and collection operations are supervised by an overseer to maintain quality control and low reef impact. Breakage of large colonies into small pieces for shipment is not allowed.

I observed collection of coral pieces on two reefs, during which a baseline survey was being conducted by an independent consultant for preparation of a management plan. Many of the pieces were obtained from fragments lying loose on the reef below or outside of growing colonies. The remaining corals collected were broken off the reef using a small chisel without disturbance to other corals, with the only indication of sampling activity being a small bare spot on the reef which would be invisible within a short time. Corals were very abundant in both areas with total coverage estimated at >50%. Given the large size of the resource, the spatial variability of coral coverage on the reef and the comparatively small quantity of corals being collected, it would be in my judgment impossible to detect any impact of this level of harvesting activity by any monitoring method. In addition, it should be pointed out that this harvesting is being done on reefs that underwent complete coral bleaching and subsequent extensive mortality in 2000. During the six months following the bleaching event, Aquarium Fish suspended coral harvesting until it was apparent the resource was recovering. The resettlement, colonization and growth of corals during the two year recovery period, especially of species of the *Acropora* and *Pocillopora* species that are favorites for the live coral trade, has been quite astounding. Coverage of these on the reef at the second site visited is now at the point where growth of adjacent colonies are starting to overlap.

Assessment of the resource and potential impact of coral harvesting is now being conducted for preparation of management plans for the companies involved in live coral trade, and these plans are scheduled for completion and submission in November. If the activities by the other two companies are shown to be consistent with those practiced by Aquarium Fish, live coral harvesting will be indicated to be totally sustainable and justifiable as a long-term industry for Fiji.

Phase 2 Priorities

The following activities should be given priority for completion in Phase 2 to establish the basis of sustainability for various activities in the Fiji coral trade:

1. Site visits, discussions and observations of live coral collection by the Walt Smith International and Ocean 2000 Ltd. Companies.
2. Site visits, discussions and observations of curio coral collection by the Seaking and Acropora International Ltd. companies.
3. Visits to additional villages involved in live rock extraction and a village's reef where this activity has bee done in the past and discontinued.
4. For at least one reef where live rock is presently being taken, a survey using plotless sampling methods to determine the total area of extraction and percentage of reef directly impacted by this activity. This could be done simultaneously with a survey of reef fishes in the extraction area
5. Determinations of the total quantities of live rock harvested at by each village at the present time and in the past, estimated through interviews with villages and exporters, including estimates of percentages of rock that are extracted but not of sufficient quality for shipment or payment.

APPENDIX 3 – Fiji 2000 to 2004 live rock monthly export data from MFF (in kg.)

YEAR	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
WALT SMITH INTERNATIONAL													
2000	58,875	49,236	53,311	41,719	30,669	35,635	41,696	44,133	47,336	46,258	40,252	51,845	**540,965**
2001													**605,620**
2002	72,222	51,045	66,702	59,463	26,078	33,654	30,739	52,173	55,247	66,097	51,541	60,170	**625,131**
2003	78,837	36,334	61,698	63,030	37,582	51,712	47,589	51,269	47,306	60,291	54,389	2,240	**592,277**
2004	15,183	64,975	70,264	80,422	28,207	40,268	50,707	72,990	71,269	50,056	60,732	110,278	**715,351**
OCEAN 2000													
2000													**0**
2001													**0**
2002													**0**
2003	31,070	3,455	16,029	10,576	9,594	7,704	20,823	20,186	1,988	908	10,007	4,349	**156,689**
2004	28,654	43,157	27,397	27,397	21,263	17,230	16,375	25,674	27,564	37,243	27,682	19,621	**319,257**
WATERLIFE EXPORTERS FIJI Ltd.													
2000	9,100	17,000	14,500	10,000	10,000	10,000	8,000	12,850	16,550	13,150	21,315	14,450	**156,915**
2001	14,000	14,000	17,500	14,000	17,500	12,000	9,000	15,000	9,000	16,000	20,000	20,500	**178,500**
2002	22,500	18,000	18,000	18,000	22,500	18,000	18,000	22,500	18,000	22,500	18,000	18,000	**234,000**
2003				3,000	12,000	8,000	4,150	0	7,050	6,000	5,100	13,288	**58,588**
2004	6,450	6,256	9,185	11,408	5,980	6,095	4,485	6,555	20,355	19,205	27,255	5,980	**129,209**
REL													
2000													**0**
2001													**0**
2002													**0**
2003	33,140	28,072	23,746	28,692	32,824	26,982	33,514	33,728	24,272	31,868	12,560	8,580	**317,978**
2004	31,947	30,863	30,684	31,570	10,780	14,448	7,310	10,440	11,492	5,720	6,096	8,888	**200,238**
TROPICAL FISH FIJI Ltd.													
2000	7,859	7,837	18,010	7,162	8,079	8,747	6,118	5,781	4,624	6,127	9,057	6,648	**96,049**
2001	19,321	18,368	19,998	4,545	7,428	4,643	4,602	8,067	11,790	15,390	5,994	7,939	**128,085**
2002													**0**
2003													**0**
2004													**0**