



## Trends in small-scale artisanal fishing of sea cucumbers in Oceania



Steven W. Purcell<sup>a,\*</sup>, Poasi Ngaluafé<sup>b</sup>, Karibanang T. Aram<sup>c</sup>, Watisoni Lalavanua<sup>d</sup>

<sup>a</sup> National Marine Science Centre, Southern Cross University, PO Box 4321, Coffs Harbour NSW 2450, Australia

<sup>b</sup> Ministry of Agriculture & Food, Forests and Fisheries, PO Box 871, Nuku'alofa, Tonga

<sup>c</sup> Ministry of Fisheries & Marine Resources Development, PO Box 64, Bairiki, Tarawa, Kiribati

<sup>d</sup> Partners in Community Development Fiji, 8 Denison Rd, Suva, Fiji

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### ABSTRACT

Multi-species sea cucumber fisheries in Oceania involve vast numbers of small-scale fishers exploiting stocks on coral reefs and tropical lagoons. Fishery development measures might need to be specific to locations or fisher groups, and regulations should be appropriate to fishing activities. To understand fishing among countries, locations, gender and age, we conducted questionnaire-based interviews of 479 sea cucumber fishers in Fiji, Kiribati, New Caledonia and Tonga. Fishers included youth and elderly, and the average age within countries was 36–42 years. Women commonly gleaned sea cucumbers from shallow habitats and dived for them in some countries. Although spatially variable, our results indicate intense fishing pressure based on high trip frequencies and fishing effort. Catch-per-unit-effort (CPUE) differed significantly among countries and locations, and fishers on some islands caught high numbers of low-value species. Young fishers went fishing more often, but age did not affect fishing effort and CPUE. Fishers collected a wide range of sea cucumbers, and up to 27 species were harvested in Fiji. Species composition in catches differed significantly among countries and between genders; women usually harvest species typical of shallower reef habitats. Fishers tended to view stocks as declining or greatly over-exploited. Based on fisher knowledge, recent catch rates for an average fishing day have declined by 33–92% across the study countries compared to 10+ years in the past. Our study shows that fishing modes, catch rates and catch composition in small-scale fisheries can be highly context-dependent. Management measures and interventions to support fisher livelihoods must consider gender differences and location-specific fishing activities. Sharp declines in catch rates over time in all countries, fisher perceptions of resource trajectories, and a predominance of low-value species in present-day harvests, provide strong evidence of widespread over-exploitation.

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## 1. Introduction

### 1.1. Small-scale fisheries and exploitation of reef invertebrates worldwide

Small-scale fishing for fish and invertebrates has occurred for millennia (Pinnegar and Engelhard, 2008). Small-scale fisheries (SSFs) employ more than 90% of fishers worldwide (FAO, 2012). SSFs in developing countries produce more fish than large-scale fisheries (Mills et al., 2011) and contribute about one-quarter of all global fisheries catches (Pauly and Charles, 2015). In developing countries, SSFs play a vital role in food and nutritional security (Bell

et al., 2009; FAO, 2012; Kawarazuka and Béné, 2010; Zeller et al., 2007) and are a source of employment to help alleviate poverty (Allison and Ellis, 2001; Béné et al., 2010).

Although termed 'small-scale', based on the use of simple fishing gears and small vessels, the environmental footprint of SSFs can be substantial (Kittinger, 2013). In the Pacific islands, captures from artisanal fishers appear to have declined by almost half in the past two decades (Zeller et al., 2015). Over-exploitation in small-scale fisheries is a conservation concern globally, and has placed some tropical invertebrates at risk of extinction (Kemp et al., 2012; Purcell et al., 2014b). Understanding fishers, fishing rates and captures in SSFs should be integral to the development of responsible fishery management plans (Friedman et al., 2008), such as restricting catches, numbers of fishers or fishing gears.

Invertebrates are the most economically important inshore fishery resources in the Pacific Islands (Dalzell et al., 1996). Fishing

\* Corresponding author.

E-mail address: [steven.w.purcell@gmail.com](mailto:steven.w.purcell@gmail.com) (S.W. Purcell).

methods can be variable in small-scale invertebrate fisheries and involve a range of fishing gears (Castilla and Defeo, 2001; Leiva and Castilla, 2001; Toral-Granda et al., 2008). Women often play significant roles in artisanal invertebrate fisheries (Crawford et al., 2010; Harper et al., 2013; Kronen, 2002; Lambeth et al., 2014), and may differ from men in their catch rates, fishing grounds and species harvested (Fröcklin et al., 2014; Lambeth et al., 2014).

Increasing fishing pressure on invertebrate fisheries has resulted in declining stocks and catches of many groups such as octopi and echinoderms (Anderson et al., 2011b). Understanding changes in catch rates over time is important for conservation and fishery management measures but such data need careful interpretation because fishers may shift to new fishing grounds or lower-value species (Neis et al., 1999). Fisher knowledge of past catch rates contribute to fishery diagnosis and can put current-day catches into context (Ainsworth et al., 2008; Rochet et al., 2008; Sáenz-Arroyo et al., 2005).

### 1.2. Exploitation of tropical sea cucumbers

Sea cucumbers are harvested in more than 70 countries worldwide, primarily in small-scale fisheries using artisanal methods (Purcell et al., 2013). In tropical waters they are commonly collected by hand on shallow coral reefs and inshore sandy habitats. The tropical fisheries involve multiple species, predominantly from the order Aspidochirotrida (Purcell et al., 2013; Toral-Granda et al., 2008). The vast majority of harvested sea cucumbers are exported to Asian seafood markets in the dried form, called beche-de-mer.

Owing to their high economic value (Purcell et al., 2014b) and ease of storage and transport, sea cucumbers have been over-exploited throughout most tropical fisheries (Anderson et al., 2011a; Purcell et al., 2013). Fishing methods, usually gleaning, breath-hold diving and SCUBA diving, vary among countries and women and children are involved in some fisheries (Choo, 2008; Conand, 2008; Eriksson et al., 2015a; Kinch et al., 2008b; Muthiga and Conand, 2014). Stock status is often inferred from data on exports (Anderson et al., 2011a; Conand, 1990; Kinch et al., 2008b), or assessed through underwater population surveys (e.g. Cariglia et al., 2013; Conand, 1989; Dissanayake and Stefansson, 2010; Eriksson et al., 2015b; Friedman et al., 2011; Purcell et al., 2009; Shepherd et al., 2004; Skewes et al., 2010). Few studies have assessed sea cucumber fisheries using fisher knowledge and socio-economic data (e.g., Conand and Muthiga, 2007; Eriksson et al., 2012; Ochiewo et al., 2010).

In Oceania (central-western Pacific), sea cucumbers have been exploited as a high-value export commodity for at least 170 years (Conand, 1990; Kinch et al., 2008b). Although the fisheries are predominantly artisanal, exploitation in the Pacific Islands is vast and there are at least 300,000 fishers (Table S1 in Purcell et al., 2013; and considering data gaps). Declining stocks have prompted management agencies to set moratoria in many countries and, at the time of our field work, Fiji, Kiribati, Tonga and New Caledonia were among the few Oceania fisheries still permitting exports of beche-de-mer (Pakoa and Bertram, 2013; Purcell et al., 2014a). In the past couple years, some fisheries, such as in Vanuatu, have re-opened with new management arrangements (Léopold et al., 2015).

### 1.3. Purpose and significance of this study

Understanding heterogeneity in fishers and their fishing practices is important for resource management (Muallil et al., 2013; Muthiga and Conand, 2014). Management of coastal Pacific Island fisheries requires a hierarchical approach (Kronen et al., 2010), thus information about fishing at national and sub-national scales is needed. Here, we examine variations in fishing effort, targeted species and catch rates within and among four Pacific Island coun-

tries (New Caledonia, Kiribati, Tonga, Fiji) using responses from interviewed fishers. This paper examines differences in fishing activities among these small-scale fisheries and explores the implications to fishery management. Our sampling design allowed us to examine heterogeneity in fishing activities across countries and locations within countries, and potential relationships with fisher age and fishing experience. Women were unequally represented among the fisher groups, locations and countries, so our study offers a modest assessment of gender variation in these fisheries. We further aimed to use several lines of evidence from the surveys to infer status of stocks in these four countries.

## 2. Materials and methods

### 2.1. Study locations

The study was conducted in Fiji, New Caledonia (Melanesia), Kiribati (Micronesia) and Tonga (Polynesia) (Fig. 1). In consultation with national or provincial fishery authorities, we selected locations (provinces or island groups) within each country that were important to the sea cucumber fisheries and known to have active fishing (Supplementary material, Table S1). Generally, we visited 3–6 villages within each location in each country. Within locations, villages were chosen where sea cucumber fishing was active.

Interviews with fishers in New Caledonia were conducted from Aug–Dec 2007 (Purcell et al., 2009). Interviews in Tonga and Kiribati were done during May–Oct 2011, and those in Fiji were conducted in Feb–Sept 2014. Despite the 7-year gap between surveys in New Caledonia and Fiji, fishing and exports in these four countries operate independently and the species caught and exported from New Caledonia were the same as those from Fiji 7 years later. Nonetheless, we interpret inter-country comparisons tentatively. One to two weeks were spent in each location within countries, depending on site accessibility and the number of interviewers.

In New Caledonia, compressed-air diving and night diving were banned, and there were some minimum size limits imposed for certain species (Purcell et al., 2009). Recent community-based management systems concern only one community in a small section of the overall fishery (Léopold et al., 2013). In Kiribati, there were no fishery regulations, and virtually no marine reserves existed at the study locations. In Tonga, a moratorium on all sea cucumber harvests had been imposed from 1997 to 2007, and thereafter fishing was regulated by a ban on compressed-air diving, size limits and export quotas (Pakoa et al., 2013b). In Fiji, fishing for sea cucumbers is regulated by a single size limit across all species, and SCUBA diving was permitted only for authorised communities (Pakoa et al., 2013a; Ram et al., 2016). In all countries, community-based management and co-management arrangements related to a minor part of the fishery or were non-existent.

### 2.2. Survey methodology and data collection

On average, five fishers were interviewed per village, although we only found one or two sea cucumber fishers in some villages. We consulted village elders to find sea cucumber fishers and used key informants and a 'snowball' technique (Cinner, 2005; Henry, 1990) to find other sea cucumber fishers. Our sampling took a gender-inclusive approach (Kleiber et al., 2014) by interviewing women fishers where possible. Otherwise, we told villagers that fishers could be young or old, part-time or full-time, and that the fishing mode did not matter for sampling.

Interviews were predominantly at fishers' homes or in open places within villages, and followed ethics approval and

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