Population status, fisheries and trade of sea cucumbers in the Western Central Pacific

Jeff Kinch, Steve Purcell, Sven Uthicke and Kim Friedman

Papua New Guinea: a hotspot of sea cucumber fisheries in the Western Central Pacific

Jeff Kinch, Steve Purcell, Sven Uthicke and Kim Friedman

Population status, fisheries and trade of sea cucumbers in the Western Central Pacific

Jeff Kinch
Secretariat for the Pacific Regional Environment Program
Apia, Samoa
E-mail: jeffk@sprep.org

Steven Purcell
The WorldFish Center
Noumea Cedex, New Caledonia
E-mail: SteveP@spc.int

Sven Uthicke
Australian Institute of Marine Science
Queensland, Australia
E-mail: s.uthicke@aims.gov.au

Kim Friedman
Secretariat of the Pacific Community
Noumea Cedex, New Caledonia
E-mail: KimF@spc.int

Kinch, J.; Purcell, S.; Uthicke, S.; Friedman, K. 2008. Population status, fisheries and trade of sea cucumbers in the Western Central Pacific. In V. Toral-Granda, A. Lovatelli and M. Vasconcellos. Sea cucumbers. A global review of fisheries and trade. *FAO Fisheries and Aquaculture Technical Paper*. No. 516. Rome, FAO. pp. 7–55.

SUMMARY

In the Western Central Pacific region, most sea cucumber fisheries have exhibited boom-and-bust cycles since the late nineteenth century. Since the 1980s, elevated export prices and demand from Asian markets have been the catalysts for increased fishing. At many localities, high-value species have been depleted and previously unfished species are now exploited. The sustainability of these fisheries is of widespread concern.

Australia and Melanesian countries are the largest exporters of bêche-de-mer in the region. While annual exports from Melanesian countries have not declined markedly over the last two decades, those from Polynesia and Micronesia have. The declining exports appear to be attributed to unsustainable fishing pressure and naturally low abundances of many commercial species in remote Pacific islands and atolls.

Currently, 35 sea cucumber species in the families Holothuriidae and Stichopodidae are thought to be harvested. Greater endemicity occurs in Melanesian countries with sea cucumber species richness generally declining eastward of Papua New Guinea (PNG). On average, 13 species are harvested per country.

The vast majority of sea cucumbers are exported as dried bêche-de-mer; relatively small amounts are exported frozen or salted. A few species are exported as ornamentals and this component of trade is commonly under-reported. Many reports showed that some form part of subsistence diets, particularly for Polynesians. In some of these cases, just the gonads and/or intestine are taken and the animal is released to regenerate these organs for re-harvesting.

Especially in the Pacific Island Countries and Territories (PICTs), sea cucumbers are collected by hand in coral reefs and shallow lagoons. The exploitation often involves a high number of artisanal fishers, accessing stocks from shore or using small boats. Values of catch-per-unit-effort varied greatly among the published studies, and generally declined over time. Rural poverty in Papua New Guinea is causing some fishers to continue to collect sea cucumbers even when returns fall below 1 specimen per 10 hours of diving.

The multispecies nature of these fisheries adds difficulty for management and trade reporting. Export data are sometimes inaccurate, amalgamated across species groups, or missing, which adds to the difficulty of monitoring catches. Comparisons of past and recent trade data show an alarming trend of increasing proportions of low-value species in exports and a greater range of species in exports. This is particularly evident in Papua New Guinea and the Solomon Islands, where biodiversity is high.

The authors compare data from past and recent field surveys, and present a case study of *Holothuria whitmaei* densities among fished and unfished locations. Populations of most higher-priced species in the Western Central Pacific are, apparently, grossly depleted compared to virgin densities.

For some coastal villages, sea cucumber fishing is the primary source of income to residents. Financial benefits are generally distributed widely, at the village level, although processing by exporting companies is an increasing trend. In most fisheries, the depletion of sea cucumber stocks is already impacting the potential incomes of coastal and island communities and national revenues. In some cases, overfishing is affecting the sustainability of these fisheries for the long term.

The development of sustainable management in the Western Central Pacific region has been difficult. Management tools like size limits, gear restrictions, spatial and temporal closures, quotas and marine reserves have not curbed overfishing. Much of their ineffectiveness can be attributed to a lack the necessary funds and technical capacity for adequate awarness raising in most PICTs. Commonly, there are also conflicts of interest within differing levels and agencies of government, politicians and influential business people. Fishing moratoria have been declared in some countries, including Solomon Islands, Fiji, Tonga and Vanuatu. Although breeding populations at some localities have recovered, empirical studies show that populations for other species have failed to rebuild after years of respite. International support is needed to evaluate CITES listing for the conservation of rare and threatened species.

Restocking using hatchery-produced juveniles is technically feasible, but will be an expensive remedy to overfishing. International translocation of stocks for restocking or sea ranching is discouraged. Recent research has focussed on underwater population surveys, to assess population densities, and socio-economic surveys. In particular, the SPC PROCFish/C programme has trained fisheries officers in these survey methods and is providing comparative analyses of stock status in PICTs. Effort must now turn to aiding PICTs to develop practical management frameworks that allow breeding populations to recover to productive levels with a limited institutional capacity for compliance and enforcement of regulations.

CONVENTIONS

To be consistent with the terminology for this fishery, "holothurians" or "sea cucumbers" are used throughout this report when referring to live animals and "bêche-de-mer" is used when referring to the dead animal when processed for commercial purposes.

Where older taxonomic classifications have been used in referenced texts or in information provided by colleagues, these have been changed to their new taxonomic determinations. For example, in this report, the authors adhere to the results of a recent morphological and genetic study (Uthicke *et al.*, 2004) that suggests that all black teatfish in the area covered in this review are *H. whitmaei*; with the presumption that *H. nobilis* does not exist in the Western Central Pacific region. All white teatfish are referred to as *H. fuscogilva*, though there is a possibility that this species may also have its taxonomic designation revised in the future.

Similarly, where imperial or colonial names have been used for countries, districts or islands in the past, their modern names, post-independence or associations have now been used instead.

1. THE WESTERN CENTRAL PACIFIC REGION

The Western Central Pacific region (for purposes of this report) is an area that encompasses the 22 Pacific Island Countries and Territories (PICTs) that are affiliated to the Secretariat of the Pacific Community (SPC) (Figure 1), Australia and New Zealand; but excludes, Hawaii (United States of America) and Easter Island (Chile).

Information on sea cucumber fisheries is available for 23 of the 24 countries and territories under this review.

The Western Central Pacific region can be broken into the following geographical and cultural areas:

- Micronesia: Palau, Guam, the Commonwealth of the Northern Mariana Islands (CNMI), the Federated States of Micronesia (FSM), the Marshall Islands, Nauru and Kiribati;
- Polynesia: Tuvalu, Wallis and Futuna, Tokelau, Samoa and American Samoa, Tonga, Pitcairn Islands, Niue, the Cook Islands, and French Polynesia;

FIGURE 1

Region under study and countries covered in this review (highlighted in yellow). The dashed line denotes the boundary of the SPC Pacific Island Countries and Territories. The region encompasses mainly the FAO Statistical Areas 71 (Western Central Pacific), 77 (Eastern Central Pacific) and 81 (Pacific Southwest)

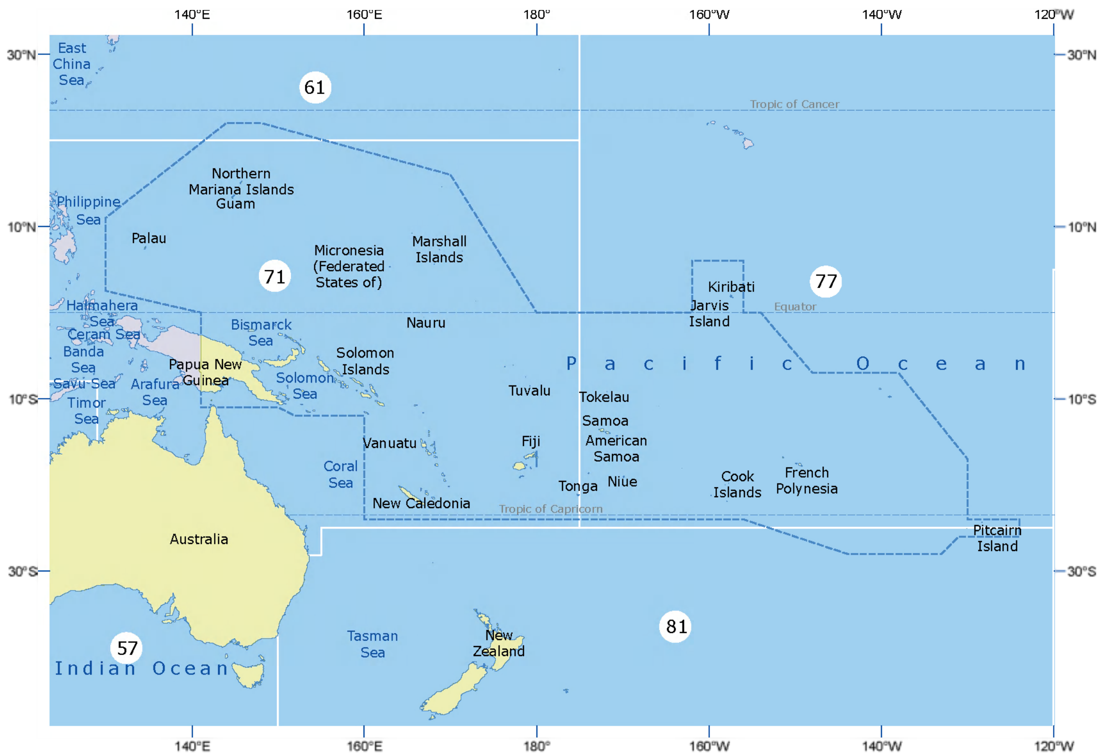


FIGURE 2

Varied habitats of the tropical Western Central Pacific region. Left: *H. scabra* in a muddy inshore seagrass bed. Right: *A. mauritiana*, in complex habitat on the reef crest

COURTESY OF S. PURCELL

- Melanesia: Papua New Guinea (PNG), the Solomon Islands, Vanuatu, New Caledonia and Fiji; and
- Australia and New Zealand (the latter also culturally and geographically part of Polynesia).

Most of the sea cucumber fisheries in this region exist in shallow tropical waters. Whereas the waters in Southeast Asia and the Indian Ocean are nutrient rich, many localities in the Western Central Pacific region are isolated and nutrient poor, and do not support a high biomass of sea cucumbers. However, the warm tropical waters of the Western Central Pacific region have afforded a high level of speciation. Habitats for sea cucumbers in the Western Central Pacific Region are predominantly coastal seagrass beds near mangroves and the soft and hard substrata of coral reefs (Figure 2). It is both the warm temperatures and shallow habitats that permit easy harvesting by coastal fishers and make these fisheries vulnerable to degradation from impacts associated with global climate change.

2. BIOLOGICAL AND POPULATION STATUS

2.1 Key taxonomic groups

In the Western Central Pacific region there are approximately 300 shallow-water holothurian species (Preston, 1993), with species diversity tending to decline eastwardly into the tropical Pacific (Clark, 1946).

There are 35 known sea cucumber species utilized for the production of bêche-de-mer in the Western Central Pacific region (Table 1). These are species that generally have thick body walls and belong to the order Aspidochirotida. Of this order, only the families Holothuriidae (genera *Actinopyga, Bohadschia, Pearsonothuria* and *Holothuria*) and Stichopodidae (genera *Stichopus* and *Thelenota*) are harvested and exported to overseas markets.

The actual number of exploited sea cucumber species maybe as high as 57 when misidentifications are taken into consideration (Table 1). Conand (1998) notes that some processed *Actinopyga* and *Bohadschia* spp. are not commercially distinguished to species level. This is also true for some *Holothuria* and *Stichopus* spp.

2.2 Biology and ecology of sea cucumbers

The evolutionary development of holothurians appears to have played a large role in the manner in which population assemblages (or taxocoenoses) are distributed within the marine environment (Table 2). Coastal processes are also important factors in regulating the distribution of sea cucumber species, as hydro-dynamics influence sediment granulometry, which is a key habitat characteristic for defining the niches of holothurians, and larval dispersion (Massin and Doumen, 1986).

TABLE 1
Holothurians used for the production of bêche-de-mer in the Western Central Pacific region. The table includes sea cucumber species known to be utilized (shaded) and other possible species that are misidentified once processed

Holothuriidae		Stichopodidae
Actinopyga albonigra	*Holothuria arenicola*	*Stichopus chloronotus*
A. caerulea	*H. atra*	*S. godeffroyi*
A. echinites	*H. cinerascens*	*S. herrmanni*
A. lecanora	*H. coluber*	*S. horrens**
A. mauritiana	*H. difficilis*	*S. monotuberculatus**
A. miliaris	*H. edulis*	*S. naso**
A. palauensis	*H. flavomaculata*	*S. pseudohorrens*
A. spinea	*H. fuscocinerea*	*S. vastus*
Bohadschia anaes	*H. fuscogilva*	*S. ocellatus*
B. argus	*H. fuscopunctata*	*Australostichopus mollis*
B. bivitatta	*H. grises*	*Thelenota ananas*
B. geoffreyi	*H. guamensis*	*T. anax*
B. maculisparsa	*H. hilla*	*T. rubralineata*
B. marmorata	*H. impatiens*	
B. similis	*H. leucospilota*	
B. subrubra	*H. maculata*	
B. tenuissima	*H. pardalis*	
B. vitiensis	*H. pervicax*	
	H. scabra	
	H. scabra var. *versicolor**	
	H. verrucosa	
	H. whitmaei	
	Holothuria sp. (Hongpai – Solomon Islands)	
	Holothuria sp. (Tulele – Solomon Islands)	
	P. graeffei	

* taxonomic review in progress.

Tropical coral reefs offer a broad range of habitats with high floral and faunal diversity, often resulting in highly speciose sea cucumber populations. This high species richness in the Western Central Pacific region is probably attributed largely to these diverse micro-habitats.

Many sea cucumber species in the Western Central Pacific region have been reported to exhibit episodic spawning behaviour throughout the year, with a period of enhanced activity from October–February (Conand, 1981; Lokani, 1990; Ramofafia, Gervis and Bell, 1995; Ramofafia, Battaglene and Bryne, 2001; Ramofafia, Byrne and Battaglene, 2001, 2003; Battaglene and Bell, 2004; Kinch, 2004a) (Table 3).

The mechanisms and triggers for the settlement of holothurians are still somewhat unknown because the larvae are, as yet, difficult to identify by species and the juveniles are generally cryptic. Conand (1993) and Uthicke (1994) suggest settlement of *S. herrmanni* and *S. chloronotus* in reef flat zones and subsequent migration towards other areas. *H. scabra* was demonstrated to settle in shallow seagrass beds (Mercier, Battaglene and Hamel, 2000a) and some eventually happen to make it to deeper waters (Mercier, Battaglene and Hamel, 2000b; Hamel *et al.*, 2001). Recruitment in sea cucumber populations is thought to be highly irregular and variable.

Several common holothurians in the Western Central Pacific region also reproduce asexually through transverse fission, whereby the body is split into an anterior and posterior section (Conand, 1996; Uthicke, 1997; Purwati, 2001; Purwati and Thinh Luong Van, 2003), and this may be linked to anthropogenic or ecological disturbances in some species and areas (Doty, 1977; Ebert, 1978; Harriott, 1982; Conand, 1989, 1996; Uthicke, 1997). Fission in the Western Central Pacific region has been observed in

TABLE 2
Characteristics of selected commercial holothurian species in the Western Central Pacific region

Species	Average length (cm)	Average wet weight (kg)	Body wall thickness (cm)	Habitat preference	Depth range (m)
Actinopyga echinites	20	0.3	0.7	Reef flats of fringing and lagoon-islet reefs, rubble reefs and compact flats	0–12
A. lecanora	25	0.4	0.6	Hard substrates (nocturnal)	0–20
A. mauritiana	20	0.3	0.6	Outer reef flats and fringing reefs, mostly in the surf zone	0–20
A. miliaris	25	0.4	0.6	Reef flats of fringing and lagoon-islet reefs, never found on barrier reefs	0–10
Bohadschia argus	36	1.8	1.0	Barrier reef flats and slopes, or outer lagoons on white sand	0–30
B. similis	18	0.3	0.4	Coastal lagoons and inner reef flats, often burrowed in sandy-muddy bottoms	0–3
B. vitiensis	32	1.2	0.7	Coastal lagoons and inner reef flats, often burrowed in sandy-muddy bottoms	0–20
Holothuria atra	20	0.2	0.4	Inner and outer reef flats and back reefs or shallow coastal lagoons	0–20
H. coluber	40	0.3	0.4	Inner and outer reef flats and back reefs or shallow coastal lagoons	0–15
H. edulis	20	0.2	0.3	Inner reef flats of fringing and lagoon-islets reefs, and shallow coastal lagoons	0–30
H. fuscogilva	42	2.4	1.2	Outer barrier reefs and passes, also on shallow seagrass beds	0–40
H. fuscopunctata	36	1.5	1.0	Reef slopes and shallow seagrass beds	0–25
H. leucospilota	20	0.2	0.2	Rubble, consolidated rubble and boulder	0–5
H. scabra	22	0.3	0.6	Inner reef flats of fringing reefs, lagoon-islets	0–15
H. whitmaei	37	1.7	1.2	Reef flats, slopes and shallow seagrass beds	0–20
Pearsonothuria graeffei	35	0.7	0.4	Reef slopes, close to the coast	0–25
Stichopus chloronotus	18	0.1	0.2	Reef flats and upper slopes, mostly on hard substrates	0–15
S. herrmanni	35	1.0	0.8	Seagrass beds, rubble and sandy-muddy bottoms	0–25
S. horrens	20	0.2	0.2	Reef flats and upper slopes, mostly on hard substrates	0–15
Thelenota ananas	45	2.5	1.5	Reef slopes and near passes, hard bottoms with large rubble and coral patches	0–25
T. anax	55	3.5	1.5	Reef slopes, outer lagoon and near passes, large rubble and sand patches	10–30

Source: SPC, 2003.

H. atra (Doty, 1977; Harriott, 1982; Conand, 1993, 1996; Seeto, 1994; Uthicke, 1997), *H. edulis* (Harriott, 1985; Uthicke, 1997), *S. chloronotus* (Franklin, 1980; Uthicke, 1997), *H. coluber* (Conand, Morel and Mussard, 1997) and *T. ananas* (Reichenbach, Nishar and Saeed, 1996).

Information on growth rates of holothurians has been difficult to ascertain because conventional methods to measure growth of marine organisms are difficult to apply. Methods used to date have included marking the calcareous (epipharyngeal) rings (Ebert, 1978), chemical marking of spicules (Purcell and Simutoga, 2008), external tagging (Shelley, 1981; Conand, 1989), internal tagging (Lokani, 1992), by following the mean weight of a population over time (Chao, Chen and Alexander, 1994), and Modal Progression Analysis (Franklin, 1980; Shelley, 1985; Conand, 1988; Uthicke, 1994). From these studies, growth rates of holothurians in the Western Central Pacific region have been determined to range between 3 and 30 g mo^{-1}. Genetic tagging and recapture studies confirmed growth rates in that range for *H. whitmaei*, but also indicated that larger individuals can shrink over time (Uthicke and Benzie, 2002; Uthicke, Welch and Benzie, 2004).

Mortality rates for sea cucumbers in the Western Central Pacific region have been estimated for *S. chloronotus* with a life span of about five years, whilst *T. ananas*,

TABLE 3

Peak spawning periods (shaded) for selected commercial holothurian species in the Western Central Pacific region

Species	Location	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Actinopyga echinites	New Caledonia	■	■											Conand, 1988, 1989, 1993
	PNG												■	Shelley, 1981
A. mauritiana	Guam				■	■	■	■	■					Richmond, 1996a
	New Caledonia	■											■	Conand, 1989
	Solomon Islands	■									■	■	■	Ramofafia, Byrne and Battaglene, 2001
A. miliaris	New Caledonia					■						■	■	Conand, 1988, 1989, 1993
Bohadcshia vitiensis	PNG												■	Shelley, 1981
	Palau							■	■					Hendler and Meyer, 1982
B. argus	Australia (GBR)						■							Uthicke, 1994
	New Caledonia												■	Conand, 1988, 1989, 1993
Holothuria atra	Australia (GBR)	■				■	■					■	■	Harriott, 1980, 1982, 1985
	Fiji									■	■	■	■	Seeto, 1994
H. edulis	Australia (GBR)	■											■	Harriott, 1985
H. fuscogilva	New Caledonia	■										■	■	Conand, 1981, 1988, 1989, 1993
	Solomon Islands								■	■	■			Ramofafia *et al*., 2000
H. fuscopunctata	Australia (GBR)												■	Uthicke, 1994
	New Caledonia	■	■										■	Conand, 1988, 1989, 1993a
H. leucospilota	Australia (GBR)	■	■	■								■	■	Franklin, 1980
	Australia (NT)				■									Purwati, 2001
	Cook Islands	■	■	■	■							■	■	Drumm, 2004
	Cook Islands	■									■	■	■	McCormack, 1984
H. scabra	Australia (GBR)	■										■	■	Harriott, 1980
	Australia (GBR)											■	■	Morgan, 2000
	Australia (NT)	■	■										■	DEH, 2004
	New Caledonia	■							■	■			■	Conand, 1988, 1989, 1993
	PNG											■	■	Shelley, 1981
	Solomon Islands									■	■	■	■	Ramofafia, Byrne and Battaglene, 2003
H. whitmaei	Australia (GBR)				■	■	■							Shiell and Uthicke, 2005
	Australia (WA)				■	■	■							Shiell and Uthicke, 2005
	Guam				■	■	■	■	■					Richmond, 1996a
	New Caledonia						■	■	■					Conand, 1981, 1988, 1989, 1993
Pearsonothuria graeffei	Australia (GBR)	■	■									■	■	Uthicke, 1994
Stichopus chloronotus	Australia (GBR)	■			■							■	■	Uthicke, 1994
S. herrmanni	Australia (GBR)											■		Uthicke, 1994
	New Caledonia		■											Conand, 1988, 1989, 1993
Thelenota ananas	Guam	■	■		■	■	■	■	■			■	■	Richmond, 1996a
	New Caledonia	■	■	■										Conand, 1981, 1988, 1989, 1993

Note: Australia – **GBR** = Great Barrier Reef; **NT** = Northern Territory; **WA** = Western Australia.

A. echinites, *A. mauritiana* have life spans in excess of 12 years (Shelley, 1981; Conand, 1990). Natural mortalities ranged from 16–60 percent y^{-1} for the latter species. Ebert (1978) estimated a natural survival rate of 40 percent annually for *H. atra* at Enewetak Atoll in the Marshall Islands.

Population genetics studies have shown that some populations are highly connected. For example, studies conducted by Uthicke and Benzie (2001, 2003) determined that contiguous range expansion for *H. whitmaei* in the Australian region probably began in the late Pleistocene, with the existing population genetic structure probably formed prior to the last ice age. Uthicke and Benzie (2001, 2003) also found *H. whitmaei* populations could not be distinguished genetically from each other within the Great Barrier Reef, but did exhibit some restrictions in gene-flow with populations in West Australia and the Coral Sea. This suggests that on evolutionary time scales, sea cucumber stocks could be replenished from a large variety of sources, but are not highly relevant on the ecological time scales required for fisheries management.

Genetics studies on *H. scabra* have shown that populations from Australia (the Northern Territory, the Torres Strait, the Solomon Islands, the Great Barrier Reef), the Solomon Islands, and New Caledonia are distinct populations with little gene-flow between these populations (Uthicke and Benzie 1999, 2001; Uthicke and Purcell, 2004). The fragmented meta-population is a likely result of shorter larval time when compared to *H. whitmaei*, but also probably due to the hydro-dynamic retainment in the coastal areas and bays where *H. scabra* occurs. Gene-flow estimations for *H. atra* and *S. chloronotus* from the Great Barrier Reef, the Torres Strait and Réunion, have been hampered by high rates of asexual reproduction. However, it appears that gene-flow is high for these species, though there are some limitations in population connectivity between inshore and mid-shelf areas of the Great Barrier Reef (Uthicke, Benzie and Ballment, 1998, 1999; Uthicke, Conand and Benzie, 2001).

Apart from harvesting, sea cucumbers in the Western Central Pacific region generally suffer low predation owing to their chemical and physical defense mechanisms (Bakus, 1968; 1973). These include the release of cuvierian tubules (collagenous fibres that are extremely sticky), and the ability to eviscerate parts of their internal organs or body to evade predators (Mercier and Hamel, 2000). One common holothurian, *H. atra*, possesses strong toxins (mainly saponins), generally referred to as "holothurine", which is thought to interfere with the action of the fish branchiae (Bakus, 1973; FAO, 1990). The calcareous ossicles (or "spicules") in the outer body wall of holothurians also provides structural defence to their body wall; for example, *H. scabra* spicules are more densely packed in the dermis of juveniles than adults (Purcell, Blockmans and Nash, 2006). Predators that will take sea cucumbers in the Western Central Pacific region include seagulls, sharks, gastropods (in particular *Tonna* spp.), fish (notably Balistidae, Labridae, Lethrinidae and Nemipteridae), sea stars and crustaceans (Kropp, 1982; Francour, 1997; Mercier and Hamel, 2000; Dance, Lane and Bell, 2003), and loggerhead turtles (Cannon and Silver, 1987).

2.3 Exploitation of sea cucumbers for subsistence purposes

In many countries in the Western Central Pacific region, *A. miliaris, A. echinites, A. mauritiana, H. atra, H. scabra, H. leucospilota, H. verrucosa, H. fuscopunctata, B. argus, B. similis, B. vitiensis, T. ananas, S. horrens* and *S. herrmanni* are consumed (or their intestines and/or gonads) as delicacies or as a protein component to traditional diets (Conand, 1990; Dalzell, Adams and Polunin, 1996; Lambeth, 1999, 2000; Mathews, 1995; Mathews and Oiterong, 1991, 1995; Smith, 1992). Local consumption is particularly important in times of hardship and following cyclones (Adams, 1992). The top three species consumed across the countries in which subsistence use was reported are *A. mauritiana, H. atra* and *S. horrens* (Table 4).

Micronesia

Mathews and Oiterong (1991, 1995) noted the consumption of gonads and/or intestines of *S. vastus, A. echinites, H. scabra* and *H. verrucosa* in Palau. The leathery body wall of an unidentified *Actinopyga* sp. is also consumed. The ejected cuvierian tubules of certain *Bohadschia* spp. are also used by the youth of Palau to coat the soles of their feet to protect them while walking on the reef (Adams *et al.*, 1994). Smith (1986) reported *S. horrens* and *H. atra* consumed in Guam.

Due to economic hardship, Nauruans have started to exploit whatever marine resources are edible, and subsequently target *A. mauritiana* and *H. atra* for subsistence purposes (Vunisea, A., Secretariat of the Pacific Community, personal communication).

Polynesia

Conand (1990) reported that sea cucumbers were consumed in Wallis and Futuna. Conversely, sea cucumbers and their body parts are not reported in the traditional diet of Tuvalu islanders (Belhadjali, 1997).

TABLE 4
Subsistence use of holothurian species in the Western Central Pacific Region

Species	Micronesia			Polynesia						Melanesia		Total No. of countries
	Palau	Guam	Nauru	Wallis-Futuna	Samoa	Cook Islands	Tonga	Nuie	French Polynesia	Papua New Guinea	Fiji	
Actinoypa echinites	✓											1
A. mauritiana	✓		✓	✓	✓	✓			✓	✓		7
A. miliaris	✓											1
Bohadschia argus				✓	✓							2
B. vitiensis					✓						✓	2
Holothuria atra		✓	✓		✓	✓		✓	✓			6
H. cinerascens						✓						1
H. fuscogilva	✓			✓					✓			3
H. hilla					✓	✓						2
H. leucospilota					✓	✓	✓					3
H. scabra	✓			✓						✓	✓	4
H. scabra var. *versicolor*										✓	✓	2
H. verrucosa	✓											1
H. whitmaei	✓								✓			2
Stichopus chloronotus				✓					✓			2
S. herrmanni					✓	✓						2
S. horrens		✓		✓	✓	✓	✓					5
S. vastus	✓											1
Thelenota ananas	✓			✓					✓			3
Total	**9**	**2**	**3**	**7**	**8**	**7**	**2**	**1**	**6**	**3**	**3**	**–**

In the southern Cook Islands, *H. leucospilota* and *H. cinerascens* are harvested for their gonads (Zoutendyk, 1989a). *H. leucospilota* is heavily exploited by women and children throughout the year, with harvesting intensifying during the summer months from October–March (Baquie, 1977; Drumm and Lonergan, 2005; Drumm, 2004; Dzeroski and Drumm, 2003; Hoffman, 2001; Tiraa-Passfield, 1997). The removal of gonads appears to have no impact on the survival, with the body-wall of gutted animals healing within 7–14 days, while the gonads regenerate after 41 days. It is thought, however, that their body weight, general sheltering, feeding behaviours and spawning is affected (Drumm and Loneragan, 2005).

FIGURE 3
Roadside stall for locally consumed sea cucumber product (mainly the body wall of *B. vitiensis* and some viscera of *S. horrens*) in Samoa

COURTESY OF H. ERIKSSON

During recent surveys in Samoa, the subsistence sea cucumber fishery was considered to be an important element to fishers' livelihoods and their families (Figure 3), with 29 percent of all fishers surveyed selling either all or part of their sea cucumber catch at local markets (Eriksson, 2006; Friedman *et al.*, 2006). Assessments of markets by the Samoan Fisheries Division has shown that there has been a decline in the sale of *S. horrens*, with the less sought after *B. vitiensis* increasing in sales between 2000 and 2004. This is possibly an indication that the availability of *S. horrens* is declining, or possibly not satisfying local consumer demands (Eriksson, 2006; Friedman *et al.*, 2006). Both *S. horrens* and *H. leucospilota* are also exploited for local consumption and sale in Tonga.

Sea cucumbers are not a common sea food in French Polynesia, with consumption limited to some of the southern islands of the Austral Archipelago, especially Rurutu Island (Gibert, A., Tahiti Eco Clams Project, personal communication), where *A. mauritiana, H. atra, S. chloronotus* and *T. ananas* are commonly consumed (Stein, A., Polynésie française, Service de la pêche, personal communication).

Melanesia

Apparently, there is no subsistence use of sea cucumbers in the Solomon Islands (Adams *et al*., 1992), though it has been reported that bêche-de-mer (most probably *H. scabra*) is baked with cabbage and coconut cream in North Malaita (Foale, S., James Cook University, personal communication). In Papua New Guinea, some *Actinopyga* spp. are consumed in the West New Britain Province, and some areas in Manus use the toxins of *H. atra* to fish for octopus (Lokani, 1990). *H. scabra* is regularly consumed grilled in the Western Central Province and in the Trobriand Islands in the Milne Bay Province (Kinch, 2002; 2004b; Kinch *et al.*, 2007).

Qalovaki (2006) reports *H. scabra* and *H. scabra* var. *versicolor* used as food in Fiji, whilst Adams (1992) includes *B. vitiensis*. Dalzell, Adams and Polunin (1996) estimated that approximately seven tonnes of sea cucumbers were sold for food in markets and produce stores in Fiji in the mid-1990s.

There is also probably considerable domestic consumption and probably small levels of harvesting by Asian residents and workers in countries throughout the Western Central Pacific region.

2.4 Background of the commercial sea cucumber fishery

In the Western Central Pacific region, sea cucumber fisheries have existed for several centuries. These initially centred on the north-west peninsular of present day West Papua Province of Indonesia (Souter, 1963) and in the Northern Territory of Australia (McKnight, 1976; Cannon and Silver, 1987). Sea cucumber harvesting in the Northern Territory by Macassans from Indonesia continued right up until 1907 when the South Australian government which then controlled the Northern Territory ceased issuing fishing licenses (McKnight, 1976). Oral history of Torres Strait Islanders also indicates that Chinese and Malays regularly visited the islands to harvest sea cucumbers long before European explorers arrived (Laade, 1966).

Increased exploitation of sea cucumber stocks in the Western Central Pacific region began in the latter years of the eighteenth century with European and Japanese colonial expansion. Bêche-de-mer exports became important components of early English, Dutch, German, Spanish, French and Japanese colonial administrations (Ward, 1972; Moore, 2003).

All throughout the Western Central Pacific region, the bêche-de-mer trade followed a similar pattern: the sea cucumber fisheries peaked in the early nineteenth century and then slowly declined. This was partly due to over-harvesting in some areas, and partly because bêche-de-mer was replaced by other goods, such as copra (Ward, 1972; Moore, 2003). Production of bêche-de-mer in the Western Central Pacific region also remained at low levels for much of the early part of the twentieth century (Conand, 1990). Outside of Micronesia, the Sino-Japanese War and World War II also caused a decline in exports (Richmond, 1996b), and it was only in the early 1960s that sea cucumber fisheries regained some importance throughout the region.

In the 1980s, price increases and an enhanced demand in China and in Chinese communities around the world led to increasing effort in the re-development of sea cucumber fisheries in many PICTs (Preston, 1993). Increased trade was also facilitated by the removal of trade barriers to China and its concurrent increasing affluence and concomitant drops in supplies from traditional source countries closer to Asia, such as Sri Lanka. This greater demand and higher prices paid to fishers also provided a strong incentive for many coastal and island people in the region to shift from other "traditional" fisheries, to neglect agricultural cash-cropping and to relax religious, both "traditional" and Christian taboos on the harvesting of sea cucumbers (Kinch *et al.*, 2006, 2007). An example of the latter is the harvesting of sea cucumbers for cash by Seventh Day Adventists who are prohibited under the Bible scripture, Leviticus 11: 9–12; to touch or eat marine animals that do not have fins or scales (Kinch *et al.*, 2006).

Even with this re-emergence of exploitation, only a subset of species was mainly targeted. These initial species were *H. scabra*, *H. whitmaei*, *H. fuscogilva*, *A. miliaris* and *T. ananas* (Sachithananthan, 1971a, b; Crean, 1977; Shelley, 1981; Kinch, 1999).

As noted in Section 2.1, today there are approximately 35 sea cucumber species in trade, with possibly another 22 also utilized to varying degrees in countries of the Western Central Pacific region (Table 5).

Micronesia

The 1830s was the main period of exploitation in Micronesia with sea cucumber fisheries starting in the CNMI (Morrell, 1832), before starting in Yap (Cheyne, 1852) and in the Marshall Islands (Coulter, 1847). Exploitation continued through the Japanese mandate era (prior to World War II), with an estimated 5 124 tonnes exported during this period (Richmond, 1996b). Chuuk Atoll, in the Federated States of Micronesia, is reported to have exported nearly 454 tonnes y^{-1} during the early part of the twentieth century (SPC, 1979). Smith (1947) identifies the chief centres of production during this period as Chuuk Atoll (producing 61% of exports), Palau (18%), Pohnpei (11%), Saipan (6%) and Yap (4%). Sea cucumber populations were also heavily impacted during World War II, when large numbers of Japanese soldiers were left without food, and subsequently harvested significant amounts of sea cucumbers to supplement their diets.

Palau does not have an active export trade for bêche-de-mer at present due to a moratorium that was implemented a decade ago, though several species are used for subsistence purposes.

Guam does not have an active commercial fishery, although there is an increase in local consumption due to recent influx of other Micronesian Islanders (Kerr, A., University of Guam, personal communication).

The sea cucumber fishery re-started in the CNMI in 1995. Because *A. mauritiana* and *S. chloronotus* were available in relative abundance, they were the main species targeted on the island of Rota, and fishing continued there through to 1996, when operations moved to Saipan due to a drop in harvest rates because of seasonal weather conditions and over-exploitation of accessible areas (Trianni, 2001, 2002). The Saipan sea cucumber fishery also targeted *A. mauritiana* (making up 99% of all exports) and some *H. whitmaei* but stopped in 1997 due to declining CPUE (Trianni, 2002). Resource surveys, in the period shortly after harvesting had ceased, estimated that the remaining population of *A. mauritiana* was between 10 and 22 percent of its initial population size (Trianni, 2002). A 10-year moratorium on the harvest of all sea cucumbers was put in place across the CNMI in 1998.

In the FSM, only *A. mauritiana* and *S. chloronotus* were thought abundant enough to support commercial exploitation (Kerr, 1994; Edward, 1997). These two species have been commercially harvested since 1996, with *A. mauritiana* being targeted principally (Lindsay, 2001a). Between 2005 and late 2007, *A. miliaris* and another local *Actinopyga* sp. has been commercially harvested from Yap. Due to uncontrolled expansion in the fishery a moratorium was institued in late 2007.

Based on the information collected by SPC-Pacific Regional Oceanic and Coastal Development Project Coastal Component (PROCFish/C), the only species with

FIGURE 4
A fisher processing his catch at Wallis Island

COURTESY OF K. FRIEDMAN

potential for commercial harvests in Nauru appears to be *A. mauritiana* (Kim Friedman, unpublished data).

In Kiribati, small sea cucumber fisheries operate on Christmas (Kiritimati) Island and within the Gilbert Island Group. The fishery boomed from 2000–2002, but is now considered depleted. Commercial sea cucumber species targeted include *H. fuscogilva* and *T. ananas*, with smaller quantities of *H. whitmaei*, *S. chloronotus*, *B. argus*, *B. vitiensis* and *A. mauritiana* also exploited and exported (Kronen, M., Secretariat of the Pacific Community, personal communication). *H. atra* was not collected previously, but due to the scarcity of other higher-value species, it is now also being harvested (Tekanene, M., Kiribati Ministry of Fisheries and Marine Resources Development, personal communication).

Polynesia

Fishing in Polynesia began early with the first records of sea cucumber exports around 1810 from French Polynesia (Ward, 1972), and 1825 from Hawaii (Morrell, 1832) expanding elsewhere throughout the region soon after.

With increasing prices paid for bêche-de-mer and subsequent increasing interest from fishers, many countries began to take advantage of the new economic opportunities and began exploiting their sea cucumber stocks for export.

On Wallis, there is a small but growing sea cucumber fishery, which exports bêche-de-mer to New Caledonia for on-routing to Asian markets (Figure 4) (Kronen, M., Secretariat of the Pacific Community, unpublished data). Futuna does not have an active fishery due to transport and marketing problems. Species taken at Wallis include *H. scabra, S. chloronotus, S. herrmanni, T. ananas, H. whitmaei, H. fuscogilva*, and *A. mauritiana*.

In Tuvalu, the Fisheries Department received funding from the United Nations Development Program in 1978 to redevelop its sea cucumber fishery. Shortly after, a total of 1.8 tonnes of bêche-de-mer was bought from fishers in Nukufetau and exported to Fiji (Belhadjali, 1997). Production then fell, because fishers lacked interest, until 1993 when the fishery was re-established by Fiji-based Asian companies. From 1993–1995, the main species targeted for export were *H. fuscogilva* (64%), *T. ananas* (18%), *H. fuscopunctata* (8%) and *H. whitmaei* (3%) (Belhadjali, 1997). Since April 2007 fishing has recommenced in at least 3 of the islands including the main island of Funafuti

The bêche-de-mer trade in Samoa recommenced in the 1960s, with ad-hoc exports up until the mid-1990s (Mulipola, 1994). Exports in 1993–1994 consisted of *B. vitiensis* (44%), *A. mauritiana* (30%), *B. argus* (19%), *S. chloronotus* (3%), *H. whitmaei* (2%), *H. atra* (2%), and very small amounts of *H. fuscogilva* and *T. ananas* (Mulipola, 1994). After 1994, the commercial fishery stalled and bêche-de-mer exports have been closed since then, though some sea cucumbers have been sold for the aquarium trade (Mulipola 2002). Currently, harvesting is concentrated on supplying the domestic market, targeting mostly *S. horrens, B. vitiensis,* and *H. atra* (Eriksson, 2006). In 2004, 1.7 tonnes of *S. horrens* and *B. vitiensis* were sold at local markets (Friedman *et al.*, 2006).

American Samoa does not have an export trade for bêche-de-mer although there is a small subsistence fishery (Fenner, D., American Samoa Department of Marine and Wildlife Resources, personal communication).

The early-1980s saw the re-commencement of the sea cucumber fishery in Tonga (as an extension of the Fiji fishery) using SCUBA and hookah. Sea cucumber harvests were thought to have peaked in 1994 (Tonga Ministry of Fisheries, 1995; Kailola, Petelo and Gillett, 1995). A moratorium on harvesting and exports, declared in 1999 after a recognized depletion in stocks, persists in Tonga, but is due to be lifted in 2008.

A fisheries survey was conducted in 1994 in the Pitcairn Islands, whereby 640 kg gutted wet weight of *H. whitmaei* was collected as part of an assessment of the potential of the sea cucumber fishery and taken to New Zealand (Sharples, 1994). The industry has not developed further (Dunn, E., Office of the Commissioner of Pitcairn Islands, personal communication).

Following a marine resources assessment of Niue in 1990, Dalzell, Lindsay and Patiale (1993) concluded that sea cucumber stocks offered little commercial potential, unless the fishery was to target the low-valued *H. atra*. Recent assessments provided the same conclusion (Kronen, M., Secretariat of the Pacific Community, personal communication).

The Cook Island fishery recommenced in the mid-1980s, with the exploitation and export of *T. ananas, S. chloronotus, A. mauritiana, H. atra, H. whitmaei* and *B. argus* (Zouthendyk, 1989b).

Currently, French Polynesia does not have an active bêche-de-mer trade (Gibert, A., Tahiti Eco Clams Project, personal communication). However, there is a small trade from the Tuamotu Islands supplying the Chinese community in Tahiti (Stein, A., Polynésie française, Service de la pêche, personal communication). In Moorea, commercial sea cucumber species observed in recent underwater surveys include *B. argus, H. fuscogilva, H. whitmaei* and *T. ananas* (SPC, 2006a).

Melanesia

The sea cucumber fishery in PNG was first described in 1873 but it was most likely exploited earlier than that (Russell, 1970; Shelley, 1981; Kinch, 2004b). During the period 1878-1900, bêche-de-mer exports were reported at around 37 tonnes y^{-1}, but this is likely a gross under-estimation as most shipments went unreported (Russel, 1970). Fort (1886) highlights in official dispatches during the 1880s, that approximately 500 tonnes y^{-1} of bêche-de-mer was being produced from the Louisiade Archipelago in the Milne Bay Province alone. In the early-to-mid-1930s, the Territories of Papua and New Guinea were exporting an estimated 158 tonnes y^{-1} (Shelley, 1981). In the early 1980s, Shelley (1981) reported seven sea cucumber species in trade in Papua New Guinea consisting of *A. echinites, A. mauritiana, A. miliaris, H. scabra, H. whitmaei, H. fuscogilva* and *T. ananas.* In 1989, the high-valued *H. scabra* accounted for 70 percent of the total bêche-de-mer exports from Papua New Guinea (Lokani, 1990). More recently, catches have shifted to mostly low-value species, particularly *B. vitiensis* and *H. atra* (Kinch, 2004b).

The sea cucumber fishery was active in the Solomon Islands in 1844 (Cheyne, 1852; Bennett, 1987; Ward, 1972), with exports to Australia during the 1870–1880s averaging around 90 tonnes y^{-1} (Bennett, 1987). In 1966, the sea cucumber fishery re-commenced in the Solomon Islands, and a processing plant was established in the early 1970s, but was unsuccessful (Sachithananthan, 1971a, 1971b). In 1977, exports consisted of *H. fuscogilva, H. whitmaei, A. miliaris, T. ananas* and *A. echinites.* Fifteen species were being harvested in 1988, which increased to 18 in 1991 (Adams *et al.*, 1992; Holland, 1994a, 1994b). In 2004, Kinch (2004c) identified 28 sea cucumber species as having commercial value in the Solomon Islands, including the rare *T. rubralineata* (Lane, 1999; Kinch, 2005). The sea cucumber fishery in the Solomon Islands peaked in 1992, when 715 tonnes were exported (Kinch, 2004c). In 1999, the high-valued *H. fuscogilva* contributed 50 percent of exports from the Solomon Islands and dropped to 2 percent in 2002; in comparison, the low-valued *H. atra* made up 22 percent of exports in 2000, increasing to 60 percent in 2003 (Ramofafia, 2004). In 2004, several exporters did not renew their trading licenses due to dwindling catches (Ramofafia,

FIGURE 5
A sea cucumber purchasing board of an agent in Vanuatu

COURTESY OF D. SCHULTZ

2004), and a moratorium was placed by the Solomon Island government on the harvesting and export in December 2005 (Nash and Ramofafia, 2006). This moratorium was lifted for humanitarian reasons following an earthquake and tsunami in April 2007, and an interim management plan has been devised, which will be revised in December 2007 (Nash, W., WorldFish Center, personal communication).

There is a small sea cucumber fishery in Vanuatu, though stocks are generally regarded as depleted around the more populated areas (Figure 5). Areas under Customary Marine Tenure have managed to protect some high-value populations. Recently, an Australian-based company has invested in trial sea ranching of *H. scabra* in Vanuatu using juveniles produced in their Australian-based hatchery.

The fishery in New Caledonia began in the 1840s (Cheyne, 1852; Conand, 1990). Catches during the 1920s ranged from 100–150 tonnes y^{-1} (Conand 1990). Most previous and current harvesting in New Caledonia has centred around the country's main island of La Grande Terre. In the Loyalty Islands Province, *H. whitmaei* has been fished on Ouvéa, with light harvesting on Lifou and Maré due to customary restrictions. However, *H. whitmaei* is now being fished regularly in Maré (Purcell, Gossuin and Agudo, in press). In New Caledonia, the numerically dominant species in catches are *H. scabra*, *H. whitmaei*, *A. miliaris*, *A. palauensis*, *A. spinea* and *T. ananas*. Species caught in moderate quantities include *A. echinites*, *A. mauritiana*, *H. scabra* var. *versicolor*, *H. fuscogilva*, and *S. herrmanni*. Since 2003, export statistics show declines in catches of *H. scabra* but concomitant increases in catches of reef-dwelling species. The fishery now comprises a network of village fishers gleaning reef flats or by skin divers utilizing small boats, and semi-industrial fishing companies using larger boats of 10–20 m in length (Purcell, Gossuin and Agudo, in press).

In 1813, the sea cucumber fishery started in Fiji and from 1827–1835, approximately 600 tonnes of bêche-de-mer were exported (Ward, 1972). By 1834, sea cucumber populations on reefs of the Western Central and northern Vanua Levu and south-east Viti Levu were considered depleted (Ward, 1972). In the early 1980s, fishing recommenced in Fiji, peaking in 1988 when 717 tonnes of bêche-de-mer were exported. The actual export figure is thought to be closer to 1 000 tonnes, as some product was labeled as "miscellaneous mollusks" (Adams, 1992). Prior to 1988, *A. miliaris*, *H. fuscogilva*, *H. whitmaei* and *H. scabra* were the most important commercial species followed by *A. echinites*, *A. lecanora* and *H. atra*. Other species, such as *B. argus*, *B. vitiensis*, *H. edulis*, *H. fuscopunctata*, *Pearsonothuria graeffei*, *S. chloronotus*, *T. ananas* and *T. anax* were considered to have no or low commercial value (Preston, 1988). The establishment of centralised processing facilities in the mid-1980s enabled mass-processing of *A. miliaris* which made up approximately 95 percent of all exports in 1988 (Preston, 1990). With subsequent decline in *A. miliaris* stocks, the exploitation of *S. chloronotus*, *A. mauritiana*, *H. fuscogilva*, *H. whitmaei*, *H. scabra*, *S. herrmanni*, *H. atra* and *B. vitiensis* increased in importance (Adams, 1992). Currently, the sea cucumber fishery in Fiji is controlled by licensed companies who prefer to buy wet products from local fishers but also have their own teams of 15–30 divers who use SCUBA (Qalovaki, 2006).

Australia and New Zealand

The first reports of fishing on the Great Barrier Reef date to 1804, with further developments occurring in the 1840–1850s (Sumner, 1981). In 1846, the fishery was established in the Torres Strait (Beckett, 1977), and by 1870, the fishery was considered to be over-harvested. From 1896 to 1928, between 16 and 558 tonnes of bêche-de-mer were exported from Thursday Island in the Torres Strait annually (Harriott, 1984). The sea cucumber fishery in Torres Strait is almost exclusively fished by indigenous inhabitants. The major species harvested in the Torres Straits are *H. scabra* and *A. mauritiana*, with some smaller landings of *H. whitmaei*, *H. fuscogilva*, *H. atra*, *A. echinites* and *H. fuscopunctata* (AFMA, 2004, 2005).

TABLE 5
Past and present commercially exploited holothurian species in the Western Central Pacific region

	Micronesia							Polynesia							Melanesia					Australia and New Zealand							
Species	Palau	Guam	CNMI	Federated States of Micronesia	Marshall Islands	Nauru	Kiribati	Tuvalu	Wallis and Futuna	Samoa	Tonga	Niue	Cook Islands	French Polymrsia	Papua New Guinea	Solomon Islands	Vanuatu	New Caledonia	Fiji	Australia (Coral Sea)	Australia (Torres Strait)	Australia (Great Barrier Reef)	Australia (Morteon Bay)	Australia (Northern Territory)	Australia (Western Australia)	New Zealand	Total
Actinopyga caerulea															✓												1
A. echinites	✓	✓	✓	✓							✓				✓	✓		✓	✓		✓	✓		✓	✓		13
A. lecanora	✓			✓							✓				✓	✓	✓	✓	✓		✓						9
A. mauritiana	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					22
A. miliaris	✓		✓	✓			✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓					17
A. palauensis	✓			✓							✓	✓				✓		✓									6
A. spinea																		✓				✓					2
Australostichopus mollis																										✓	1
Bohadschia anaes																			✓								1
B. argus	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓								17
B. similis	✓			✓							✓			✓	✓	✓	✓	✓	✓								9
B. vitiensis	✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓						17
Holothuria atra	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		23
H. cinerascens		✓																									1
H. coluber	✓			✓					✓		✓				✓	✓	✓	✓	✓								9
H. edulis	✓	✓	✓	✓			✓				✓				✓	✓	✓	✓	✓		✓						12
H. flavomaculata	✓			✓												✓	✓	✓									5
H. fuscogilva	✓			✓			✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		18
H. fuscopunctata	✓	✓	✓	✓			✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓					17
H. grisea																✓											1
H. leucospilota		✓		✓	✓		✓			✓	✓		✓		✓	✓			✓								10
H. scabra				✓			✓		✓						✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		13
H. scabra var. *versicolor*											✓				✓	✓	✓	✓	✓		✓	✓					8
Holothuria sp. (Hongpai – the Solomon Islands)																✓											1
Holothuria sp. (Tulele – the Solomon Islands)																✓											1
H. whitmaei	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		23
Pearsonothuria graeffei		✓		✓			✓								✓	✓		✓	✓								7
S. chloronotus	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					20
S. herrmanni	✓			✓			✓		✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓					14
S. horrens	✓	✓		✓			✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓								14
S. ocellatus																				✓	✓	✓		✓			4
S. pseudohorrens															✓												1
S. vastus	✓			✓											✓	✓	✓				✓	✓					7
Thelenota ananas	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		22
T. anax	✓	✓		✓			✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓						16
T. rubralineata															✓	✓											2
Total	21	15	10	24	4	4	17	11	4	14	21	7	9	13	26	29	21	25	23	8	16	14	1	6	6	1	–

In 1986, the fishery recommenced in Queensland (Beumer, 1992). The targeted species in this fishery are *A. echinites, A. mauritiana, A. miliaris, H. atra, H. fuscogilva, H. fuscopunctata, H. whitmaei, H. scabra, H. scabra* var. *versicolor, S. chloronotus, S. herrmanni* and *T. ananas* (DEH, 2006).

In the Northern Territory, the main target species is *H. scabra* (DEH, 2004). The Northern Territory fishery generally has a hiatus from November-April due to monsoonal weather (DEH, 2004). Fishing operations are vessel-based, with a "mother boat" anchoring in deeper offshore waters, while dinghies supplying compressed air follow divers through the harvesting areas (DEH, 2004).

The Western Central Australian sea cucumber fishery began in 1995, peaking at 382 tonnes in 1997, then declining to a more current average of 80 tonnes y^{-1} (DEH, 2005). Six species are harvested: *H. scabra*, *H. whitmaei*, *H. fuscogilva*, *T. ananas, A. echinites* and *H. atra* (DEH, 2005). Harvesting in Western Central Australia is year round, but confined to neap tides in some areas (DEH, 2005).

Australostichopus mollis is common along many coastlines of New Zealand and southern coasts of Australia (Pawson, 1970). In 1990 *A. mollis* was commercially exploited in New Zealand, when one company was granted a special permit to harvest by SCUBA up to 74 tonnes wet weight of *A. mollis* from the south-eastern fjords to evaluate the potential of this fishery (Morgan and Archer, 1999).

2.5 Species in trade

As mentioned above, the vast majority of sea cucumbers harvested in the Western Central Pacific region are those that have thick body walls and are subsequently processed for bêche-de-mer. Exports of salted sea cucumbers are limited to small shipments from New Caledonia and possibly Kiribati. Frozen sea cucumbers are also exported from Australia and New Zealand, and previously Tonga.

Several species of sea cucumbers are used for the aquarium trade. For example, *T. ananas, H. leucospilota, B. argus* and *H. hilla* are exported as ornamentals from the Solomon Islands (Kinch, 2004a), and some probably also from the Cook Islands, Fiji, French Polynesia, Tonga and Kiribati. Small amounts of colourful sea cucumber species are collected from Moreton Bay for the Queensland Marine Aquarium Fishery (DEH, 2006). There are no current data available on sea cucumber exports for the aquarium trade. Wabnitz *et al.* (2003) and Green (2003) have highlighted problems with trade statistics and the Global Marine Aquarium Database as sea cucumbers are often aggregated simply as invertebrates (which also includes other echinoderms such as starfish, and marine molluscs) or as "tropical fish".

Within the Western Central Pacific region, one company in Vanuatu, Unicorn Pacific, exports TBL-12, an immuno-therapy treatment that is produced from sea cucumbers and other marine organisms (Carroll, 2005).

2.6 Population status

Most surveys of sea cucumber resources have aimed to assess the potential for developing a fishery, or in response to determining status of a declining resource. When comparing density records, one must be aware that the data collection method, position and scale of the study can affect results. Equally, the state of the habitat available or the bio-geographical position can affect the potential of populations and species diversity (e.g. the Cook Islands has a restricted species range due to its easterly position in the Pacific). Higher densities in some countries may also reflect the presence of moratoriums which may have allowed for some regeneration of sea cucumber stocks (e.g. Tonga, Palau, Federated States of Micronesia and Samoa), stronger management controls either at the government or local level (e.g. New Caledonia and Vanuatu) or remoteness from marketing opportunities.

Micronesia

In Palau, Birkeland *et al.* (2000) believed that over-fishing was the most likely reason for the low densities of the eight sea cucumber species recorded on Helen Reef. On the main islands of Palau, *H. whitmaei* was reported as relatively common (Ilek, 1991) and this observation was confirmed in recent SPC surveys in 2007 (>10 ind. ha^{-1} in broad-scale surveys). In a study from Airai (Anon, 2003), high densities of *S. vastus* (1 800 ind. ha^{-1}), an unidentified species of *Actinopyga* (137 ind. ha^{-1}) and *H. scabra* (40 ind. ha^{-1}) were recorded.

Assessments in CNMI in the late-1980s suggested that sea cucumbers have not recovered from the heavy exploitation during the 1920–1940s (Tsuda, 1997; Trianni, 2001, 2002). Trianni (2002) showed changes in densities after the 1997 boom at Saipan had finished.

In the Federated States of Micronesia, starting with Yap, surveys of Ngulu Atoll in 1985 found *T. ananas* in greater abundance then *H. whitmaei* and *H. fuscogilva,* with smaller populations of *B. argus, S. herrmanni* and *H. fuscopunctata* (Moore and Marieg, 1986). On Yap itself, 17 species of commercial sea cucumbers were recorded, mainly in low densities for the high value species (SPC, 2006a). In Chuuk, 19 species were recorded, but despite wide distribution across the lagoon, populations were considered depleted (SPC, 2006a). Surveys in Pohnpei in 2000 found populations of the commercially important species, *H. whitmaei, H. fuscopunctata, B. vitiensis, S. herrmanni, S. chloronotus* and *T. ananas* in relatively high densities, though Lindsay (2000a, 2001b) notes suitable sea cucumber habitats are not abundant.

In the Marshall Islands, surveys in 1970s found weak potential for a fishery, with the exception of *H. atra* because suitable habitat was limited (McElroy, 1990; see also Ebert, 1978; Lawrence, 1979). Lindsay (2001a) and Lindsay and Abraham (2004) also found low densities of commercially valuable species, except *H. atra.* At Jaluit Atoll, *H. whitmaei*, *H. fuscopunctata*, *B. vitiensis*, *S. herrmanni* and *T. ananas* were also scarce (Bungitaki and Lindsay, 2004).

In Nauru, six commercial species were recorded during recent in-water surveys, with only *A. mauritiana* moderately common in certain areas (Kim Friedman, unpublished data).

In Kiribati, assessments at the populated atoll of Tarawa (Pauly, 2000) found *H. atra* and *B. vitiensis* to be fairly common. Eleven species were recorded in the Gilbert group (Fufudate, 1999). More current SPC PROCFish/C surveys recorded very low densities of sea cucumbers in the Gilbert Group and in the Line Islands (Kim Friedman, unpublished data).

Polynesia

In Tuvalu in 1978, only the atolls of Funafuti and Nukufetau were identified as having commercial densities of *H. fuscogilva, B. argus, T. ananas, H. fuscopunctata, A. miliaris, A. mauritiana, H. whitmaei* and *B. vitiensis* (Belhadjali, 1997). Later surveys in the islands of Funafuti, Nukufetau, Vaitupo and Niutau in 2005 recorded 10 commercial species, with *H. fuscogilva* and *T. ananas* of interest for small-scale commercialization.

In Tokelau, sea cucumbers were generally at low density in surveys, except for *H. atra*, which was noted at 8 000–12 000 ind. ha^{-1}. At Fakaofo Atoll, both *B. argus* and *A. mauritiana* were recorded in moderately high densities in some places by Passfield (1998), but were considered to be at low abundance by Fisk, Axford and Power (2004a). Similar findings were noted for Fakaofo and Atafu (Fisk, Axford and Power, 2004b, c).

From Samoa, there is little sea cucumber stock density data, except for what can be gleaned from marine protected area planning studies (e.g. Fisk, 2002). Recent surveys found 11 commercial species (Friedman *et al.*, 2006). High-value sea cucumber species were found in low densities (no *H. scabra* was recorded) and, apart from *S. chloronotus*, there was a general paucity of medium value species available for exploitation.

In Tonga, surveys in the 1990s showed stocks to be overfished following rapid commercialization of sea cucumber resources (Preston and Lokani, 1990; Lokani, Matoto and Ledau, 1996). Following the institution of a 10-year moratorium on commercial fishing, a survey in 2004 found that there was recovery of *H. fuscogilva* in the nutrient poor, isolated island group of Ha'apai, but *H. whitmaei* was still at depleted levels (Friedman *et al.*, 2004).

A broad fisheries resource survey in Pitcairn Islands visited all the islands in the mid 1990s (Sharples, 1994) and made cursory searches for marketable sea cucumbers. Significant densities were only observed for *H. whitmaei* at Ducie and Oeno Atolls.

During surveys of Niue in the late-1980s, 95 percent of all observed sea cucumbers were the low-valued *H. atra* (Dalzell, Lindsay and Patiale, 1993). Surveys in mid 2005 by SPC PROCFish/C re-iterated the fact that there is a limited number of sea cucumber species available for commercial fishing and the exposed environment (plus effects of cyclone Heta in 2004) possibly limits abundances (see Fisk, 2004, 2005).

In the Cook Islands, most sea cucumber surveys have been conducted at Rarotonga (Drumm, 2004), Aitutaki (Zoutendyk, 1989b) and Palmerston Atoll (Preston *et al.*, 1988) in the southern group. At the latter site, *B. argus, H. fuscogilva* and *H. whitmaei* were sparse, although *A. mauritiana* was relatively abundant. At Rarotonga, the low-valued *H. atra* and *H. leucospilota* were numerous, averaging 9 942 and 8 330 ind. ha^{-1} respectively (Drumm, 2004). Re-survey of all these sites were completed by SPC PROCFish/C in 2007 (SPC, 2007a, b).

In the late-1990s, surveys of sea cucumber population in Tahiti, Rangiroa and Moorea were conducted for the Ministère de la mer de Polynésie française (Anon., 1997, 1998, 1999), whereby a non-conservative annual catch was set at between 20 to 33 percent of the total estimated biomass for each of the sites surveyed. At Tahiti, the estimated catch was 4.1 kg ha^{-1} $year^{-1}$ for *H. whitmaei*, 70.6 kg ha^{-1} $year^{-1}$ for *B. argus* and 67.7 kg ha^{-1} $year^{-1}$ for *H. atra*. At Rangiroa, no *H. whitmaei* were recorded, but potential catches for *B. argus* were listed at 4.1 kg ha^{-1} $year^{-1}$ and 1 210 kg ha^{-1} $year^{-1}$ for *H. atra*. The island of Moorea generally had lower estimates than Rangiroa and Tahiti (Anon, 1998). The overall potential production (wet weights) for Tahiti was suggested to be 2 500 tonnes, 10 792 tonnes for Rangiroa and 142 tonnes for Moorea. Other species noted over the three sites were *T. ananas*, *T. anax*, *B. vitiensis* and *A. mauritiana*. In these assessments no deeper-water surveys were completed, although Costa (1995) noted that *H. fuscogilva* was currently fished. More recent assessments in 2004 by SPC PROCFish/C found restricted ranges of species at Tahiti, the Tuamotu, Austral group and Moorea, although moderately high densities for some species were recorded.

Melanesia

Recent surveys in Papua New Guinea show that stocks are depleted. In the Milne Bay Province, Skewes *et al.* (2002a) found low densities of commercial holothurians (average of 21 ind. ha^{-1}). Low survey densities and a comparison of historical and recent catch data indicate that *H. scabra* and *H. whitmaei* populations have been grossly overexploited. Surveys in the Manus Province in 2006 found most shallow water species depleted but *H. fuscogilva* still present in moderate numbers in deeper water, despite active fishing (SPC, 2006b). In New Ireland Province, sparse populations were observed of *H. scabra,* which was targeted at all sizes (SPC, 2006b; NFA, 2007a).

In the Solomon Islands, a survey conducted by several conservation non-governmental organizations and the Division of Fisheries and Marine Resources commonly recorded only two low-valued species: *H. edulis* and *P. graeffei* (Ramohia, 2006). *T. ananas*, *A. lecanora*, *S. chloronotus*, *H. whitmaei* and *S. herrmanni* were seen only in low numbers, while *A. caerulea*, *A. mauritiana*, *H. coluber*, *H. scabra*, *B. similis*, *S. horrens*, *S. pseudohorrens* and *T. rubralineata* were rare (Ramohia, 2006). Surveys conducted under the International Waters Program in the Marovo Lagoon also report sea cucumber densities to be low (Kinch *et al.*, 2006). Some data are also available from a long term resource survey of the Arnavon Marine Conservation Area in the Isabel Province (Lincoln-Smith *et al.*, 2000). The generally bleak picture of sea cucumber resource status was again recorded in 2006, when sparse populations were found at four survey sites in Guadalcanal, Central and Western Central Provinces (SPC, 2006b).

Vanuatu's volcanic islands generally lack large protected lagoons, but reasonable densities of sea cucumbers exist. A past survey found *S. chloronotus* and *H. atra* abundant at Gaua Island (Baker, 1929). Chambers (1989) found relatively dense populations of *A. miliaris* (785 ind. ha^{-1}) and *H. scabra* (43 ind. ha^{-1}) in studies in 1987. Recent surveys found a wide range of species present, but densities were low at the island of Efate, compared with results from the island of Malekula (Friedman, K., unpublished data).

New Caledonia's holothurians have been well documented by Conand's (1989) thesis on the ecology and biology and densities of commercial sea cucumber species. Inshore surveys by the WorldFish Center in New Caledonia during 2003–2005, found variable densities of *H. scabra*, indicating some over-harvesting. Of 35 sites surveyed, 33 of them had mean densities under 30 ind. ha^{-1}, with only two with densities over 100 ind. ha^{-1} (Purcell, S., unpublished data). Likewise, *H. scabra* was found at only one of the five SPC PROCFish/C survey sites (Friedman, K., unpublished data). In a 2004 survey of New Caledonia by conservation NGOs, *H. whitmaei* and *T. ananas* were observed at low densities (Lindsay and McKenna, 2006). Field surveys of 50 lagoon and barrier reef sites in a ZoNéCo project have found generally low densities of commercial species, but occasional dense (>100 ind. ha^{-1}) patches of certain species, like *A. palauensis*, *A. spinea*, *S. chloronotus*, *S. herrmanni*, *S. horrens* and *T. ananas* (Purcell, Gossuin and Agudo, in press).

In Fiji, Stewart (1993) observed *H. scabra* at 625 ind. ha^{-1} and SPC PROCFish/C in 2003 estimated reasonably high densities of 160 ha^{-1} close to Suva (Friedman, K., unpublished data). In the 1980s, *A. miliaris* made up a large proportion of the commercial catch, and occurred at high density at some sites (Preston *et al.,* 1989). Surveys of the Vanua Levu Lagoon sites over a decade later found both a more restricted distribution and lower densities for this species (Friedman, K., unpublished data).

Australia and New Zealand

Recent research has shown that most stocks in three of Australia's sea cucumber fisheries are overexploited. These are the Torres Strait (Skewes, Burridge and Hill, 1998), the Timor Sea MOU74 Box (Skewes *et al.,* 1999), and Queensland (Uthicke and Benzie, 2000a). Uthicke and Benzie (2000a) found an approximately 1:5 ratio for populations of *H. whitmaei* in fished and non-fished areas, respectively, on the Great Barrier Reef.

In 1996, a survey of Warrior Reef in the Torres Strait showed suppressed stocks of *H. scabra*, comprised of small individuals (Long *et al.,* 1996). A follow-up survey in 1998 confirmed these observations, so the management body closed the fishery (Skewes, Burridge and Hill, 1998). Surveys in 2000 (Skewes, Dennis and Burridge, 2000), 2002 (Skewes *et al.,* 2002b) and 2004 (Skewes *et al.,* 2004) demonstrated a slow recovery of *H. scabra* stocks on Warrior Reef (Skewes *et al.*, 2006). After the *H. scabra* closure in 1998, fishers targeted other species, particularly *H. whitmaei, H. fuscogilva* and *A. mauritiana.* By 2002, there was evidence of some depletions elsewhere, with population densities for many species <10 ind. ha^{-1} (Skewes *et al.*, 2006). Following a large survey of the east Torres Strait fishery, and catch analysis, fishing was closed for many other species in 2003 (Skewes *et al.*, 2006). Even though Australia is one of the most developed countries in the region and has adopted several management measures, most of the exploitation has resulted in stock depletion of the high-value species.

Surveys of *Australostichopus mollis* in New Zealand conducted in the early-1990s found densities of 10–20 ind. ha^{-1} (Mladenov and Gerring, 1996).

Fishing pressure across the Western Central Pacific region

From the density records reported, and noting the general decline in availability of sea cucumbers, it can be seen that sea cucumbers across the Western Central Pacific region are, or have been, under high fishing pressure. In most cases, the depletion of stocks is negatively impacting the potential incomes of coastal communities and in some cases is affecting the sustainability of fisheries for the long term.

Recognizing weaknesses in past research, sea cucumber surveys are now being approached with a more regional focus, using standardized methods to assess status. Despite this recent regional approach, there is still insufficient data to describe definitively the densities required to sustain sea cucumber populations within an active fishery. What is becoming apparent is that availability and condition of habitats, and their connectivity with nearby reef systems plays a major role in defining the potential of populations. The outlook for understanding questions of "stock health" will rely on on-going monitoring of stocks and catches at relevant scales, to determine changes in populations from different reef systems under various management regimes. Data from populations recovering from periods of fishing, (e.g. in areas under moratorium such as Samoa and Tonga) and unfished populations in marine protected areas (e.g. green zones of the Great Barrier Reef compared with open zones fished on three year rotations) will also be of great value. Finally, fisheries management decisions should also incorporate new information on life histories of commercial species from aquaculture and sea ranching studies.

Fishing pressure* H. whitmaei: *an example

H. whitmaei is one of the most valuable species across sites in the Western Central Pacific region (and Western Australia). This geographical spread represents nearly the entire distributional range of this species, with the exception of populations in Southeast Asia.

Several studies have been conducted on unfished reefs, including, "closed" (green zones) reefs on the Great Barrier Reef (Uthicke, Welch and Benzie, 2004), isolated reefs near Lord Howe Island (Oxley *et al.*, 2004) and Ningaloo Reefs in Western Australia (Shiell, 2004). Without exception, all of these reefs have densities above 12.5 ind. ha^{-1} (Figure 6), and on rare occasions densities as high as 108.6 ind. ha^{-1} at one site in New Caledonia (Purcell, S., unpublished data). Noting the range of densities found at "closed" sites it seems a conservative assumption that densities above 12.5 ind. ha^{-1} represent a "natural" density for this species on suitable habitat.

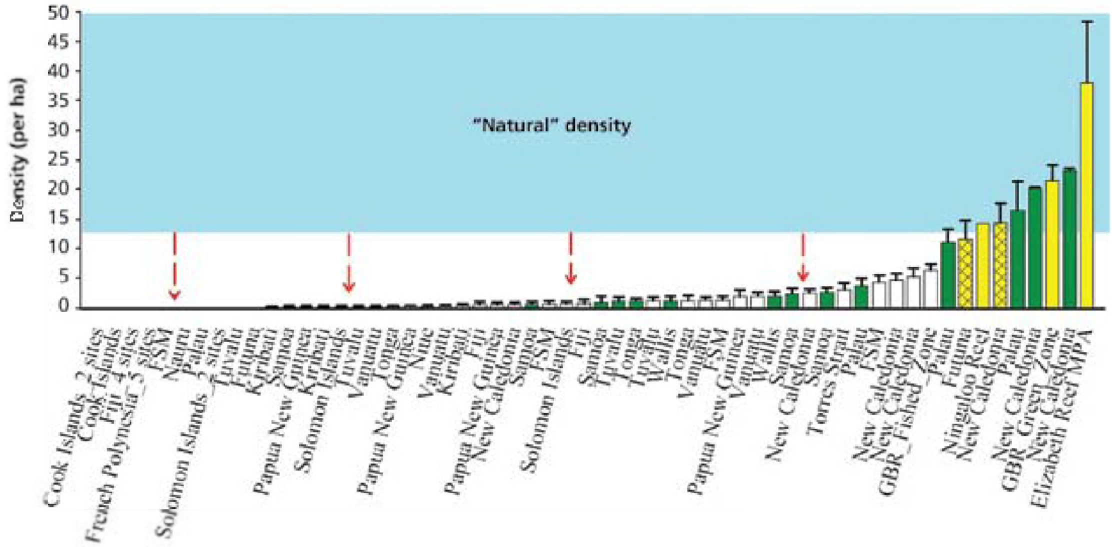
When compared to reefs open to fishing, it becomes clear that most fished reefs have populations with less than ca. 5 ind. ha^{-1} (Figure 6). Although some of this variation may be due to habitat differences, the fact that most of the "open" reefs hold less than 25 percent of the "natural" *H. whitmaei* populations suggests that these reefs are overfished.

A second important finding from this case study is that "open" reefs that have been "closed" after a period of fishing, have not generally shown signs of strong recovery after a reasonable closure period (e.g. 10 years). This is supported by surveys on the Great Barrier Reef where stocks of *H. whitmaei* have not increased after four years of fishery closure (Uthicke, Welch and Benzie, 2004), and surveys in Ha'apai in Tonga where densities recovered only marginally after seven years of closure (0.3–1.2 ind. ha^{-1}, Friedman *et al.*, 2004).

H. whitmaei, like most holothurians, is a broadcast spawner. Subsequently, fertilization success for this species, as in other sea cucumber species, is density

FIGURE 6

***H. whitmaei* densities recorded from fished and unfished sites in the Western Central Pacific region**



Note: Fished sites across the Western Central Pacific region are represented by white bars (SPC and Timothy Skewes, Commonwealth Scientific and Industrial Research Organization). Unfished sites are split into three categories. Firstly, remote marine protected area sites (yellow bars) such as Elizabeth reef in the Great Barrier Reef and Ningaloo Reef in Western Australia. Secondly SPC PROCFish/C and WorldFish unfished sites in populated areas which are represented by yellow hatched bars. Thirdly, green bars represent areas where fishing has been halted for a decade or more.

dependent, and a reduction to fewer than 5 ind. ha^{-1} could more than double average distance between individuals. It is thus possible that remnant populations on most reefs have "effective" population sizes close to zero, and the reproduction and larval supply is mostly from populations in marine reserves.

Catch per unit effort

Catch rates usually refer to the number of individuals collected per fisher per hour. Monitoring the effort and related catches in a sea cucumber fishery is useful, but care should be taken in comparing values between sites, as fishing conditions, gear used and a range of economic factors (such as community demands, incentives paid by companies, debt cycles, etc.) can have a major impact on the productivity of divers. Fishers are also often involved in multiple livelihoods, or harvesting of sea cucumbers is integrated into other fishing activities, which can mask signals of declining catch rates. It should be noted that unless these complexities of monitoring the fishing effort are noted, and there is some spatial understanding of the effort expended, then CPUE records can be a poor indicator of population status.

A summary of CPUE data for the Western Central Pacific region is given in Table 6.

2.7 Catch

The main areas of production of bêche-de-mer across the Western Central Pacific region are Australia and the countries within Melanesia. In the early 1990s, the Western Central Pacific Region bêche-de-mer trade was thought to represent 7 percent of all trade in marine resources by weight and 15 percent by value (excluding Australia and New Zealand) (Dalzell and Adams, 1994).

There is no commercial-level mariculture or sea ranching at present in the Western Central Pacific region. There have been however, some small research projects by The WorldFish Center, and a couple of experimental projects in Australia and Kiribati. Thus, all bêche-de-mer exports from the Western Central Pacific region are considered to be from capture fisheries.

The main harvesting methods in the Western Central Pacific region are gleaning and free-diving. Bombs (a weighted barb on a string line to harvest sea cucumbers at

TABLE 6
Catch per unit of effort (CPUE) rates for the Western Pacific Central region

Species	Location	No./diver/h	Reference
Actinoypa echinites	New Caledonia	118.0	Conand, 1989
A. mauritiana	PNG (Milne Bay)	<0.1	Allen, Kinch and Werner, 2003
A. miliaris	PNG (Milne Bay)	<0.1	Allen, Kinch and Werner, 2003
A. miliaris and *A. echinites*	Palau	68.2	Mathews and Oiterong, 1991
Bohadschia argus	PNG (Milne Bay)	0.4	Allen, Kinch and Werner, 2003
B. vitiensis	PNG (Milne Bay)	<0.1	Allen, Kinch and Werner, 2003
Holothuria atra	PNG (Milne Bay)	0.3	Allen, Kinch and Werner, 2003
	Solomon Islands (Western)	<519.0	Adams *et al.*, 1992
H. echinites	PNG (Central)	110.0	Shelley, 1981
H. fuscogilva	Fiji	~13.0	Conand, 1989
	Fiji	16.0	Gentle, 1979
	PNG (Central)	4.5	Shelley, 1981
	PNG (Milne Bay)	0.4	Sebatian and Foale, 2007
	PNG (Milne Bay)	0.2	Allen, Kinch and Werner, 2003
H. fuscopunctata	PNG (Milne Bay)	0.2	Allen, Kinch and Werner, 2003
H. scabra	New Caledonia	~13.0	Conand, 1989
	Palau	65.5	Mathews and Oiterong, 1991
	PNG (Central)	103.0	Shelley, 1981
H. whitmaei	Australia (Great Barrier Reef)	2.0–3.0	Uthicke and Benzie, 2000a
	New Caledonia	31.0	Conand, 1989
	PNG (Central)	15.1	Shelley, 1981
	Solomon Islands (Ontong Java)	11.1	Crean, 1977
	Solomon Islands (Ontong Java)	3.5	Bayliss-Smith, 1986
Stichopus chloronotus	PNG (Milne Bay)	0.3	Allen, Kinch and Werner, 2003
S. herrmanni	PNG (Milne Bay)	0.1	Allen, Kinch and Werner, 2003
	Palau	61.7	Mathews and Oiterong, 1991
Australostichopus mollis	New Zealand	52.0	Mladenov and Gerring, 1996
Thelenota ananas	New Caledonia	42.0	Conand, 1989
	PNG (Central)	10.0	Shelley, 1981
	PNG (Milne Bay)	0.2	Allen, Kinch and Werner, 2003
T. anax	PNG (Milne Bay)	0.1	Allen, Kinch and Werner, 2003

between 12–30 m depth), trawling, and the use of SCUBA and hookah, are also used occasionally. Women and children are often involved in gleaning on reef flats, whereas men do most of the diving. The use of trawl gear has been reported in Ontong Java in the Solomon Islands, whereby a small net is dragged along the sea bed behind two small boats (Ramofafia, 2004). Sea cucumbers also comprise some of the bycatch of trawl fisheries in Australia, but these are not allowed to be retained (DEH, 2006).

Usually, all species in accessible marine habitats are harvested. Fishing in recent years has changed in most PICTs to include a greater proportion of low-value species in exports and a greater range of species.

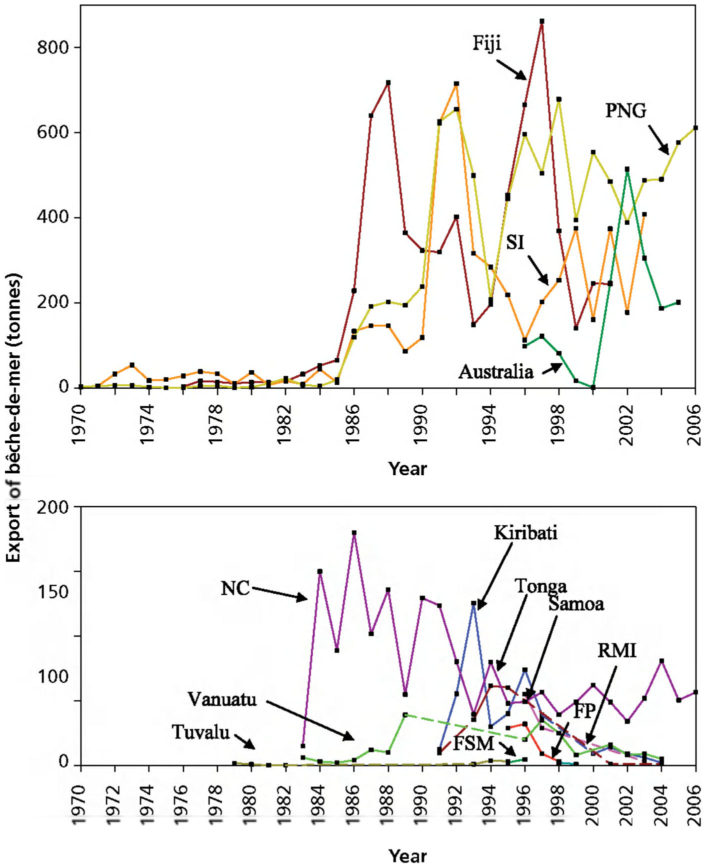
Catch figures are largely unobtainable, except for some limited data from Australia. The production of bêche-de-mer is mostly an export-driven industry. To obtain estimates of wet weight of catch, export figures need to be increased by a ratio of 1:10 (Preston, 1993). The authors present only the export data here (Figure 7; Appendix A). Of note though, is that the export data do not take into consideration such issues of buying "wet" or "first-boiled" sea cucumbers, shrinkage during processing and storage, rejection of undersize or damaged sea cucumbers/bêche-de-mer at point of sale, and sea cucumbers collected for subsistence use. Therefore, even using conversion ratios will under-estimate catches.

The export "production" of bêche-de-mer has varied more than an order of magnitude among some countries. The Melanesian countries and Australia are clearly the larger exporters. These countries have relatively large land mass and coastal lagoon area to support sea cucumber populations compared to Micronesian and Polynesian countries.

Within each country, exports have been markedly different over time. There is some indication of boom-and-bust cycles, for example in Fiji, over time periods of 3–10 years. This may, however, be accentuated by sociological and economic affects as much as the natural variability in resource abundance.

Interestingly, while bêche-de-mer exports from Melanesian countries have not particularly declined over the last two decades, those from Polynesia and Micronesia have. Steady declines in exports from most Polynesian and Micronesian countries are likely due to unsustainable fishing pressure and the fact that the sea cucumber populations are relatively sparse over relatively small areas. Sea cucumber populations in these countries are most likely limited, mostly depleted, and under the greatest risk of local extinctions of some species.

FIGURE 7
Exports of bêche-de-mer from the Western Central Pacific Region



Note: High-volume countries (above) and medium- to low-volume countries (below). FP = French Polynesia, FSM = Federated States of Micronesia, NC = New Caledonia, PNG = Papua New Guinea, RMI = Republic of the Marshall Islands, and SI = Solomon Islands. No data for some years may simply reflect missing data rather than no exports. Each dashed line represents a period between two datum points for which data were unavailable.

2.8 Management measures

Sea cucumber fisheries are multi-species and thus present more complex management problems than a single-species fishery such as trochus (*Trochus niloticus*). Part of the complexity is owing to the diverse range of benthic habitats in which different species occur and differing demographic traits among species. SPC and ACIAR produced underwater identification cards of many of the common, commercially important holothurians, with biological traits and preferred habitats (Figure 8). The development of sustainable management in the Western Central Pacific has not been easy and current management tools like size limits, gear restrictions, spatial and temporal closures, quotas and marine reserves have not been overly effective (Preston, 1993; Dalzell, Adams and Polunin, 1996; Kinch, 2004b). An added problem is that, many countries in the Western Central Pacific region, except Australia and New Zealand, lack the necessary funds and technical capacity for adequate surveillance and enforcement (Adams, 1992; Jimmy, 1995, 1996; Kinch, 2002, 2004b; Kinch *et al.*, 2007; Trianni, 2002). In some countries, there are also conflicts of interest within differing levels and agencies of government, politicians and influential business people.

Gear restrictions and size limits are the most commonly used fisheries management tools in the Western Central Pacific region (Tables 7 and 8), with the harvesting of undersize animals a considerable problem (Kinch, 2002, 2004b, 2004c; Kinch *et al.*, 2007; Qalovaki, 2006). An economic analysis conducted by Callaghan (1996) in Micronesia showed that net revenue would fall as the size of sea cucumbers became smaller. Also,

FIGURE 8

Cover page and example (*H. scabra*) of waterproof identification cards for live and dried sea cucumbers of the Western Pacific Central region

Source: Prepared and distributed by the SPC.

COURTESY OF A. DESURMONT

fishers would actually lose money by collecting smaller sea cucumbers because the unit price remains low, while the cost of collection and processing is constant. Despite this, it is common practice by fishers in the PICTs to measure profit by the amount of cash that goes into their pocket, and subsequently continue to harvest any size of sea cucumber to gain immediate income from sale (Kinch *et al.*, 2007).

Micronesia

In Guam, current regulations permit the harvesting of 100 sea cucumbers pers^{-1} d^{-1} (Kerr, A., University of Guam, personal communication). There are current moratoriums in Palau and the CNMI. In 1997, the government of Kosrae in the FSM placed a moratorium on commercial fishing, but it was later lifted due to lack of scientific data. Subsequently, a brief survey showed limited stocks (Lindsay, 2001b). The moratorium was therefore reinstated in 2000. In Yap a moratorium was instituted after the uncontrolled expansion of the fishery in 2007. The moratorium is due to be lifted in 2008 once a management plan for the fishery has been developed.

Polynesia

In Samoa, a moratorium was placed in 1994 (Mulipola, 1994). King and Fasili (1999) also reported that commercial fishing was banned in 41 percent of Samoan villages; and a number of villages have banned the harvesting of *S. horrens* for subsistence use (Eriksson, 2006). Following resource surveys in 1996, the Tonga Fisheries Authority recommended a moratorium in 1997 when the fishery was in serious decline after heavy fishing in the early 1990s (Preston and Lokani, 1990).

Melanesia

The National Fisheries Authority (NFA) is responsible for the conservation, management, development and sustainable use of PNG's fisheries under the 1998 *Fisheries Management Act*. The NFA has gazetted the 2001 *National Bêche-de-mer Management Plan* for regulation and management of the sea cucumber fishery (Polon, 2004). Its aim is to ensure that Papua New Guinea and its people obtain the maximum economic benefit from the fishery, and that fishing is sustainable and that fishing has a minimal impact on the marine and coastal environment. Following recent research, and the high proportion of undersized bêche-de-mer being purchased by exporting companies (Friedman and Gisawa, 2008), the NFA is now considering a three-year moratorium on the sea cucumber fishery, with consultation currently being conducted amongst stakeholders.

Previously in the Solomon Islands, there were no national fishery regulations, except for the ban on fishing for *H. scabra* in 1998, which was repealed in 2000. Following results of resource surveys by the Department of Fisheries and Marine Resources (DFMR) and other groups, fishing and exporting all sea cucumbers was banned in December 2005 until a management plan was put in place (Nash and Ramofafia, 2006). The ban was later lifted in order to allow communities in the tsunami-stricken Western Central and Choiseul provinces a means of gaining income but has recently been closed again.

In Vanuatu, an annual quota of 35 tonnes was established by legislation in 1991, and finally implemented in 1996 (Jimmy, 1995, 1996). A cooperative management scheme exists in which the Vanuatu Fisheries Division provides scientific information and advice, and coastal villages handle surveillance and local enforcement of the fishery regulations. Today, many villages employ temporal and spatial closures on harvesting sea cucumbers. Due to concernes on unsustainable harvesting of the sea cucumber a moratorium on fishing was imposed in 2008, and will be in place for a period of 5 years.

Prior to 2006, the only regulations for harvesting sea cucumbers in New Caledonia were a ban on the use of SCUBA and hookah, and no collection at night or in marine reserves. The government of the Northern Province has now imposed species-specific size limits for dried product and live animals. In the north, the Arama community suspends sea cucumber fishing during the April-January crab season (Northern Province Fisheries Division, 1993). In the Loyalty Islands Province, healthy stocks of many valuable species still persist, largely owing to district chiefs who forbid commercial fishing in a desire to preserve ecosystem health.

In 1984, Fiji introduced the *Bêche-de-Mer Exploitation Guidelines* (Qalovaki, 2006), and in 1988, imposed a size limit of 7.6 cm for all dried bêche-de-mer (Adams, 1988; Seeto, 1994). This strategy was initially effective, and exports dropped after the law came into force in 1989 (though this is probably linked to a resource decline). However, quantities of undersized product were reported in 1990, so new laws enabled the Fiji Fisheries Division to enforce the size limit at the exporting premises. There is evidence today that undersized product is still being exported from Fiji (Ram, in prep.). Although the number of exporters was also limited at one time, conflicts arose among stakeholders and this measure was rescinded (Adams, 1992). Fiji also prevents export of *H. scabra*, since it is a local food source.

Australia and New Zealand

In Australia, sea cucumbers are considered as regulated native species under national law (DEH, 2004, 2005; Shelly and Puig, 2004). The Torres Strait and Coral Sea fisheries are managed by the Australian Commonwealth through the Australian Fisheries Management Authority, while the remainder are managed by the their respective fisheries agencies in each State.

The Torres Strait fishery regulations include limiting the method of taking sea cucumber to either hand or a hand held non-mechanical implement, a ban on the use of hookah or SCUBA gear, a limit to boat length, limiting fishing of the one non-Islander licensed operator, minimum size limits, and a competitive TAC measured in gutted wet weight of harvested sea cucumbers. Minimal traditional fishing for subsistence is also allowed.

Commercial fishing on the Great Barrier Reef in Queensland is managed principally through a mixed species TAC of 380 tonnes gutted wet weight. In 2004/2005, the TAC allowed no *H. whitmaei*, 127 tonnes of *H. fuscogilva* and 253 tonnes of other species.

TABLE 7
Past and previous management measures adopted in selected countries in the Western Central Pacific region

Species	Micronesia				Polynesia		Melanesia					Australia and New Zealand							Total
	Palau	Guam	CNMI	FSM	Samoa	Tonga	Papua New Guinea	Solomon Islands	Vanuatu	New Caledonia	Fiji	Coral Sea	Torres Strait	Great Barrier Reef	Moreton Bay	Northern Territory	Western Australia	New Zealand	
Area restrictions												✓		✓	✓	✓	✓		5
Bag limits		✓										✓	✓	✓					4
Effort controls												✓	✓	✓	✓	✓	✓		6
Gear restrictions				✓		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		11
Moratorium	✓		✓	✓	✓	✓		✓											6
No night harvesting							✓			✓									2
Quotas (for companies)									✓			✓		✓				✓	4
Restricted fishery (Nationals only)							✓				✓								2
Rotational harvesting												✓		✓					2
Size limits					✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		11
Temporal closures							✓								✓				2
Total allowable catches							✓					✓	✓	✓	✓				5

TABLE 8
Live size limits (cm – body length) adopted in selected countries in the Western Central Pacific region (dry size limits in parenthesis)

Species	Polynesia	Melanesia			Australia				
	Samoa	PNG	New Caledonia (Province Nord)	Fiji	Torres Strait	Great Barrier Reef	Moreton Bay	Northern Territory	Western Australia
Actinopyga echinites		25 (12)			12	20		12	12
A. lecanora		15 (10)							
A. mauritana		20 (8)	25 (12)		22				
A. miliaris		15 (10)	25 (12)		22				
Bohadschia argus		20 (10)							
B. similis		25 (7)							
B. vitiensis		20 (10)							
Holothuria atra		30 (15)			15	20		15	15
H. edulis		25 (10)							
H. fuscogilva		35 (15)	35 (16)		32	40		32	32
H. fuscopunctata		45 (15)			24				
H. scabra		22 (10)	20 (10)		18	16	17	16	16
H. scabra var. *versicolour*			30 (11)						
H. whitmaei		22 (10)	30 (16)		25	30		26	26
Stichopus chloronotus	(6.3)	20 (10)							
S. herrmanni		25 (10)	35 (15)		27				
S. horrens							17		
Thelenota ananas		25 (10)	45 (20)		30	50		30	30
T. anax		20 (10)							
All species				(7.6)					
All species with exception of *S. chloronotus*	(7.6)								

For other species, catch trigger points have been set. Once a trigger point is reached, the sea cucumber industry must carry out a stock assessment of that particular species to determine a TAC (Lowden, 2005). There are currently 18 licences in the fishery held by two companies. Minimum size limits are also in place for all the major species (Roelofs, 2004, 2005). A Rotational Zoning Scheme (RZS) was implemented in 2004, allowing limited harvesting of a zone once every three years. Recreational harvesting is limited to an in-possession limit of five specimens, excluding *H. whitmaei* which is banned (Roelofs, 2005).

The Moreton Bay fishery, near Brisbane, is managed through permits as a developmental fishery and stringent harvest controls. Only *H. scabra* and *S. horrens* can be fished (McCormack, 2005), though *S. horrens* is currently not taken (Skewes, T., Commonwealth Scientific and Industrial Research Organization, personal communication). Management regulations also include minimum size limits, a seasonal closure, limits to number and size of boats and the number of fishers, fishing zones, gear restrictions (harvesting by hand collection only), an annual TAC, zonal trigger limits and rotational harvesting (McCormack, 2005).

In the Northern Territory, fishing is restricted to waters seaward of the high water mark to three nautical miles. The fishery is divided into two zones. Three licenses are permitted in each zone, now acquired by one company. There is no TAC set for the sea cucumber fishery in the Northern Territory, though a management action is triggered if the annual harvest of sea cucumbers exceeds 640 tonnes. This figure is set at the level that equates to twice the highest reported catches taken since 1992 and allows for continued growth in the fishery, within what is considered to be a sustainable harvest level. There are concerns however that this reference point does not take into account available research on the sustainability of the target stock and is not sufficiently precautionary to ensure the ecological sustainability of the fishery (DEH, 2004).

In Western Central Australia, the fishery management regulations include limited entry, species size limit and limits on the number of divers permitted to harvest under each licence. Currently six licences and one exemption are in operation.

3. TRADE

As noted above, monitoring of the bêche-de-mer trade is difficult and complicated, and the collection of accurate trade data from the Western Central Pacific region has proven difficult. The predominant form of sea cucumber product exported from the Western Central Pacific region is bêche-de-mer with very small amounts exported frozen or salted.

Bêche-de-mer is primarily exported from producing countries in the Western Central Pacific region to central markets in China Hong Kong SAR, and Singapore, and then re-exported to China and to other Chinese consumers worldwide. Apart from species and size, factors that affect price for the dried product are the general appearance (colour, shape), odour, moisture content and spoilage. A pleasing smooth surface, uniform shape and clean (not ragged) cut in the body wall demonstrate proper handling and processing and a pleasant smell reflects proper storage.

As a result of demand and increasing prices, both the volume and total value of bêche-de-mer exports from the region have increased in recent years. Prices on the international market for bêche-de-mer also vary considerably between importing country, though an increasing upward trend is easily observed. Export prices vary between the different producer countries as well. It is very difficult to get Asian import prices for several reasons. Firstly, prices for bêche-de-mer vary, often according to the amount and quality sent. Secondly, prices include profit margin and wider knowledge of this may push the threshold price up, resulting in lower profits. Thirdly, prices vary according to how they are purchased, for example if a foreign financier advances money to a in-country licence holder, the financier is the one who

TABLE 9
Bêche-de-mer imports to China Hong Kong SAR from the Western Central Pacific region (tonnes)

	Micronesia			Polynesia		Melanesia				Australia and New Zealand	
Year	Palau	Marshall Islands	Kiribati	Samoa	Tonga	PNG	Solomon Islands	Vanuatu	Fiji	Australia	New Zealand
1993			99.0			179.0	319.0	6.0	119.0		
1994			130.0			150.0	247.0	40.0	176.0		
1995						236.0	161.0		402.0		
1996			23.2	17.5		351.6	141.7	25.1	550.4	78.9	9.5
1997			6.5	10.7		470.1	134.5	35.1	562.7	76.1	2.8
1998			14.9	4.4		639.8	260.6	25.4	304.3	119.3	
1999			6.5	5.7		350.3	49.7	8.0	168.3	125.3	0.5
2000			9.1			531.9	149.1	28.5	364.4	146.5	11.0
2001			22.8			541.1	259.7	16.6	291.1	186.9	31.2
2002	6.4		8.6			380.6	248.8	8.4	235.5	138.7	15.8
2003	2.6	2.7	5.5		0.3	447.6	222.8	9.0	264.3	136.4	3.5
2004	17.8		1.9		1.1	518.3	153.3	5.3	282.3	128.1	1.7
2005	24.9		3.6		0.1	555.3	155.1	9.9	313.9	144.8	6.9
Total	**51.6**	**2.7**	**331.6**	**38.3**	**1.5**	**5351.6**	**2502.1**	**217.3**	**4034.0**	**1280.9**	**83.0**

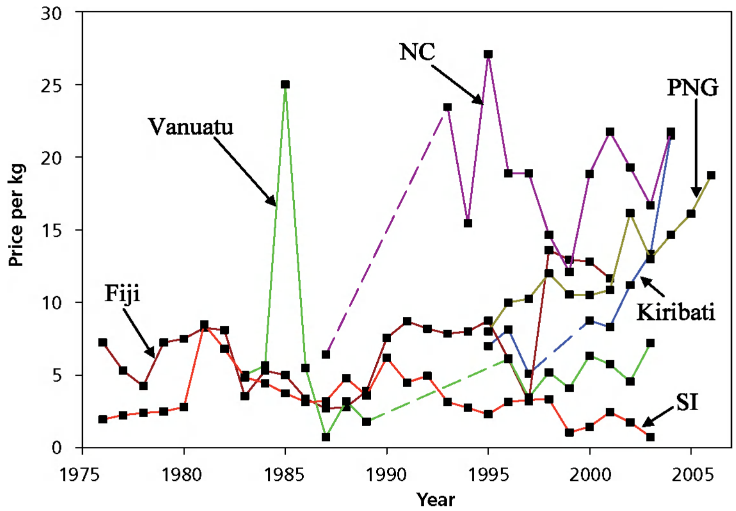
Source: TRAFFIC Hong Kong Special Administrative Region; Ferdhouse, 1999, 2004; CITES, 2006; Conand, 2006. Note: Where figures vary from sources, the highest value has been used.

TABLE 10
Singapore bêche-de-mer imports from the Western Central Pacific region (tonnes)

	Melanesia			Australia and New Zealand	
Year	PNG	Solomon Islands	Fiji	Australia	New Zealand
1993	146.0	3.0	3.0	13.0	4.0
1994	80.0	4.0	8.0	47.0	9.0
1995	89.0		17.0	80.0	
1996					
1997				12.0	5.0
1998	2.0			7.0	13.0
1999	1.0		20.0	14.0	12.0
2000	1.0			4.0	19.0
Total	**319.0**	**7.0**	**48.0**	**177.0**	**62.0**

Source: Ferdhouse, 1999, 2004; Conand, 2006. Note: Where figures vary from sources, the highest value has been used.

FIGURE 9
Average prices per kg for bêche-de-mer exported from the Western Central Pacific region



Note: Compiled from export data. NC = New Caledonia, PNG = Papua New Guinea, and SI = Solomon Islands. Data are for years in which both the export quantity and value was recorded in national data; each dashed line represents a period between two data points for which data were unavailable.

takes the risk and subsequently expects to pay less for product purchased. There are also considerable costs along the chain of custody such as direct costs (e.g. processing, packing, freight, insurance, commissions, wastage, interest), and indirect costs or overheads (e.g. power, transport, wages, fuel, travel, communications) before adding a profit margin.

A summary of bêche-de-mer imports from the Western Central Pacific region into China Hong Kong SAR, and Singapore is provided in Tables 9 and 10. Small amounts of bêche-de-mer are known to be imported into the United States of America, Malaysia and China, but no accurate or current data are available. There is also probably a small amount of bêche-de-mer exported by air for personal consumption from countries that have subsistence fisheries in Micronesia and Polynesia, as well as by Asians residing in PICTs.

An analysis of average export prices of bêche-de-mer over time among different countries revealed two key findings (Figure 9). Firstly, some countries have received up to 10 times greater prices than others for the bêche-de-mer they exported. This could be due three reasons: the fishers are receiving a better price for the same product than those in other countries; or countries exported a greater percentage of the species of higher value on the Asian seafood market; or the grade exported bêche-de-mer is better in some countries because animals are larger or better processed. Notably, New Caledonia, Papua New Guinea and Kiribati mostly received relatively good prices for the bêche-de-mer exported, while Vanuatu and Solomon Islands generally received poor prices.

Secondly, the average prices of exported bêche-de-mer have evolved considerably over time. For Fiji and Kiribati, the export prices received for bêche-de-mer have increased markedly in recent years. Again, this could be due to several factors notably that the importers, or foreign buyers, gave increasingly attractive prices and/or that fishers started collecting and exporting higher-value species (although this is less likely). In at least the Solomon Islands, export prices have declined since the early 1980s, most likely due to exports comprising progressively higher proportions of low-value species each year.

4. SOCIO-ECONOMIC IMPORTANCE TO LOCAL FISHING COMMUNITIES

Human populations in the Western Central Pacific region are at various stages of Western-style development. Subsequently, socio-economic conditions vary widely between and within countries. In general, Australians, New Zealanders and peoples of the dependent territories of metropolitan countries have better access to goods and services than those of the independent nations. In general, urban residents live a more consumer merchandised lifestyle than those with relatively low incomes who follow a more subsistence way of life in small isolated islands and remote coastal areas. It is this latter group that the sea cucumber fishery has a direct impact on their sociological and economic well-being by providing income-earning opportunities and direct financial benefits where other earning opportunities are limited (Figure 10) (Kinch, 2002; Kinch *et al.*, 2007).

Details are not generally available on the depth of dependency of coastal communities on the sea cucumber fishery in the Western Central Pacific region. The only sources identified were household census information, country specific studies and the regional SPC PROCFish/C data sets. Only a limited number of household censuses taken in the Pacific contained questions pertaining directly to sea cucumbers. A scan of questionnaires from other countries in the Pacific revealed many questions relating to fisheries, but no particular sections targeting information on sea cucumbers.

Country-specific data collection have been conducted in the Solomon Islands (Ramofafia, 2004; Ramofafia *et al.*, 2007), Papua New Guinea (Kinch *et al.*, 2007; NFA, 2005, 2006, 2007b), and Samoa (Eriksson, 2006), and New Caledonia (Purcell, Gossuin and Agudo, in press). Each of these studies found sea cucumber fisheries to be of great importance to fisher communities, being in some cases, the major source of income.

FIGURE 10
Artisanal sea cucumber fishers and processors in the Western Central Pacific region. Fishers in Fiji taking their catch to be sold to a local buyer. Centre: Fishers in New Caledonia with home-dried bêche-de-mer. Right: Children processing *H. scabra* in the Western Province, Papua New Guinea

COURTESY OF K. FRIEDMAN, S. PURCELL, J. KINCH

During recent surveys in Samoa, the subsistence sea cucumber fishery was considered to be an important element to fishers' livelihoods and their families, with 29 percent of all respondents selling either all or part of their sea cucumber catch at local markets (Eriksson, 2006; Friedman *et al.*, 2006).

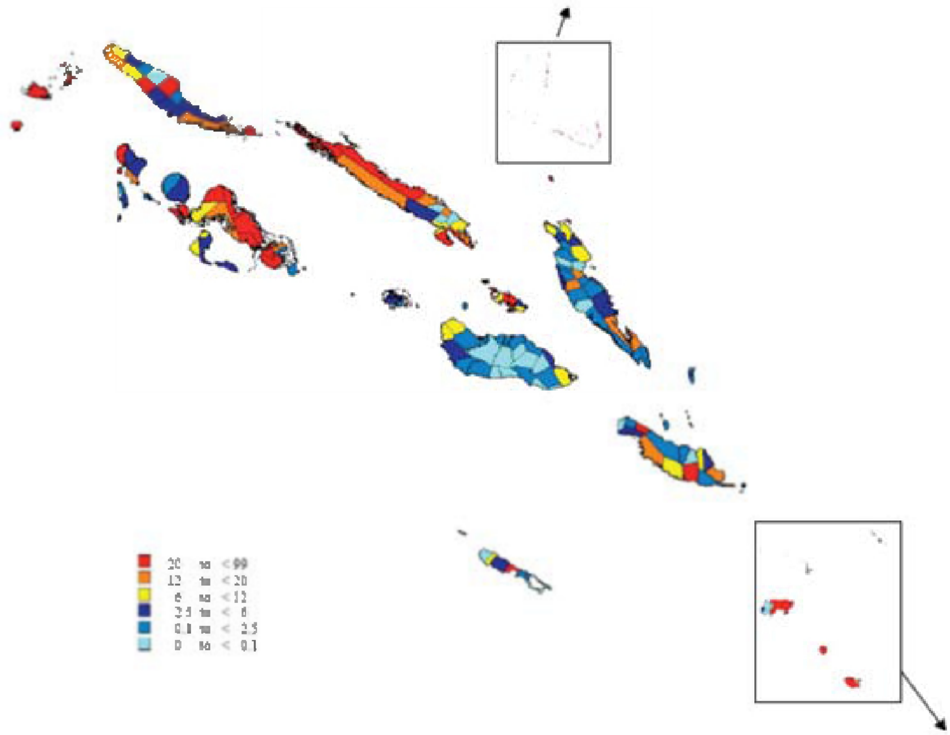
During the lead author's (Jeff Kinch) PhD work at Brooker Island in the Milne Bay Province, bêche-de-mer sales contributed 47 percent of all household incomes (Kinch, 1999). A socio-economic survey conducted by Coastal Fisheries Management and Development Program (CFMDP) in the Milne Bay Province showed that 22 percent of households surveyed, harvested sea cucumbers for income (NFA, 2006). A similar survey in the New Ireland Province showed that 12 percent of households harvested sea cucumbers for income (NFA, 2005). In the West New Britain Province, Koczberski *et al.* (2006) also found the sale of bêche-de-mer to be an important source of income.

A recent socio-economic assessment of the sea cucumber fisheries in the Western Central, Central and Manus Provinces of Papua New Guinea by Kinch *et al.* (2007) showed that on average, households that harvested sea cucumbers could make between USD 1 000–3 000 y^{-1} from the sale of bêche-de-mer. In Manus Province, of all households surveyed, 75 percent stated that harvesting sea cucumbers was their most important income stream (Kinch *et al.*, 2007). During this survey, between 24 and 40 percent of all households stated they would move to other forms of fishing and harvesting other marine resources if they could no longer harvest sea cucumbers, and thus possibly starting a spiral of fishing down other valuable species. Of particular concern would be the fishing for sharks for sharkfins, and sea turtles.

In Solomon Islands the 1999 census showed that village wards (a local-level census unit that may consist of part of a village, a village or a group of villages) with a predominantly coastal location had 12 percent of households involved in selling sea cucumbers as bêche-de-mer. Sea cucumber fishery is of more importance in the smaller island groups of Ontong Java, the Reef Islands and Temotu, and especially the Western Province (Figure 11). The number of people fishing for sea cucumbers is believed to have increased greatly subsequent to the census as the ethnic tension closed down national systems for exporting copra and cocoa, leaving many rural communities with no other source of income. In the Rennell and Belona island groups, where cyclones have recently destroyed plantations, bêche-de-mer remains the main source of cash, while at Ontong Java, bêche-de-mer has been the main source of income for decades

FIGURE 11

A depiction of the percentage of households that sell bêche-de-mer in the Solomon Islands. Wards in yellow support the average numbers of sellers whereas those in orange and red have the highest level of household involvement in the trade. Box inserts are Ontong Java in the North East, and the Reef Islands and Temotu in the South East



COURTESY OF SPC

(Bayliss-Smith, 1986). In 1999, Donnelly (2001) also conducted a household survey, towards research into the economics of the Live Reef Fish Food Trade (LRFFT). He stated that a quarter of all households in the Marovo Lagoon were obtaining cash from the harvesting sea cucumbers. During the recent International Waters Project (IWP) surveys in 2004, it was determined that 63 percent of households at Mbili Passage stated that bêche-de-mer contributed to household income, whilst 27 percent at Chea stated likewise (Kinch *et al.*, 2006). Kia community had a high reliance on the bêche-de-mer fishery for income (Ramofafia *et al.*, 2007). Despite the fishery showing signs of overfishing, little effort had been made neither to address those warning signs nor to pro-actively investigate alternative means of providing community income.

In New Caledonia, sea cucumbers were the most economically important wild fishery export in 2007, being twice the value of finfish exports (Purcell, Gossuin and Agudo, in press). Sea cucumbers are the most important income source for most of the fishers who collect them, while some others rely more on fishes, molluscs, and crusteans. Fishers remote from urban processing centres tend to process the sea cucumbers into bêche-de-mer themselves and rely on selling this and other non-perishable transformed marine animals more than fishes or bivalves for their income (Purcell, Gossuin and Agudo, in press).

When comparing the benefits of other fisheries such as tuna versus sea cucumbers, it is important to note that the extremely diffuse, village-level nature of the sea cucumber fishery means that the financial benefits are very widely distributed amongst coastal and island villages. Although tuna fisheries and their licensing fees also bring in foreign currency, they contrast with sea cucumber fisheries in being centralized and highly capital-intensive, with benefits delivered at the national scale over a long term, rather than locally and immediately.

5. CURRENT RESEARCH AND PROJECTS

Fisher, buyer and exporter surveys are currently being conducted in 17 PICTs as part of the SPC PROCFish/C programme (funded by the European Union). This includes the collection of species specific catch and value information through fully structured questionnaires conducted with fishers, buyers and exporters.

In the Solomon Islands, a project implemented by the WorldFish Centre (funded by ACIAR) examined the importance of the sea cucumber fishery for the community at Kia, in the Santa Isabel Province, one of the major areas of bêche-de-mer production in that country. This project entitled "Improving Sustainability and Profitability of Village Sea cucumber Fisheries in Solomon Islands" was halted when the Solomon Islands government placed a moratorium on the sea cucumber fishery in December 2005.

Biological and ecological surveys are underway across the Pacific by the SPC-PROCFish/C programme to get a better understanding of current densities of sea cucumbers (Figure 12). In-water surveys are being conducted in 17 PICTs with the purpose of providing governments and communities with information that will assist them in improving management and governance of reef fisheries and coastal environments. In this regional overview, four to six sites are surveyed for each PICT and the same survey techniques are employed throughout the region, allowing comparison between, as well as within, countries. Further analysis will assist in distilling the various survey techniques employed in this study, to develop indicators for monitoring sea cucumber fisheries in the future.

With a similar regional approach, but concentrating more on ecosystems than fisheries, NOAA is surveying US-affiliated Pacific Islands. The Coral Reef Ecosystem Division (CRED) of NOAA uses consistent survey methodology to get data on applied management-relevant issues for coral reef ecosystems, which includes data on sea cucumbers (Brainard, R., National Aeronautical and Oceanographic Agency, personal communication).

A recent project within the ZoNéCo programme evaluated population densities, abundances and sizes of sea cucumbers at 50 sites along New Caledonia's main island, La Grande Terre (WorldFish Center and SPC). Along with landing and sociological surveys, the underwater survey data were used to provide recommendations for better management of sea cucumber resources (Purcell, Gossuin and Agudo, in press).

With continued Asian market demand, mariculture could provide a substantial share of the bêche-de-mer market, and partially replace wild stocks. Baine (2004) suggests that the push for hatchery and restocking programmes is linked to the difficulties of managing sea cucumber fisheries. It should be cautioned here, that whilst these programmes have potential, they are only in their experimental stages at present, with just one (possibly two) species under investigation. Restocking and sea ranching should not be heralded as replacements for sound management. Moreover, inter-regional

FIGURE 12
Surveying for sea cucumbers under the SPC-PROCFish/C Project. Left: A diver with manta board, conducting a population survey. Right: The data sheet and tally counter on the manta board for recording species counts and habitat features

COURTESY OF K. FRIEDMAN

translocation of the main species of interest, sandfish *H. scabra,* is strongly discouraged, as it can lead to introgression of foreign genes into the existing populations, or allow for a non-interbreeding population to out compete local stocks (Uthicke and Purcell, 2004). Unless done carefully, and with local broodstock, translocations can also risk the introduction of new parasites and diseases.

Over the past decade, several hatchery, grow-out and optimal releasing projects have been undertaken by the WorldFish Center (previously ICLARM) in the Solomon Islands and New Caledonia with the aim of assessing the potential for restocking to restore depleted sea cucumber fisheries (Purcell, Gardener and Bell, 2002). Purcell and Simutoga (2008) recently indicated that it takes at least 2–3 years for *H. scabra* released in the wild to grow to a good market size of around 700 g, with roughly 7–20 percent survival if the habitats for releasing juveniles and the size-at-release are well chosen. Early experiments showed that *H. scabra* could be co-cultured with juvenile shrimp (Purcell, Patrois and Fraisse, 2006b), but further trials dismissed commercial culture with larger shrimp (Bell *et al.*, 2007). Recent findings give hope to commercial on-growing of sandfish in monoculture in earthen ponds, with fast growth rates of 1–3 g ind. day^{-1} (Bell *et al.*, 2007).

As a component of ACIAR's "Sustainable Aquaculture Development in the Pacific Islands Region and Northern Australia", production technology was transferred from the WorldFish Center to the Queensland Department of Primary Industries and Fisheries in Cairns, Australia. Broodstock of *H. scabra* from the Moreton Bay area was used in three spawnings. Juveniles from these productions were used for grow-out trials in shrimp farms in Townsville and Cairns, but these also indicated that *H. scabra* juveniles could not be co-cultured with shrimp (Hair, C., Queensland Department of Primary Industries and Fisheries, unpublished data).

A new sea ranching/restocking research project began in 2007 and will have four years to apply the experimental hatchery and release methods developed for sandfish, *H. scabra* (WorldFish Center and partners, funded by ACIAR). This project aims to assess the economic and social feasibility of sea ranching and restocking through commercial-scale trials with communities in the Northern Territory, Australia, and in the Philippines.

In addition, a private company from Queensland, Australia, has also been successful in mass producing *H. scabra* in the hatchery. They have released thousands of juvenile *H. scabra* in designated aquaculture areas over the last few years to try to enhance yields (Ivy and Giraspy, 2006). The company also intends to transfer juvenile *H. scabra* from Australia to communities in the Pacific, in joint fishing arrangements, but this has been met with controversy over the translocation issues discussed above.

The Fisheries Division of Kiribati has maintained a sea cucumber hatchery for many years and has cultured *H. fuscogilva* and released the juveniles in the wild for stock enhancement. Tens of thousands of juvenile *H. fuscogilva* have been placed on the reefs around Tarawa and neighbouring Abaiang Atoll, but survival has been poorly monitored, so there is limited information on optimal habitats and sizes for release (Friedman and Tekanane, 2006).

6. ADDITIONAL THREATS TO SEA CUCUMBER POPULATIONS

The biggest immediate threat to sea cucumber fisheries in the Western Central Pacific region is over-harvesting. As high value species become overexploited the focus shifts to lower-value species. Another trend is fishers exploiting new grounds further a field once they have removed all animals from a location. Until recently, deep water and remoteness have provided refuge for some heavily fished species, because most collection was done by wading or snorkeling. Some studies indicate that overexploited populations of sea cucumbers may require as much as 50 years in the absence of fishing pressure to rebuild (Bruckner, Johnson and Field, 2003; Uthicke, 2004).

Overfishing has been documented in Tonga (Lokani, Matoto and Ledau, 1996), Fiji (Preston, 1988), the Solomon Islands (Nash and Ramofafia, 2006), Papua New Guinea (Skewes *et al.*, 2002a; Kinch, 2002, 2004a; Kinch *et al.*, 2007), New Caledonia (Conand, 1989, 1990), Australia (Shiell, 2004; Skewes *et al.*, 2000, 2002b, 2006; Uthicke and Benzie, 2000a; Uthicke, 2004; Uthicke, Welch and Benzie, 2004). The reefs located in the Timor MOU Box in Western Australian reef are also heavily fished by Indonesian fisherman (Vail and Russel, 1990; Skewes *et al.*, 1999; Smith *et al.*, 2001, 2002; Rees *et al.*, 2003).

Continued over-harvesting of sea cucumbers can lead to reduced densities, and this can lead to disproportionally reduced larval production (Uthicke, 2004), a form of Allee effect (Allee *et al.*, 1949). Because holothurians are broadcast spawners, when adults are at low densities, eggs released by females may not encounter sperm by distant males, thus continuing a spiral of declining local population size.

Sea cucumbers can also be affected by coastal run-off, particularly those species that inhabit areas near riverine environs.

Global climate change is recognized as a major threat to the coral reefs. Significant coral bleaching events have been observed in recent years throughout the Western Central Pacific region (Wilkinson, 2004), thus affecting some sea cucumber species' habitats.

Human-induced increases in of atmospheric carbon dioxide (CO^2) concentrations are expected to cause rapid changes in the earth's climate causing significant effect on coastal ecosystems, especially estuaries and coral reefs through changes in temperature, sea level rise, the availability of water and associated nutrients from precipitation and runoff from land, wind patterns, and storminess. Increased CO^2 concentrations lower ocean pH, which in turn lower saturation states of the carbonate minerals calcite, aragonite, and high-magnesium calcite, the materials used to form supporting skeletal structures in many major groups of benthic calcifiers such as corals calcifying macroalgae, benthic foraminifera, molluscs, and echinoderms resulting in smaller size and body weight (Shirayama and Thornton, 2005). It is possible, but untested, that reduced calcification rates would also effect holothurian spicule formation.

Rising temperatures also influence organism's biology, affect dissolved oxygen concentrations in water, and play a direct role in sea level rise and in major patterns of coastal and oceanic circulation. Global climate change, thus has a major potential to affect sea cucumber populations and could in fact, result in the extinction of some species, the alteration of species distributions, and modifications in the flow of energy and cycling of materials within ecosystems. On reefs near low-lying coastal areas, sea level rise would likely increase coastal erosion rates, thus degrading water quality and reducing light penetration.

The coral reefs of New Caledonia, Samoa, Solomon Islands and Vanuatu have been damaged by cyclones in recent years. Cyclone Erica in 2003 destroyed 10–80 percent of live coral cover in some areas of New Caledonia, while Cyclone Heta struck Samoa in 2004, damaging 13 percent of the coral reefs (Lovell *et al.*, 2004).

ACKNOWLEDGEMENTS

The authors would like to thank the following persons for their input, advice and/or provision of information: Alessandro Lovatelli, Aliti Vunisea, Antoine Gilbert, Arsene Stein, Cathy Hair, Chantal Conand, Chris Ramofafia, Franck Magron, Frank Rowe, Joe Konno, Kalo Pakoa, Marcelo Vasconcellos, Marion Henry, Mark Baine, Masahiro Ito, Mecki Kronen, Michael Tekanene, Paul Christian Ryan, Paul Dalzell, Poh Sze Choo, Sam Grant, Samasoni Sauni, Semese Alefaio, Sheila McKenna, Timothy Lam, Timothy Skewes, Veronica Toral-Granda, Warwick Nash, William Sommerville and Yves Samyn. WordFish Center contribution number 1851.

REFERENCES

Adams, T. 1992. Resource Aspects of the Fiji Beche-de-mer Industry. *SPC Beche-de-Mer Information Bulletin*, 4: 13–16.

Adams, T. 1998. The Interface between Traditional and Modern Methods of Fishery Management in the Pacific Islands. *Ocean and Coastal Management*, 40: 127–142.

Adams, T., Aldan, C., Alfred, V., Bertram, I., Bukkurrou, A., Cruz, J., Flores, T., Rosa, F., Seman, R. & Taman, J. 1994. *Assessment of the Northern Marianas Trochus Resource and Recommendations for the Fishery.* Report prepared for South Pacific Commission, Noumea, New Caledonia.

Adams, T., Leqata, J., Ramohia, P., Amos, M. & Lokani, P. 1992. *Pilot Survey on the Status of Trochus and Beche-de-mer Resources in the Western Province of the Solomon Islands with Options for Management*. Report prepared for South Pacific Commission, Noumea, New Caledonia.

Allee, W., Emerson, A., Park, O., Park, T. & Schmidt, K. 1949. *Principles of Animal Ecology.* W.B. Saunders, Philadelphia.

Allen, M., Kinch, J. & Werner, T. 2003. A Basic Stock Assessment of the Coral Reef Resources of Milne Bay Province, Papua New Guinea, Including a Study of Utilization at the Atisanal Level. *In: A Rapid Biodiversity Assessment of the Coral Reefs of Milne Bay Province, Papua New Guinea – Survey II (2000).* G, Allen, J. Kinch, S. McKenna and Seeto, P. (eds.). RAP Bulletin of Biological Assessment No. 29. pp. 56–74. Washington, DC, Conservation International.

Anon. 1997. *L'exploitation des holothuries en Polynésie Française. Papeete, Tahiti, Polynésie Française.* Papeete, Service de la Mer et de l'Aquaculture.

Anon. 1998. *Rapport final relatif à la réalisation d'une étude préalable sur l'exploitation des bêches de mer (Rori): Analyse, par simulation, de la rentabilité économique d'une exploitation des holothuries en Polynésie Française.* Papeete, BIODAX Consulting.

Anon. 1999. *Rapport interne de mission: Exploitation des holothuries (rori) à Fakarava par S. C. A. Hirifa.* Papeete, BIODAX Consulting.

Anon. 2003. *Invertebrate Survey for Airai State*. Report prepared for The Environment Inc., Koror, Republic of Palau.

Australian Fisheries Management Authority. 2004. *Draft Assessment Report – Torres Strait Beche-de-mer Fishery.* Report prepared for the Australian Fisheries Mangement Authority, Thursday Island, Queensland, Australia.

Australian Fisheries Management Authority. 2005. *Draft Assessment Report – Torres Strait Beche-de-mer Fishery.* Report prepared for the Australian Fisheries Management Authority, Thursday Island, Queensland, Australia.

Baine, M. 2004. From the Sea to the Market Place: An Examination of the Issues, Problems and Opportunities in Unravelling the Complexities of Sea Cucumbers and Trade. *In: Advances in Sea cucumber Aquaculture and Management. A.* Lovatelli, C. Conand, S. Purcell, S. Uthicke, J-F. Hamel and A. Mercier, (eds). pp 119–131. FAO, Rome.

Baker, J. 1929. On the Zonation of Some Coral Reef Holothuria. *Journal of Ecology*, 17: 141–143.

Bakus, G. 1968. Defensive Mechanisms and Ecology of some Tropical Holothurians. *Marine Biology*, 2: 23–32.

Bakus, G. 1973. The Biology and Ecology of Tropical Holothurians. *In. Biology and Geology of Coral Reefs.* O. Jones and R. Endean, (Eds.). 2 Volumes. pp 325–367. New York, Academic Press.

Baquie, B. 1977. *Fishing in Rarotonga*. Unpublished M.A. Thesis, University of Auckland, Auckland, New Zealand.

Battaglene, S. & Bell, J. 2004. The Restocking of Sea Cucumbers in the Pacific Islands. *In: Case Studies in Marine Ranching*. D. Bartley and K. Leber, (eds). FAO Fisheries Technical Paper, No. 429. pp 109–128. FAO, Rome.

Bayliss-Smith, T. 1986. *Ontong Java Atoll: Population, Economy and Society, 1970-1986.* Occasional Paper, No. 9. Fiji, South Pacific Smallholder Project.

Beckett, J. 1977. The Torres Strait Islanders and the Pearling Industry: A Case of Internal Colonialism. *Aboriginal History,* 1(1): 77–104.

Belhadjali, K. 1997. Beche-de-mer Production in Tuvalu. *SPC Beche-de-Mer Information Bulletin,* 9: 2–3.

Bell J., Purcell S., Agudo N., Blazer P., Simutoga M., Pham D. & Della Patrona, L. 2007. Grow-out of Sandfish *Holothuria scabra* in Ponds shows that Co-culture with shrimp *Litopenaeus stylirostris* is not Viable. *Aquaculture,* 273: 509–519.

Bennett, J. 1987. *Wealth of the Solomons: A History of a Pacific Archipelago, 1800–1978.* Pacific Islands Monograph Series, No. 3. Honolulu, University of Hawaii Press.

Beumer, J. 1992. Queensland's Beche-de-mer Fishery. *SPC Beche-de-Mer Information Bulletin,* 4: 12.

Birkeland, C., Green, A., Guilbeaux, M., Donaldson, T., Emilio, D., Kirkendale, L., Mangel, J., Myers, R., Wemg, K. & van Woesik, R. 2000. *Helen Reef Marine Resources in the Year 2000 - Results of Scientific and Community Monitoring Surveys: April 24-May 3, 2000, Hatohobei State, Republic of Palau.* Report prepared for the Helen Reef Marine Resource Management Program, Koror, Republic of Palau.

Bruckner, A., Johnson, K. & Field, J. 2003. Conservation Strategies for Sea cucumbers: Can a CITES Appendix II listing Promote Sustainable International Trade? *SPC Beche-de-Mer Information Bulletin,* 18: 24–33.

Bungitaki, J. & Lindsay, S. 2004. Marine Resource Survey and Assessment of Jaluit Atoll, Republic of the Marshall Islands. *SPC Beche-de-Mer Information Bulletin,* 19: 33–35.

Callaghan, P. 1996. An Economic Model of Sea cucumber Export in Micronesia. *In: Suggestions for the Management of Sea cucumber Resources in Micronesia: Results of the Workshop 'A regional management plan for a sustainable Sea Cucumber Fishery for Micronesia'.* R. Richmond, (Ed). University of Guam Marine Laboratory Technical Report, No. 101. pp 51–65. Mangilao, University of Guam.

Cannon, L. & Silver, H. 1987. *Sea Cucumbers of Northern Australia.* Brisbane, Queensland Museum.

Carroll, T. 2005. Immune from Pessimism: Unicorn Pacific Makes a Mark in Vanuatu. *Pacific Magazine,* August: 13.

Chambers, M. 1989. A Survey of the Beche-de-mer of Vanuatu. *In: The Marine Resources of Vanuatu.* T. Done and K. Navin, (eds.). pp. 107–114. Townsville, Australian Institute of Marine Science.

Chao, S., Chen, C. & Alexander, P. 1994. Reproduction and Growth of *Holothuria atra* (Echinodermata: Holothuroidea) at Two Contrasting Sites in Southern Taiwan. *Marine Biology,* 119: 565–570.

Cheyne, A. 1852. *A Description of Islands in the Western Pacific Ocean.* London.

Clark, H. 1946. *The Echinoderm Fauna of Australia.* Washington, DC, Carnegie Institute of Washington.

Conand, C. 1981. Sexual Cycle of Three Commercially Important Holothurian Species (Echinodermata) from the Lagoon of New Caledonia. *Bulletin of Marine Science,* 31(3): 523–543.

Conand, C. 1988. *Beche-de-mer in New Caledonia: Biology and Fishing.* Paper prepared for the South Pacific Commission's Workshop on Pacific Inshore Fishery Resources, 14–25 March, 1988, Noumea, New Caledonia.

Conand, C. 1989. *Les Holothuries Aspidochirotes du Lagon de Nouvelle-Caledonie: Biologie, Ecologie et Exploitation.* Etudes et Thesses, ORSTROM, Paris, France. (in French – the 'ecology' and 'biology' sections translated into English by the SPC).

Conand, C. 1990. *The Fishery Resources of Pacific Island Countries, Part Two: Holothurians. Fisheries Technical Paper,* No. 272.2. Rome, Food and Agriculture Organization.

Conand, C. 1993. Reproductive Biology of the Holothurians from the Major Communities of the New Caledonian Lagoon. *Marine Biology,* 116: 439–450.

Conand, C. 1996. Asexual Reproduction by Fission in *Holothuria atra*: Variability of some Parameters in Populations from the Tropical Indo-Pacific. *Oceanologia Acta,*19(3–4): 209–216.

Conand, C. 1998. Holothurians (Sea cucumbers, Class Holothuroidea). *In: The Living Marine Resources of the Western South Pacific, Volume 2: Cephalopods, Crustaceans, Holothurians And Sharks. Species Identification Guide For Fishery Purposes.* K. Carpenter and V. Neim, (eds). pp 1157–1191. Rome, FAO.

Conand, C. 2006. Harvest and Trade: Utilization of Sea Cucumber; Sea Cucumber Fisheries; Current International Trade; Illegal, Unreported and Unregulated Trade; By-catch; and Socio-economic Characteristics of the Trade in Sea Cucumbers. *In: Proceedings of the CITES Workshop on the Conservation of Sea Cucumbers in the Families Holothuriidae and Stichopodidae, 1–3 March, 2004, Kuala Lumpur, Malaysia.* A. Bruckner, (ed). NOAA Technical Memorandum, NMFS-OPR-34. pp 51–73. Silver Spring: NOAA.

Conand, C. & Hoffschir, C. 1991. Recent Trends in Sea cucumbers Exploitation in New Caledonia. *SPC Beche-de-Mer Information Bulletin,* 3: 5–7.

Conand, C. & Secretariat of the Pacific Community. 1996. Statistics on Beche-de-mer Exports. *SPC Beche-de-Mer Information Bulletin,* 8: 14–15.

Conand, C., Morel, C. & Mussard, R. 1997. A New Study of Asexual Reproduction in Holothurians: Fission in *Holothuria leucospilota* Populations on Réunion Island in the Indian Ocean. *SPC Beche-de-Mer Information Bulletin,* 9: 5–11.

Convention on the International Trade in Endangered Species of Fauna and Flora. 2006. *Sea Cucumbers.* Paper prepared for the 22nd Meeting of the Animals Committee, 7–13 July 2006, Lima, Peru.

Costa, R. 1995. *Etude de l'abondance relative des holothuries d'intérêt commercial du lagon de Moorea.* Papeete, Service de la Mer et de l'Aquaculture.

Coulter, J. 1847. *Adventures on the Western Coast of South America, and the Interior of California: Including a Narrative of Incidents at the Kingsmill Islands, New Ireland, New Britain, New Guinea, and the other Islands in the Pacific Ocean.* 2 Volumes. London.

Crean, K. 1977. Some Aspects of the Beche-de-mer Industry in Ongtong Java, Solomon Islands. *SPC Fisheries Newsletter,* 15: 36–48.

Dalzell, P. & Adams, T. 1994. *The Present Status of Coastal Fisheries Production in the South Pacific Islands.* 25th Regional Technical Meeting on Fisheries Working Paper, No. 6. Noumea, SPC.

Dalzell, P., Adams, T. & Polunin, N. 1996. Coastal Fisheries in the Pacific Islands. *Oceanography and Marine Biology: An Annual Review,* 34: 395–531.

Dalzell, P., Adams, T. & Polunin, N. 1996. Coastal Fisheries in the Pacific Islands. *Oceanography and Marine Biology: An Annual Review,* 34: 395–531.

Dalzell. P., Lindsay, S. & Patiale, H. 1993. *Fisheries Resources of the Island of Niue.* South Pacific Commission Technical Document, No. 3. Noumea, SPC.

Dance, S., Lane, I. & Bell, J. 2003. Variation in Short-term Survival of Cultured Sandfish (*Holothuria scabra*) Released in Mangrove-Seagrass and Coral Reef Flat Habitats in Solomon Islands. *Aquaculture,* 220: 495–505.

Department of Environment & Heritage. 2004. *Assessment of the Northern Territory Trepang Fishery.* Canberra, Commonwealth of Australia.

Department of Environment & Heritage. 2005. *Assessment of the Western Australian Beche-de-mer Fishery.* Canberra, Commonwealth of Australia.

Department of Environment & Heritage. 2006. National Report: Australia. *In: Proceedings of the CITES Workshop on the Conservation of Sea Cucumbers in the Families Holothuriidae and Stichopodidae, 1-3 March, 2004, Kuala Lumpur, Malaysia.* A. Bruckner, (ed.). NOAA Technical Memorandum, NMFS-OPR-34. pp 207–214. Silver Spring, NOAA.

Department of Fisheries & Marine Resources. No date. *Fisheries Commodity Statement: Beche-de-mer.* Report prepared for the Department of Fisheries and Marine Resources, Port Moresby, Papua New Guinea.

Donnelly, R. 2001. *Socio-Economic Environment and the Effect of the Live Reef Food Fish Trade in Marovo Lagoon, Roviana Lagoon and Ontong Java, Solomon Islands.* Discussion Paper No.5. ACIAR, Canberra

Doty, J. 1977. Fission in *Holothuria atra* and Holothurian Population Growth. Unpublished M.Sc. Thesis, University of Guam, Guam.

Drumm, D. 2004. *Habitats and Macroinvertebrate Fauna of the Reef-top of Raratonga, Cook Islands: Implications for Fisheries and Conservation Management.* Unpublished Ph.D. Thesis, University of Otagao, Dunedin, New Zealand.

Drumm, D. & Lonergan, N. 2005. Reproductive Biology of *Holothuria leucospilota* in the Cook Islands and the Implications of Traditional Fishing of Gonads on the Population. *New Zealand Journal of Marine and Freshwater Research*, 39: 141–156.

Dzeroski, S. & Drumm, D. 2003. Using Regression Trees to Identify the Habitat Preference of the Sea Cucumber (*Holothuria leucospilota*) on Rarotonga, Cook Islands. *Ecological Modelling*, 170: 219–226.

Ebert, T. 1978. Growth and Size of the Tropical Sea Cucumber *Holothuria* (*Halodeima*) *atra* Juger at Enewetak Atoll, Marshall Islands. *Pacific Science*, 32(2): 183–191.

Edward, A. 1997. *Kosrae Sea cucumber Report.* Report prepared for the Kosrae State Government, Federated States of Micronesia.

Eriksson, H. 2006. The Subsistence and Artisinal Sea cucumber Fishery, with Particular Focus on *Stichopus horrens* in Samoa. *In: Sea cucumber Abundance, Diversity and Fishery in Samoa: An Assessment of Lagoon Occurring Species.* Uppsala University Minor Field Study, No.: 122. Pp: 54–73. Report prepared for the Uppsala University, Apia, Samoa.

Etaix-Bonnin, R. 1999. Recent Trends in Beche-de-mer Exports from New Caledonia. SPC Beche-de-mer Information Bulletin, 12: 24.

Fao, B. 1990. Pollution Problems. *SPC Beche-de-Mer Information Bulletin,* 2: 12–13.

Ferdhouse, F. 1999. Beche-de-Mer Markets and Utilization. *SPC Beche-de-Mer Information Bulletin,* 9: 3–9.

Ferdhouse, F. 2004. World Markets and Trade Flows of Sea Cucumber/Beche-de-mer. *In: Advances in Sea Cucumber Aquaculture and Management.* A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J-F. Hamel and A. Mercier, (eds.). pp 101–118. FAO *Fisheries Technical Paper*, No. 463. Rome, FAO.

Fisk, D. 2002. *Marine Biodiversity Assessment Baseline Survey Report: Aleipata District, May 2002.* Report prepared for the Aleipata Marine Protected Area District Committee and the Samoa Marine Biodiversity Protection and Management Project, Apia, Samoa.

Fisk, D. 2004. *Literature Review and Pilot Baseline Data.* Report prepared for the Niue International Waters Program, Niue.

Fisk, D. 2005. *Community Based Monitoring Trials and Training.* Report prepared for the Niue International Waters Program, Niue.

Fisk, D., Axford, J. & Power, M. 2004a. *Marine Resources of Tokelau Atolls: Fakaofo Marine Resource Management Plan.* Report prepared for the South Pacific Regional Environment Program, Apia, Samoa.

Fisk, D., Axford, J. & Power, M. 2004b. *Marine Resources of Tokelau Atolls: Atafu Marine Resource Management Plan.* Report prepared for the South Pacific Regional Environment Program, Apia, Samoa.

Fisk, D., Axford, J. & Power, M. 2004c. *Marine Resources of Tokelau Atolls: Nukunono Marine Resource Management Plan.* Report prepared for the South Pacific Regional Environment Program, Apia, Samoa.

Fort, G. 1886. *Report on British New Guinea, from Data and Notes by the Late Sir Peter Scratchley, Her Majesty's Special Commissioner.* 2: 953. Melbourne, Government Printers.

Francour, P. 1997. Predation on Holothurians: A Literature Review. *Invertebrate Biology*, 116(1): 52–60.

Franklin, S. 1980. The Reproductive Biology and Some Aspects of the Population Ecology of the Holothurians *Holothuria leucospilota* (Brandt) and *Stichopus chloronotus* (Brandt). Unpublished Ph.D. Thesis, University of Sydney, New South Wales, Australia.

Friedman, K. & Tekanene. M. 2005. White teatfish at Kiribati Sea cucumber Hatchery "Local Technicians Getting Them Out Again". *SPC Beche-de-Mer Information Bulletin*, 21: 31–32.

Friedman, K., Lokani, P., Fale, P., Mailau, S., Ramohia, P. & Ramofafia, C. 2004. *Survey of the Sea Cucumber Resources of Ha'apai, Tonga*. Report prepared for the Tongan Ministry of Fisheries, Tonga'tapu, Tonga.

Friedman, K., Eriksson, H., Pakoa, K., Lasi, F., Solofa A. & Mulipola, A. 2006. *Samoa Sea Cucumber Fishery Status Assessment 2006. PROCFish/C Country Status Report*. Report prepared for the Samoa Fisheries and Uppsala University, Apia, Samoa.

Friedman, K. & Gisawa, L. 2008. Sea Cucumbers: Early retirement or renewal? *Island Business*, March: 48–49

Fufudate, K. 1999. *Field Survey of Sea Cucumber Resources in the Gilbert Islands, the Republic of Kiribati.* Report prepared for the OFCF Hatchery, Kiribati.

Gaudechoux, J. 1993. Statistics on Beche-de-mer Production. *SPC Beche-de-Mer Information Bulletin*, 5: 9–10.

Gentle, M. 1979. Population Ecology of Commercial Beche-de-mer (Echinodermata: Holothuridea) in Fiji. *SPC Fisheries Newsletter*, 18: 13–15.

Green, E. 2003. International Trade in Marine Aquarium Species: Using the Global Marine Aquarium Database. *In: Marine Ornamental Species: Collection, Culture, and Conservation.* J. Cato and C. Brown (eds). pp 31-48. Ames, Iowa State Press.

Hamel J.-F. & Mercier, A. 2000. Cuvierian Tubules in Tropical Holothurians: Usefulness and Efficiency as a Defence Mechanism. *Marine and Freshwater Behaviour and Physiology*, 33: 115–139.

Hamel, J.-F., Conand, C., Pawson, D. & Mercier, A. 2001. The Sea cucumber *Holothuria scabra* (Holothuroidea: Echinodermata): Its Biology and Exploitation as Beche-de-mer. *Advances in Marine Biology*, 41: 129–223.

Harriott, V. 1982. Sexual and Asexual Reproduction of *Holothuria atra* Jaeger at Heron Island Reef, Great Barrier Reef. *Australian Museum Memoir*, 16: 53–66.

Harriott, V. 1984. *Census Techniques, Distribution, Abundance and Processing of Large Sea-cucumber Species (Echinodermata: Holothuroidea) on the Great Barrier Reef.* A Report prepared for the Great Barrier Reef Marine Park Authority, Townsville, Queensland, Australia.

Harriott, V. 1985. Reproductive Biology of Three Congeneric Sea cucumber Species, *Holothuria atra, H. impatiens* and *H. edulis*, at Heron Reef, Great Barrier Reef. *Australian Journal of Marine and Freshwater Research*, 36: 51–57.

Hendler, G. & Meyer, D. 1982. Ophiroids Flagante Delicto and Notes on the Spawning Behaviour of other Echinoderms in their Natural Habitat. *Bulletin of Marine Science*, 32(2): 600–607.

Hill, F. 2006. *Annual Status Report, 2006: Moreton Bay Beche-de-Mer Fishery.* Brisbane, Queensland State Government.

Hoffman, T. 2001. *Reefs of Life to Reefs of Death: The Political Ecology of Coral Reef Health.* Unpublished Ph.D. Thesis, University of California, Berkeley, California, United States of America.

Holland, A. 1994a. The Beche-de-mer Fishery in the Solomon Islands: Recent Trends and Suggestions for Management. *SPC Beche-de-Mer Information Bulletin*, 6: 2–9.

Holland, A. 1994b. *The Status of Global Beche-de-Mer Fisheries with Special Reference to Solomon Islands and the Potentials of Holothurian Culture.* Unpublished M.Sc. Thesis, University of Newcastle, United Kingdom.

Ilek, S. 1991. *A Preliminary Sea cucumber Survey of Reefs in the States of Koror and Airai in Palau*. Report prepared for the Palau Department of Marine Resources, Koror, Republic of Palau.

Ivy, G. & Giraspy, D. 2006. Development of Large-scale Hatchery Production Techniques for the Commercially Important Sea cucumber *Holothuria scabra* var. *versicolor* (Conand, 1986) in Queensland, Australia. *SPC Beche-de-Mer Information Bulletin*, 24: 28–34.

James, R. 1977. *Beche-de-Mer in Solomon Islands*. Regional 9th Technical Meeting on Fisheries Working Paper, No. 17. Noumea, SPC.

Jimmy, R. 1995. Country Statement: Current Management Policies and Problems of the Inshore Fisheries Resources in Vanuatu Sea cucumbers. *In: South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries: Manuscript Collection of Country Statements and Background Papers, Volume 1*. P. Dalzell and T. Adams, (comps.). Integrated Coastal Fisheries Management Project Technical Document, No. 11. pp: CP. 14. Noumea, SPC.

Jimmy, R. 1996. Current Management Policies and Problems of the Inshore Fisheries Resources in Vanuatu Sea cucumbers. *SPC Beche-de-Mer Information Bulletin*, 8: 11–12.

Kailola, P. & Lokani, P. No date. *Sea cucumbers*. Paper prepared for the National Fisheries Authority, Port Moresby, Papua New Guinea.

Kailola, P., Petelo, W. & Gillett, R. 1995. The Beche-de-mer Fishery in Tonga. *In: South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries: Manuscript Collection of Country Statements and Background Papers, Volume II*. P. Dalzell and T. Adams, (comps.). Integrated Coastal Fisheries Management Project Technical Document, No. 12. pp: BP. 32. Noumea, SPC.

Kerr, A. 1994. Shallow-water Holothuroids (Echinodermata) of Kosrae, Eastern Caroline Islands. *Pacific Science*, 48(2): 161–174.

Kinch, J. 1999. *Economics and Environment in Island Melanesia: A General Overview of Resource Use and Livelihoods on Brooker Island in the Calvados Chain of the Louisiade Archipelago, Milne Bay Province, Papua New Guinea*. Report prepared for Conservation International, Port Moresby, Papua New Guinea.

Kinch, J. 2002. An Overview of the Beche-de-mer Fishery in the Milne Bay Province, Papua New Guinea. *SPC Beche-de-Mer Information Bulletin*, 17: 2–16.

Kinch, J. 2004a. *The Marine Aquarium Trade in the Solomon Islands, with Specific Notes on the Marau Sound, Guadalcanal*. Report prepared for the Marine Aquarium Council and the Foundation of the Peoples of the South Pacific-International, Suva, Fiji.

Kinch, J. 2004b. *A Review of the Beche-de-Mer Fishery and its Management in Papua New Guinea*. Report prepared for the National Fisheries Authority, Port Moresby, Papua New Guinea.

Kinch, J. 2004c. *The Status of Commercial Invertebrates and other Marine Resources in the Santa Isabel Province, the Solomon Islands*. Report prepared for the United Nations Development Program's Pacific Sustainable Livelihoods Program, Suva, Fiji; and the Isabel Province Development Program, Buala, Santa Isabel Province, Solomon Islands.

Kinch, J. 2005. The Commercial Use of *Thelenota rubralineata* in the Solomon Islands. *SPC Beche-de-Mer Information Bulletin*, 21: 3–4.

Kinch, J., James, M., Thomas, E., Lauhi, P. & Gabiobu, R. 2007. *Socio-economic Assessment of the Beche-de-Mer Fisheries in the Western, Central and Manus Provinces, Papua New Guinea*. Report prepared for the National Fisheries Authority, Port Moresby, Papua New Guinea.

Kinch, J., Mesia, P., Kere, N., Manioli, J. & Bulehite, K. 2006. *Socio-economic Baseline Assessment for the Eastern Marovo Lagoon, Western Province, the Solomon Islands*. IWP-Pacific Technical Report, No.: 35. Apia, SPREP.

King, M. & Faasili, U. 1999. Community-based Management of Subsistence Fisheries in Samoa. *Fisheries Management and Ecology*, 6: 133–144.

Kiribati Fisheries Division. 1995. Kiribati: Country Statement. *In: South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries: Manuscript Collection of Country Statements and Background Papers, Volume 1.* P. Dalzell and T. Adams, (comps.). Integrated Coastal Fisheries Management Project Technical Document, No. 11. CP. 15. Noumea, SPC.

Koczberski, G., Curry, G., Warku, J. & Kwam, C. 2006. *Village-based Marine Resource Use and Rural Livelihoods: Kimbe Bay, West New Britain, Papua New Guinea.* TNC Pacific Islands Countries Report, No. 5. Report prepared for The Nature Conservancy, Port Moresby, Papua New Guinea.

Kropp, R. 1982. Response of Five Holothurian Species to Attacks by a Predatory Gastropod, *Tonna perdix*. *Pacific Science,* 36(4): 445–452.

Laade, W. 1966. The Islands of Torres Strait. *Bulletin of the International Committee on Urgent Anthropological Research,* 8: 111–114.

Laboute, P. 1987. Mission to the Tokelau Islands to evaluate cyclone damage to Coral Reefs. Orstom Centre, Noumea. 11 p.

Lambeth, L. 1999. *An Assessment of the Role of Women within Fishing Communities in the Republic of Palau.* Report prepared for the Community Fisheries Section, Secretariat of the Pacific Community, Noumea, New Caledonia.

Lambeth, L. 2000. The Subsistence Use of *Stichopus variegates* (now *S. herrmanni*) in the Pacific Islands. *SPC Beche-de-Mer Information Bulletin,* 13: 18–21.

Lane, D. 1999. Distribution and Abundance of *Thelenota rubralineata* in the Western Pacific: Some conservation Issues. *SPC Beche-de-Mer Information Bulletin,* 11: 19–21.

Lawrence, J. 1979. Numbers and Biomass of the Common Holothuroids on the Windward Reff Flat at Enewetak Atoll, Marshall Islands. *Proceedings of the European Colloquium on Echinoderms,* 1: 210–204.

Leqata, J. 2004. *Solomon Islands Country Report.* Paper prepared for the Seminar on Fisheries Development and Environment, 6/01–21/02, Yokohama City, Japan.

Lincoln-Smith, M., Pitt, K., Bell, J. & Ramohia, P. 2000. *Testing the Use of Marine Protected Areas to Restore and Manage Tropical Multi-species Invertebrate Fisheries at the Arnavon Islands, Solomon Islands.* Research Publication, No. 69. Report prepared for the Great Barrier Reef Marine Park Authority, Townsville, Queensland; and the Australian Centre for International Agricultural Research, Sydney, New South Wales, Australia.

Lindholm, R. 1978. *Beche-de-Mer Fishery.* Report prepared for the Department of Primary Industry, Port Moresby, Papua New Guinea.

Lindsay, S. 2000a. *Marine Resource Survey of Lenger Island, Pohnpei State, FSM.* Report prepared for the Conservation Society of Pohnpei, Kolonia, Pohnpei, Federated States of Micronesia.

Lindsay, S. 2001a. *Resource Evaluation of the Current Populations of two Commercially Harvested Sea Cucumber Species (*Actinopyga mauritiana *and* Stichopus chloronotus*), Kosrae State, FSM.* Report prepared for the Kosrae Island Resource Management Program, Kosare, Federated States of Micronesia.

Lindsay, S. 2001b. *Marine Resource Survey of U Municipality, Pohnpei State, FSM.* Report prepared for the Conservation Society of Pohnpei, Kolonia, Pohnpei, Federated States of Micronesia.

Lindsay, S. & Abraham, S. 2004. Resource Evaluation of Current Populations of Two Commercially Harvested Sea cucumber Species (*Actinopyga mauritiana* and *Stichopus chloronotus*), and Recommendations for Management for Kosrae State, Federated States of Micronesia. *SPC Beche-de-Mer Information Bulletin,* 19: 31–33.

Lindsay, S. & McKenna, S. 2006. L'evaluation D'especes Marines Macro-invertebrees Exploitees. In: *Une Evaluation Rapide de la Biodiversite Marien de Recifs Corallines du Mont Panie.* S. McKenna, N. Baillon, H. Blaffart and G. Abrusci, (eds.) RAP Bulletin of Biological Assessment No. 42. pp: 43–52. Washington, DC, Conservation International. (in French, cited from original English version).

Lokani, P. 1990. Beche-de-mer Research and Development in Papua New Guinea. *SPC Beche-de-Mer Information Bulletin,* 1: 8–11.

Lokani, P. 1992. First Results of an Internal Tag Retention Experiment on Sea cucumber. *SPC Beche-de-Mer Information Bulletin,* 4: 9–12.

Lokani, P. & Kubohojam, G. 1993. *Beche-de-Mer Processing and Marketing in Papua New Guinea.* Report to the Department of Fisheries and Marine Resources, Kavieng, New Ireland Province, Papua New Guinea.

Lokani, P., Matoto, S. & Ledau, E. 1996. S*urvey of Sea cucumber Resources art Ha'apai Tonga May/June 1996.* Secretariat of the Pacific Community Integrated Coastal Fisheries Management Project, Country Assignment Report. Report prepared for the Secretariat of the Pacific Community, Noumea, New Caledonia.

Long, B., Skewes, T., Dennis, D., Poiner, I., Pitcher, C., Taranto, T., Manson, F., Polon, P., Karre, B., Evans, C. & Milton, D. 1996. *Distribution and Abundance of Beche-de-Mer on Torres Strait Reefs.* Report to Queensland Fisheries Management Authority, Thursday Island, Queensland, Australia.

Lovell, E., Sykes, H., Deiye, M., Wantiez, L., Garrigue, C., Virly, S., Samuelu, J., Solofa, A., Poulasi, T., Pakoa, K., Sabetian, A., Afzal, D., Hughes, H. & Sulu, R. 2004. Status of Coral Reefs in the South West Pacific: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands, Tuvalu and Vanuatu. In: Wilkensen, C. (ed.). *Status of Coral Reefs of the World: 2004.* pp 337–361. Australian Institute of Marine Sciences, Townsville.

Lowden, R. 2005. Management of Queensland Sea cucumber Stocks by Rotational Zoning. *SPC Beche-de-Mer Information Bulletin,* 22: 47.

Massin, C. & Doumen, C. 1986. Distribution and Feeding of Epibenthic Holothuroids on the Reef Flat of Laing Island (Papua New Guinea). *Marine Ecology,* 31(2): 185–195.

Mathews, E. 1995. The Need for Invertebrate Conservation in the Pacific Islands region. *In: Fishing for Answers: Women and Fisheries in the Pacific Islands.* E. Mathews, (ed*.).* pp. 123–136. Suva, Women and Fisheries Network.

Mathews, E. & Oiterong, E. 1991. *The Role of Women in the Fisheries of Palau.* Division of Marine Resources Technical Report, No. 1. Report prepared for the Palau Division of Marine Resources, Koror, Republic of Palau.

Mathews, E. & Oiterong, E. 1995. Marine Species Collected by Women in Palau, Micronesia. *Micronesica,* 281: 77–90.

McCormack, C. 2005. *Annual Status Report, 2005: Moreton Bay Beche-de-Mer Fishery.* Brisbane: Queensland State Government.

McCormack, G. 1984. *Rori (Sea Cucumbers).* Report prepared for the Cook Islands Conservation Department, Raratonga, Cook Islands.

McElroy, S. 1990. *Beche-de-Mer Survey of the Gilbert Islands.* Report prepared for the Ministry of Natural Resource Development, Tarawa, Kiribati.

McKnight, C. 1976. *The Voyage to Marege: Macassan Trepangers in Northern Australia.* Melbourne, Melbourne University Press.

Mercier A., Battaglene, S. & Hamel, J.-F. 2000a. Periodic Movement, Recruitment and Size-related Distribution of the Sea cucumber *Holothuria scabra* in Solomon Islands. *Hydrobiologia,* 440: 81–100.

Mercier A., Battaglene, S. & Hamel, J.-F. 2000b. Settlement Preferences and Early Migration of the Tropical Sea cucumber *Holothuria scabra. Journal of Experimental Marine Biology and Ecology,* 249: 89–110.

Mladenov, M. & Gerring, P. 1996. *Resource Evaluation of the Sea cucumber (Stichopus mollis) in an Environmentally Sensitive Region of New Zealand.* Paper prepared for the 9th International Echinoderm Conference, August, 1996, San Francisco, California, United States of America.

Moore, C. 2003. *New Guinea: Crossing Boundaries and History.* Honolulu, University of Hawaii Press.

Moore, J. & Marieg, F. 1986. *Yap Fishing Authority Sea cucumber Development Project: Ngulu Atoll, 12 February to 29 April 1986.* Yap Fishing Authority, Kolonia.

Morgan, A. 2000. Aspects of the Spawning in the Sea Cucumber *Holothuria scabra* (Echinodermata: Holothuridea). *Bulletin of Marine Science,* 66: 47–57.

Morgan, A. & Archer, J. 1999. Overview: Aspects of Sea cucumber Industry Research and Development in the South Pacific. *SPC Beche-de-Mer Information Bulletin,* 12: 15–17.

Morrell, B. 1832. *A Narrative of Four Voyages.* New York.

Mulipola, A. 1994. *Current Status of Beche-de-Mer Resource and Exploitation in Western Samoa.* Report prepared for the Research Section, Fisheries Division, Ministry of Agriculture, Apia, Samoa.

Mulipola, A. 2002. *Marine Resources of Samoa.* Samoa's National Report for the World Summit on Sustainable Development, July 2002, Johannesburg, South Africa.

Myint, T. 1996. Beche-de-mer Exports. *PNG National Fisheries Authority Newsletter,* 2(1): 20–21.

Nash, W. & Ramofafia, C. 2006. Recent Developments with the Sea cucumber Fishery in Solomon Islands. *SPC Beche-de-Mer Information Bulletin,* 23: 3–4.

National Fisheries Authority. 2005. *Socio-economic Survey of Small-scale Fisheries in New Ireland Province, Papua New Guinea.* Kavieng, National Fisheries Authority and the Coastal Fisheries Management and Development Project.

National Fisheries Authority. 2006. *Socio-economic Survey of Small-scale Fisheries in Milne Bay Province, Papua New Guinea.* Kavieng, National Fisheries Authority and the Coastal Fisheries Management and Development Project.

National Fisheries Authority. 2007a. *Sea Cucumber Survey: New Ireland Province.* Kavieng, National Fisheries Authority and the Coastal Fisheries Management and Development Project.

National Fisheries Authority. 2007b. *Socio-economic Survey of Small-scale Fisheries in Morobe Province, Papua New Guinea.* Kavieng: National Fisheries Authority and the Coastal Fisheries Management and Development Project.

Northern Province Fisheries Division. 1993. Beche-de-mer Harvesting in the Northern Province of New Caledonia. *SPC Beche-de-Mer Information Bulletin,* 5: 7–8.

Oxley, W., Ayling, A., Cheal, J. & Osborne, K. 2004. *Marine Surveys Undertaken in Elizabeth and Middleton Reefs Marine National Nature Reserve, December 2003.* Report prepared for the Australian Department of Environment and Heritage, Brisbane, Queensland, Australia.

Passfield, K. 1998. *A Report of a Survey of the Marine Resources of Fakaofo Atoll, Tokelau.* Report prepared for the Secretariat of the Pacific Community, Noumea, New Caledonia.

Pauly, G. 2000. Benthic Ecology and Biota of Tarawa Atoll Lagoon: Influence of Equatorial Upwelling, Circulation, and Human Harvest. *Atoll Research Bulletin*, 487: 1–41.

Pawson, D. 1970. The Marine Fauna of New Zealand: Sea cucumbers (*Echinodermata: Holothuroidea*). *New Zealand Department of Science and Industry Research Bulletin,* 201: 1–50.

Polon, P. 2004. The Papua New Guinea National Beche-de-mer Fishery Management Plan. In: *Advances in Sea Cucumber Aquaculture and Management.* A. Lovateli, C. Conand, S. Purcell, S. Uthicke, J.-F. Hamel and A. Mercier, (eds.). pp. 205–217. Rome, FAO.

Preston, G. 1988. *Beche-de-Mer Exploitation in Fiji.* Inshore Fisheries Research Project Country Assignment Report. Noumea, South Pacific Commission.

Preston, G. 1990. Mass beche-de-mer production in Fiji. *SPC Beche-de-Mer Information Bulletin,* 1: 4–5.

Preston, G. 1993. Beche-de-mer. In: *Nearshore Marine Resources of the South Pacific: Information for Fisheries Development and Management.* A. Wright and L. Hill, (eds). pp. 371–407. Honiara, Forum Fisheries Agency.

Preston, G. & Lokani, P. 1990. Report of a Survey of the Sea cucumber Resources of Ha'apai, Tonga. Report prepared for the South Pacific Commission Noumea, New Caledonia.

Preston, G., Vakamoce, V., Lokain, P. & Viala, F. 1989. *Exploitation of the Sea Cucumber Actinopyga miliaris (Blackfish, Driloli) in Northern Fiji.* Reported prepared for the Government of Fiji, Suva, Fiji.

Preston, G., Lewis, A., Sims, N., Bertram, I., Howard N., Maluofenua, S., Marsters, B., Passfield, K., Tearii, T., Viala, F., Wright, D. & Yeeting, B. 1988. *The Marine Resources of Palmerston Island, Cook Islands: Report of a Survey Carried out in September 1988*. Inshore Fisheries Project Technical Document, No. 10. Report prepared for the Secretariat of the Pacific Community, Noumea, New Caledonia.

Purcell, S., Gossiun, H. & Agudo, N. In press. Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia. WorldFish Center Studies and Reviews. The WorldFish Center, Penang, Malaysia.

Purcell, S., Blockmans, B. & Nash, W. 2006a. Efficacy of Chemical Markers and Physical Tags for Large-scale Release of an Exploited Holothurian. *Journal of Experimental Marine Biology and Ecology,* 334: 283–293.

Purcell, S., Patrois, J. & Fraisse, N. 2006b. Experimental Evaluation of Co-culture of Juvenile Sea cucumbers, *Holothuria scabra* (Jaeger) with Juvenile Blue shrimp, *Litopenaeus stylirostris* (Stimpson). *Aquaculture Research,* 37: 515–522.

Purcell, S. & Simutoga, M. 2008. Spatio-temporal and Size-dependent Variation in the Success of Releasing Cultured Sea cucumbers in the Wild. *Reviews in Fisheries Science,* 16: 204–214.

Purcell, S., Gardner, D. & Bell, J. 2002. Developing Optimal Strategies for Restocking Sandfish: A Collaborative Project in New Caledonia. *SPC Beche-de-Mer Information Bulletin,* 16: 2–4.

Purwati, P. 2001. *Reproduction in Holothuria leucospilota in the Tropical Waters of Darwin, NT, Australia.* Unpublished M.Sc. Thesis, Northern Territory University, Darwin, Northern Territory, Australia.

Purwati, P. & Thinh Luong Van, J. 2003. Sexual Reproduction in a Fissiparous Holothurian Species, *Holothuria leucospilota* Clark 1920 (Echinodermata: Holothuroidea). *SPC Beche-de-Mer Information Bulletin,* 18: 33–38.

Qalovaki, S. 2006. National Report: Fiji. *In: Proceedings of the CITES Workshop on the Conservation of Sea Cucumbers in the Families Holothuriidae and Stichopodidae, 1–3 March, 2004, Kuala Lumpur, Malaysia*. A. Bruckner, (ed). NOAA Technical Memorandum, NMFS-OPR-34. pp. 149–152. Silver Spring, NOAA.

Ram, R. (in prep). Impacts of harvest and post harvest processing methods on quality and value of bêche-de-mer in Fiji Islands. Master of Science Thesis. University of the South Pacific.

Ramofafia, C. 2004. *The Sea cucumber Fisheries in Solomon Islands: Benefits and Importance to Coastal Communities*. Report prepared for the Australian Centre for International Agriculture Research, Sydney, New South Wales, Australia.

Ramofafia, C., Battaglene, S. & Bryne, M. 2001. Larval Development in the Tropical Sea Cucumber *Holothuria scabra. In: Echinoderms 2000: Proceedings of the 10th International Conference*. M. Barker, (ed). pp. 369–375. Rotterdam: A.A. Balkema.

Ramofafia, C., Byrne, M. & Battaglene, S. 2001. Reproductive Biology of the Intertidal *Actinopyga mauritiana* in the Solomon Islands. *Marine Biology,* 81: 523–531.

Ramofafia, C., Byrne, M. & Battaglene, S. 2003. Reproduction of the Commercial Sea cucumber *Holothuria scabra* (Echinodermata: Holothuriodea) in the Solomon Islands. *Marine Biology,* 142: 281–288.

Ramofafia, C., Gervis, M. & Bell, J. 1995. Spawning and Early Larval Rearing of *Holothuria atra*. *SPC Beche-de-Mer Information Bulletin,* 7: 2–6.

Ramofafia, C., Battaglene, S., Bell, J. & Byrne, M. 2000. Reproductive Biology of *Holothuria fuscogilva* (Echinodermata: Holothuroidea) in the Solomon Islands. *Marine Biology,* 136: 1045–1056.

Ramofafia, C., Nash, W., Sibiti, S., Makini, D. & Schwarz, A. 2007. *Household Socio-economics and Beche-de-Mer Resource Use in Kia Community, Isabel Province, Solomon*

Islands (June, 2005). Report prepared for the Australian Centre of International Agriculture Research, Sydney, New South Wales, Australia.

Ramohia, P. 2006. Fisheries Resources: Commercially Important Macroinvertebrates. In: *Solomon Islands Marine Assessment: Technical Report of Survey Conducted May 13 to June 17, 2004.* A. Green, P. Lokani, W. Atu, P. Ramohia, P. Thomas and J. Almany, (eds.). TNC Pacific Island Countries Report, No. 1. pp. 330–400. Brisbane, The Nature Conservancy.

Rees, M., Colquhoun J., Smith, L. & Heyward, A. 2003. *Stocks of Trochus, Beche-de-Mer and Clams at Ashmore Reef, Cartier Reef and Mermaid Reef, northwestern Australia: 2003 Report.* Report prepared for Environment Australia. Australian Institute of Marine Science, Townsville, Australia.

Reichenbach, N., Nishar, Y. & Saeed, A. 1996. Species and Size-related Trends in Asexual Propagation of Commercially Important Species of Tropical Sea Cucumbers (Holothuroidea). *Journal of the World Aquaculture Society,* 27: 475–482.

Richmond, R. 1996a. The Biology and Ecology of Sea Cucumbers. *In: Suggestions for the Management of Sea cucumber Resources in Micronesia: Results of the Workshop 'A regional management plan for a sustainable Sea Cucumber Fishery for Micronesia'.* R. Richmond, (Ed). University of Guam Marine Laboratory Technical Report, No. 101. pp. 7–25. Mangilao, University of Guam.

Richmond, R. 1996b. Introduction and Overview. *In: Suggestions for the Management of Sea cucumber Resources in Micronesia: Results of the Workshop "A regional management plan for a sustainable Sea Cucumber Fishery for Micronesia".* R. Richmond, (Ed). University of Guam Marine Laboratory Technical Report, No. 101. pp. 26. Mangilao, University of Guam.

Roelofs, A. 2004. *Ecological assessment of Queensland's East Coast Beche-de-Mer Fishery.* Report prepared for the Australian Government Department of Environment and Heritage, Canberra, Australia.

Roelofs, A. 2005. *Annual Status Report 2005: East Coast Beche-de-Mer Fishery.* Brisbane, Queensland State Government.

Russell, P. 1970. *The Papuan Beche-de-Mer Trade to 1900.* Unpublished MA Thesis, University of Papua New Guinea, Port Moresby, Papua New Guinea.

Sachithananthan, K. 1971a. *Beche-de-Mer Industry in the South Pacific Islands. I. Market Survey.* First report to the Food and Agriculture Organization of the United Nations, Rome, Italy.

Sachithananthan, K. 1971b. *Beche-de-Mer Industry in the South Pacific Islands. II. Territory of Papua New Guinea.* Second report to the Food and Agriculture Organization of the United Nations, Rome, Italy.

Sebatian, A. & Foale, S. 2006. Evolution of the Artisanal Fisher: Case-studies from Solomon Islands and Papua New Guinea. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin,* 20: 3–10.

Secretariat for the Pacific Community. 1979. *Beche-de-Mer of the Tropical Pacific: A Handbook for Fishermen.* Handbook, No. 18. Noumea, SPC.

Secretariat of the Pacific Community. 2003. *Pacific Island Sea Cucumber and Beche-de-Mer Identification Cards.* Noumea, SPC.

Secretariat of the Pacific Community. 2006a. Fieldwork in the Federated States of Micronesia (FSM). *SPC Fisheries Newsletter,* 117: 30–34.

Secretariat of the Pacific Community. 2006b. Survey Work in Papua New Guinea. *SPC Fisheries Newsletter,* 118: 6–8.

Secretariat of the Pacific Community. 2007a. Fieldwork and surveys in the Cook Islands. *SPC Fisheries Newsletter,* 120: 2–8.

Secretariat of the Pacific Community. 2007b. Fieldwork and surveys in the Cook Islands. *SPC Fisheries Newsletter,* 123: 2–12.

Seeto, J. 1994. *Reproductive Biology of the Sea cucumber Holothuria atra Jaeger 1833 (Echinodermata: Holothuroidea) in Laucala Bay, Fiji, with Notes on its Population Structure and Symbiotic Associations.* Unpublished M.Sc. Thesis, University of Otago, Dunedin, New Zealand.

Sharples, P. 1994. *Pitcairn Island Fisheries Resource Survey – 1994: Observer Trip Report.* Report prepared for the Secretariat of the Pacific Community, Noumea, New Caledonia.

Shelley, C. 1981. *Aspects of the Distribution, Reproduction, Growth and Fishery Potential of Holothurians (Beche-de-Mer) in the Papuan Coastal Lagoon.* Unpublished Master of Science Thesis, University of Papua New Guinea, Port Moresby, Papua New Guinea.

Shelley, C. 1985. Growth of *Actinopyga echinites* and *Holothuria scabra (*Holothuroidea: Echinodermata) and their fisheries potential (as Beche-de-mer) in Papua New Guinea. *Proceedings of the Fifth International Coral Reef Congress, Tahiti, French Polynesia, 27 May–1 June. 5.* pp. 297–302. Papeete, Moorea Antenne Museum-EPHE.

Shelley, C. & Puig, P. 2004. Management of Trepang in the Northern Territory, Australia, and Current Research to Further Improve Understanding of the Fishery. In: *Advances in Sea Cucumber Aquacultureand Management.* A. Lovateli, C. Conand, S. Purcell, S. Uthicke, J.-F. Hamel and A. Mercier, (eds.). pp: 221–230. Rome, FAO.

Shiell, G. 2004. Beche-de-mer – the West Australian Perspective: he Fishing History and Aspects of the Reproductive Biology and Ecology of the Black teatfish, *Holothuria nobilis. In: Advances in Sea Cucumber Aquaculture and Management.* A. Lovateli, C. Conand, S. Purcell, S. Uthicke, J.-F. Hamel and A. Mercier, (eds.). pp. 231–238. Rome, FAO.

Shiell, G. & Uthicke, S. 2005. Reproduction of the Commercial Sea cucumber *Holothuria whitmaei* (Holothuroidea: Aspidochirotida) in the Indian and Pacific Ocean Regions of Australia. *Marine Biology,* 148: 937–986.

Shirayama, Y. & Thornton, H. 2005. Effect of Increased Atmospheric CO^2 on Shallow Water Marine Benthos. *Journal of Geophysical Research,* 110:C09S08.

Skewes, T., Burridge, C. & Hill, B. 1998. *Survey of Holothuria scabra on Warrior Reef, Torres Strait.* Report to Queensland Fisheries Management Authority, Thursday Island, Queensland, Australia.

Skewes, T., Dennis, D. & Burridge, C. 2000. *Survey of* Holothuria scabra *(Sandfish) on Warrior Reef, Torres Strait.* Report to Queensland Fisheries Management Authority, Thursday Island, Queensland, Australia.

Skewes, T., Dennis, D., Jacobs, D., Gordon, S., Taranto, T., Haywood, M., Pitcher, R., Smith, G., Milton, D. & Poiner, I. 1999. *Survey and Stock Size Estimates of the Shallow Reef (0–15 m Deep) and Shoal Area (15–50 m Deep) Marine Resources and Habitat Mapping with the Timor Sea MOU 74 Box, Volume 1: Stock Estimates and Stock Status.* Report prepared for the CSIRO Marine Branch, Brisbane, Queensland, Australia.

Skewes, T., Kinch, J., Polon, P., Dennis, D., Seeto, P., Taranto, T., Lokani, P., Wassenberg, T., Koutsoukos, A. & Sarke, J. 2002a. *Research for the Sustainable Use of Beche-de-Mer Resources in the Milne Bay Province, Papua New Guinea.* Report prepared for the National Fisheries Authority, Port Moresby, Papua New Guinea; and the Australian Centre for International Agricultural Research, Sydney, New South Wales, Australia.

Skewes, T., Dennis, D., Koutsoukos, A., Haywood, M., Wassenberg, T. & Austin, M. 2002b. *Research for the Sustainable Use of Beche-de-Mer Resources in Torres Strait.* Report prepared for the Australian Fisheries Management Authority and Queensland Fishery Service, Thursday Island, Queensland, Australia.

Skewes, T., Dennis, D., Koutsoukos, A., Haywood, M., Wassenberg, T. & Austin, M. 2004. *Stock survey and Sustainable Harvest Strategies for the Torres Strait Beche-de-Mer.* Report prepared for the Australian Fisheries Management Authority and Queensland Fishery Service, Thursday Island, Queensland, Australia.

Skewes, T., Dennis, D., Taylor, S., Haywood, M. & Donovan, A. 2006. *Sustainability Assessment for the Torres Strait Beche-de-Mer Fishery.* Report prepared for the Australian Fisheries Management Authority Torres Strait Research Program, Brisbane, Queensland, Australia.

Smith, A. 1986. Reef Invertebrate Harvesting. *In: Fishing on Guam: Guide to Coastal Resources of Guam.* S. Amesbury, F. Cushing and R. Sakamoto, (Eds.). Volume 2. pp. 68–73. University of Guam: Guam.

Smith, A. 1992. *Federated States of Micronesia Marine Resource Profiles.* FFA Report, No. 17. Report prepared for the Fisheries Forum Agency, Honiara, Solomon Islands.

Smith, L., Rees, M., Heyward, A. & Colquhoun, J. 2001. *Survey 2000: Beche-de-Mer and Trochus Populations at Ashmore Reef.* Report prepared for Environment Australia. Australian Institute of Marine Science, Townsville, Australia.

Smith, L., Rees, M., Heyward, A. & Colquhoun, J. 2002. *Stocks of Trochus and Beche-de-Mer at Cartier Reef: 2001 Surveys.* Report prepared for Environment Australia. Australian Institute of Marine Science, Townsville, Australia.

Smith, R. 1947. *Survey of the Fisheries of the Former Japanese Mandated Islands.* United States Fisheries and Wilidlife Service's Fishery Leaflet, No. 273.

Souter, G. 1963. *New Guinea: The Last Unknown.* Sydney, Angus and Robertson.

Stewart, B. 1993. *Evidence for a Marked Decline of Beche-de-Mer Populations in the Suva and Beqa Areas of Fiji, and a Preliminary Description of a Method of Identifying Beche-de-Mer Individuals based on Characteristic Body Wrinkles.* University of the South Pacific Marine Studies Technical Report, No.1. Suva, USP.

Sumner, R. 1981. A Noisome Buisness: The Trepang Trade and Queensland. *Journal of Australian Studies*, 9: 61–70.

Tiraa-Passfield, A. 1997: The Harvesting of Rori (Sea cucumbers) in Rarotonga, Cook Islands. *SPC Traditional Marine Resource Management and Knowledge Bulletin, 8*: 16–17.

Tonga Ministry of Fisheries. 1995. Kingdom of Tonga Country Report: Status and Management of Inshore Fisheries. *In: South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries: Manuscript Collection of Country Statements and Background Papers, Volume 1.* P. Dalzell and T. Adams, (Comps.). Integrated Coastal Fisheries Management Project Technical Document, No. 11. pp. CP. 18. Noumea, SPC.

Trianni, M. 2001. *Evaluation of the Resource following the Sea cucumber Fishery of Saipan, Northern Mariana Islands.* Paper prepared for the 9th International Coral Reef Symposium, Bali, Indonesia.

Trianni, M. 2002. Summary of Data Collected from the Sea cucumber Fishery on Rota, Commonwealth of the Northern Mariana Islands. *SPC Beche-de-Mer Information Bulletin*, 16: 5–11.

Tsuda, R. 1997. Survey of Commercially-valued Sea cucumbers in the Saipan Lagoon, CNMI. *SPC Beche-de-Mer Information Bulletin*, 10: 15–17.

Uthicke, S. 1994. Spawning Observations from the Lizard Island Area. *SPC Beche-de-Mer Information Bulletin*, 6: 12–14.

Uthicke, S. 1997. The Seasonality of Asexual Reproduction in *Holothuria (Halodeima) atra*, *Holothuria (Halodeima) edulis* and *Stichopus chloronotus* (Holothuroidea: Aspidochirotida) on the Great Barrier Reef. *Marine Biology*, 129: 435–441.

Uthicke, S. 2004. Overfishing of Holothurians: Lessons from the Great Barrier Reef. *In: Advances in Sea Cucumber Aquaculture and Management.* A. Lovateli, C. Conand, S. Purcell, S. Uthicke, J.-F. Hamel and A. Mercier, (eds.). pp. 163–171. Rome, FAO.

Uthicke, S. & Benzie, J. 1999. Allozyme Variation as a Tool for Beche-de-mer Fisheries Management: A study on *Holothuria scabra* (Sandfish). *SPC Beche-de-Mer Information Bulletin*, 11: 18–23.

Uthicke, S. & Benzie, J. 2000a. The effect of bêche-de-mer fishing on densities and size structure of Holothuria nobilis (Echinodermata: Holothurioidea) populations on the Great Barrier Reef. *Coral Reefs*, 19: 271–276.

Uthicke, S. & Benzie, J. 2001. Restricted Gene Flow between *Holothuria scabra* (Echinodermata: Holothuroidea) Populations along the North-east Coast of Australia and the Solomon Islands. *Marine Ecology Progress Series*, 216: 109–117.

Uthicke, S. & Benzie, J. 2002. A Genetic Fingerprint Recapture Technique for Measuring Growth in "Unmarkable" Invertebrates: Negative Growth in Commercially Fished Holothurians (*Holothuria nobilis*). *Marine Ecology*, 241: 221–226.

Uthicke, S. & Benzie, J. 2003. Gene Flow and Population History in High Dispersal Marine Invertebrates: mtDNA Analysis of *Holothuria nobilis* (Echinodermata: Holothuroidea) Populations from the Indo-Pacific. *Molecular Ecology*, 12: 2635–2648.

Uthicke, S. & Purcell, S. 2004. Preservation of Genetic Diversity in Restocking of the Sea cucumber *Holothuria scabra* planned through Allozyme Electrophoresis. *Canadian Journal of Fisheries and Aquatic Sciences*, 61: 519–528.

Uthicke, S., Benzie, J. & Ballment, E. 1998. Genetic Structure of Fissiparous Populations of *Holothuria (Halodeima) atra* on the Great Barrier Reef. *Marine Biology*, 132: 141–151.

Uthicke, S., Benzie, J. & Ballment, E. 1999. Population Genetics of the Fissiparous Holothurian *Stichopus chloronotus* (Aspidochirotida) on the Great Barrier Reef, Australia. *Coral Reefs*, 18: 123–132.

Uthicke, S., Conand, C. & Benzie, J. 2001. Population Genetics of the Fissiparous Holothurians *Stichopus chloronotus* and *Holothuria atra* (Aspidochirotida): A Comparison between the Torres Strait and La Réunion. *Marine Biology*, 139: 257–265

Uthicke, S., Welch, D. & Benzie, J. 2004. Slow Growth and Lack of Recovery in Overfished Holothurians on the Great Barrier Reef: Evidence from DNA Fingerprints and Repeated Large-Scale Surveys. *Conservation Biology*, 18(5): 1395–1404.

Vail, L. & Russel, B. 1990. Indonesian Fishermen of Australia's North-West. *Australian Natural History*, 24: 211–220.

Wabnitz, C., Taylor, M., Green, E. & Razak, T. 2003. *From Ocean to Aquaria: The Global Trade in Ornamental Species.* Cambridge, UNEP/WCMC.

Ward, R. 1972. The Pacific Beche-de-mer Trade with Special Reference to Fiji. *In: Man in the Pacific: Essays on Geographical Change in the Pacific Islands.* R. Ward, (ed). pp. 91–123. Oxford, Clarendon Press.

Wilkinson, C. 2004. (ed). *Status of Coral Reefs of the World: 2004.* pp. 337–361. Australian Institute of Marine Sciences, Townsville.

Zoutendyk, D. 1989a. *Trial Processing and Marketing of the Surf redfish (Actinopyga mauritiana) Beche-de-Mer on Rarotonga, and its Export Potential in the Cook Islands.* Report prepared for the Ministry of the Marine Resources, Raratonga, The Cook Islands.

Zoutendyk, D. 1989b. *Beche-de-Mer: Rori of the Cook Islands.* Marine Resources Profile, No. 6. Rarotonga: Ministry of Marine Resources, Raratonga, The Cook Islands.

APPENDIX A

Bêche-de-mer exports (tonnes) from the Western Central Pacific region: 1960–2006

	Micronesia			Polynesia				Melanesia					Australia					
Year	FSM	RMI	Kiribati	Tuvalu	Samoa	Tonga	French Polynesia	Papua New Guinea	Solomon Islands	Vanuatu	New Caledonia	Fiji	Coral Sea	Torres Strait	Great Barrier Reef	Moreton Bay	Northern Territory	Western Australia
1960								2.0										
1961								2.0										
1962								2.0										
1963								2.0										
1964								2.0										
1965								2.0										
1966								2.0										
1967								2.0										
1968								2.0	3.0									
1969								2.0	4.0									
1970																		
1971									5.0									
1972									33.0									
1973									54.0									
1974									18.0									
1975									20.0									
1976									29.0			4.0						
1977								5.3	39.0			17.0						
1978								5.9	34.0			15.0						
1979				1.8				1.3	10.0			11.0						
1980				0.8				2.4	37.0			14.0						
1981				0.1				11.1	8.0			15.0						
1982				0.2				23.0	17.0			16.0						
1983								7.6	9.3	6.0	15.0	33.0						
1984								4.7	44.3	3.0	150.0	53.0						
1985								19.5	13.6	2.0	89.0	66.0						
1986								119.4	134.2	4.0	180.0	229.0						
1987								192.1	146.4	12.0	101.6	640.4						
1988								202.8	147.0	10.0	135.8	717.4						
1989								194.9	87.1	39.0	54.9	365.2						
1990								238.9	118.9		129.4	323.3						
1991			12.2			9.8		626.0	622.4		123.6	319.4						
1992			55.3					655.5	715.4		80.3	402.8						
1993			125.4	0.9		35.4		499.5	316.4		39.5	149.0						
1994			30.0	3.7		61.4		208.8	284.6		79.9	197.0						
1995	2.2		40.0	3.2	29.0	60.2		444.6	219.3		48.0	454.0						
1996	4.7	55.0	74.0		32.0			596.2	113.1	20.0	49.2	666.0		98.5				
1997		29.0	39.0		9.0			505.4	202.9	35.0	56.5	862.0		122				
1998					3.0		2.0	678.8	253.5	25.0	39.1	369.3		81.9				
1999							1.0	394.7	375.7	8.0	49.0	140.7		17.1				
2000			9.0					553.9	160.8		62.0	246.0		2				
2001			14.0			1.0		485.4	374.6	16.0	49.0	245.0	54.4	104.7				
2002			9.0					389.3	177.9	8.0	34.0		29.7	126.6			103.9	71.4
2003		3.0	6.0					488.0	408.7	9.0	52.0				264.0	24.7	278.0	
2004			2.0			1.0		490.8		5.0	81.0			1.2		26.7		
2005								577.0						6.1	319.0	36.3		
2006								611.8										

Source: FSM - Trianni, 2002; RMI – FAO; Kiribati – FAO; Kiribati Fisheries Division, 1995; Tuvalu - Belhadjali, 1997; Conand and SPC, 1996; Belhadjali, 1997; Samoa – FAO, Mulipola, 1994; Tonga – FAO; Tonga Ministry of Fisheries, 1995; French Polynesia – FAO; PNG - Lindohlm, 1978; DFMR, no date; Wright, 1986 cited in Kailola with Lokani, no date; Lokani and Kubohojam, 1993; Lokani, 1990; Myint, 1996; National Fisheries Authority; Solomon Islands – FAO; James, 1977; Gaudechoux, 1993; Leqata, 2004; Division of Fisheries and Marine Resources; Vanuatu – FAO; Preston, 1993; New Caledonia – FAO; Conand and Hoffschir, 1991; Northern Province Fisheries Division, 1993; Conand and SPC, 1996; Etaix-Bonnin, 1999; Fiji – FAO; Preston, 1993; Gaudechoux, 1993; Qalovaki, 2006; Australia – DEH, 2004, 2006; McCormack, 2005; Roelofs, 2005; Hill, 2006; Skewes *et al.*, 2006.