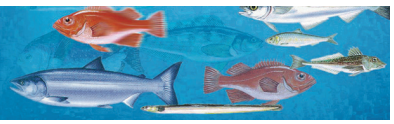
FISH and FISHERIES





# Trends, current understanding and future research priorities for artisanal coral reef fisheries research

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## Abstract

Artisanal coral reef fisheries provide food and employment to hundreds of millions of people in developing countries, making their sustainability a high priority. However, many of these fisheries are degraded and not yielding their maximum socioeconomic returns. We present a literature review that evaluates foci and trends in research effort on coral reef fisheries. We describe the types of data and categories of management recommendations presented in the 464 peer-reviewed articles returned. Identified trends include a decline in articles reporting time-series data, fish catch biomass and catch-per-unit effort, and an increase in articles containing bycatch and stakeholder interview data. Management implications were discussed in 80% of articles, with increasing frequency over time, but only 22% of articles made management recommendations based on the research presented in the article, as opposed to more general recommendations. Key future research priorities, which we deem underrepresented in the literature at present, are: (i) effectiveness of management approaches, (ii) ecological thresholds, trade-offs and sustainable levels of extraction, (iii) effects of climate change, (iv) food security, (v) the role of aquaculture, (vi) access to and control of fishery resources, (vii) relationships between economic development and fishery exploitation, (viii) alternative livelihoods and (ix) integration of ecological and socioeconomic research.

**Keywords** Artisanal fishing, coral reef fisheries, research priorities, small-scale fisheries, sustainable management

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## Introduction

The majority of fishing on coral reefs is artisanal, and despite the small-scale nature, it is the primary cause of reef fish population declines (Newton *et al.* 2007). Globally, an estimated 1.2 million artisanal fishers in the Caribbean and Americas, 0.98 million in Africa and 6.1 million in Asia collectively catch an estimated 6.9 million tons of fish per year (Chuenpagdee and Pauly 2008). These fisheries provide an important source of protein and employment for hundreds of millions of people in the developing world (Wilkinson 2008). Given the magnitude of catches, the associated environmental impacts and the number of dependants, artisanal fisheries are an important economic sector and area of research.

Some attributes of artisanal fisheries, such as relatively low bycatch, low fossil fuel use and high employment compared to industrial fisheries (Jacquet and Pauly 2008), provide opportunities for producing environmentally sustainable catches, achieving low social cost and increasing food security. However, over-exploitation is currently prevalent (Newton *et al.* 2007). Although long-term time series are uncommon, existing evidence shows declines in the size and biomass of catches (McClenachan 2009). Species composition of catches has also shifted – where predatory sharks, groupers and snappers once dominated landings, opportunistic and lower trophic level species have taken their places (Pandolfi *et al.* 2003; Bhathal and Pauly 2008; McClanahan and Omukoto 2011).

Sustainable catch limits can be exceeded with relative ease – with low fisher density and low-tech gear (Jackson *et al.* 2001; Wing and Wing 2001; Hardt 2008) – and in many locations, historical limits have been depressed by a suite of modern impacts, including climate-induced coral bleaching (Graham *et al.* 2007). Add to that high levels of bycatch and habitat-damaging fishing gears such as fish traps, nets, and dynamite and it is clear why few coral reef fisheries are sustainable (Mangi and Roberts 2006). Fortunately, these impacts are not ubiquitous, inevitable or irreversible. There are examples of reef fisheries where long-term changes have been negligible (Dalzell 1998; Craig *et al.* 2008) and declining trends have been reversed by controlling fishing effort via culturally sensitive management (McClanahan and Hicks 2011).

Management of reef fisheries is inherently ecologically and socially complex (Aswani *et al.* 2007). To explore the complexities and possibilities for achieving reef fishery sustainability, the first author (A.E.J.) invited all co-authors, representing interdisciplinary academics at the interface of policy and science, to participate on a symposium panel at the 2010 American Association for the Advancement of Science (AAAS) conference. This article and the research priorities recommended herein are an outgrowth of discussions during and subsequent to that symposium. The literature review presented here synthesizes research trends, identifies gaps in knowledge and provides a quantitative context for our recommendations. Reviews of artisanal reef fishery research have been conducted previously (Chuenpagdee and Bundy 2006), but continued reef declines and tightening funding opportunities demand a broader analysis and a coordinated research agenda that can promote increasingly sustainable management of artisanal reef fisheries.

## Literature review methodology

The literature search was conducted via Web of Knowledge, Aquatic Science and Fisheries Abstracts Database (ASFA) and WorldCat. As a rough measure of quality control and to avoid duplicative inclusion of studies published in multiple formats, we only included peer-reviewed articles. To ensure

  

wide breadth of results, searches performed in Web of Knowledge were 'topic searches', which search keywords, titles and titles of cited articles. Searches performed in ASFA looked for terms anywhere within the articles. These options were not available in WorldCat, so searches there just included title, keywords and subject. Search terms were 'traditional' plus 'fisher*', 'subsistence' plus 'fisher*', 'developing world' plus 'fisher*', 'coral reef' plus 'fisher*', 'artisanal fish*' plus 'coral', 'small scale fish*' plus 'coral' and 'fisher*' plus 'coral' plus 'catch'. Further searches were conducted for commonly used gear types: 'coral reef fish*' plus 'spear', 'trap', 'net' or 'line'. From the three databases, 464 unique, relevant, peer-reviewed articles published through December 2010 were identified for this analysis.

Each journal was categorized as focused on either natural or social science. Those categories were further subdivided into biology and ecology; conservation science; fisheries science; policy and management; and economics and sociology. Each article was examined to identify types of research conducted, data collected and management recommendations made. Categories were created based on article contents, not determined a priori. Articles were examined for whether they address our research priorities. None of these categories are mutually exclusive. A single article can, for example, present an array of recommendations; thus, graphed percentages are absolute and do not sum to one hundred. Linear regression was used to determine the existence of a temporal trend in number of articles published. Logistic regressions against publication year were computed to determine temporal trends in category frequencies.

We excluded non-reef research articles, although we acknowledge their findings can be applicable to reef fisheries. We excluded research conducted in the developed world (Australia, Japan and USA) because of the difference in socioeconomic context. We do not analyse specific study results or the weight of evidence for any particular recommendation. Despite these limitations, this literature review provides a comprehensive investigation of the current body of research on artisanal coral reef fisheries.

## Current research foci

Of the 464 peer-reviewed articles identified, the earliest was published in 1982, and the number of articles published annually has rapidly increased ($P > 0.0001$, $F_{(0,463)} = 0.0$, Fig. 1). Research conducted in southeast Asia/Indo-Pacific region was the most common (219 articles), followed by Africa (88), the Caribbean (78) and the Eastern/Central Pacific (17). Sixty-two articles synthesized information globally. The articles were published among 115 journals, the vast majority (379 articles) in natural science journals (Table 1). The low number of articles in social science journals (85 articles) is not necessarily indicative of the true distribution of research effort as social science research often appears in natural science journals.

Seventy-five percent of the research was descriptive, based on observations of the natural and socioeconomic environment (Fig. 2). Data were primarily collected using surveys of fish (underwater assessments and landings), benthos and fishers. Marine reserve research comprised 34% of the literature, modelling/theoretical articles 16%, review articles 13% and policy articles (not presenting data, only discussions of management) 5%. Experimental research, such as fishing gear selectivity

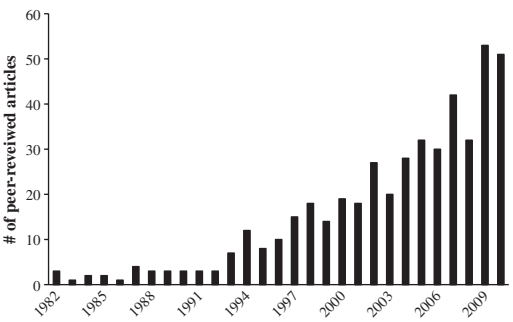


**Figure 1** Number of articles on artisanal coral reef fisheries published annually in peer-reviewed journals through 31 December 2010.

**Table 1** Types of journals and journal foci for the 464 artisanal reef fishery articles retrieved by literature searches in ISI Web of Knowledge, Aquatic Science and Fisheries Abstracts Database and WorldCat on 26 November 2011.

| Journal type | Journal foci | No. of articles |
|---|---|---|
| Natural science | Biology and ecology | 170 |
| | Conservation science | 144 |
| | Fisheries science | 65 |
| Social science | Policy and management | 66 |
| | Economics and sociology | 19 |

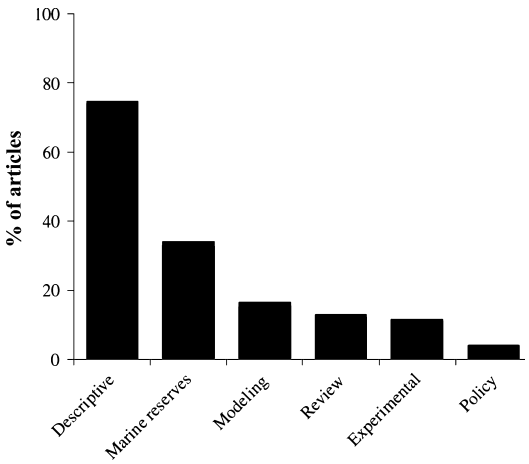


**Figure 2** Types of artisanal reef fisheries research presented in peer-reviewed articles. There were no significant temporal trends in the absolute frequency with which any article category appeared in the literature.

and herbivore exclusions, was presented in 12% of articles. There were no significant temporal trends for any article categories.

The three most frequently published types of data, each appearing in over 30% of articles, were the effects of fishing on fish communities, diversity of fish communities or catches, and fish population density (Fig. 3). The publication frequency of fish catch biomass and catch-per-unit-effort (CPUE) data has decreased over time (both $P < 0.05$, $\chi^2 = 8.7$ and $\chi^2 = 6.0$, respectively), as has the proportion of articles presenting time-series data ($P = 0.022$, $\chi^2 = 5.1$). The publication frequency of bycatch and stakeholder interview data has increased (both $P < 0.05$, $\chi^2 = 5.5$ and $\chi^2 = 5.0$, respectively). From 2005 to 2010, 31% of published articles included interview data. Articles presenting data on fisher income, traditional ecological knowledge (TEK), bycatch and mean trophic level of catch stand out for their rarity, each appearing in <5% of articles.

Management implications were discussed in 80% of articles and appeared with increasing frequency over time ($P = 0.006$, $\chi^2 = 7.3$). Actual management recommendations were made in 72% of articles, but only 22% of articles based those directly on their research results, as opposed to more general recommendations (Fig. 4). Marine reserve research represented 71% of articles testing management effectiveness. Marine reserves were also the most commonly recommended management option, appearing in 44% of articles with no temporal trend in recommendation frequency. The only recommendation presented with increasing frequency was co-management (where the government and communities collaborate on resource management; $P = 0.014$, $\chi^2 = 6.9$). That trend is not attributable to the newness of the term 'co-management'; all articles were examined for mention of concepts, not the terms themselves. Implementing size restrictions and establishing property rights were the least common recommendations, appearing in 6 and 5% of articles, respectively. Finally, although not exactly a management recommendation, 54% of articles indicated a need for additional research and monitoring to devise more appropriate management strategies.

Factors that may hinder support for and compliance with fisheries management, such as community involvement, availability of alternative livelihoods and alleviation of poverty, have received substantially less attention than the ecological aspects of management. While 10% of articles recommended incorporation of alternative liveli-

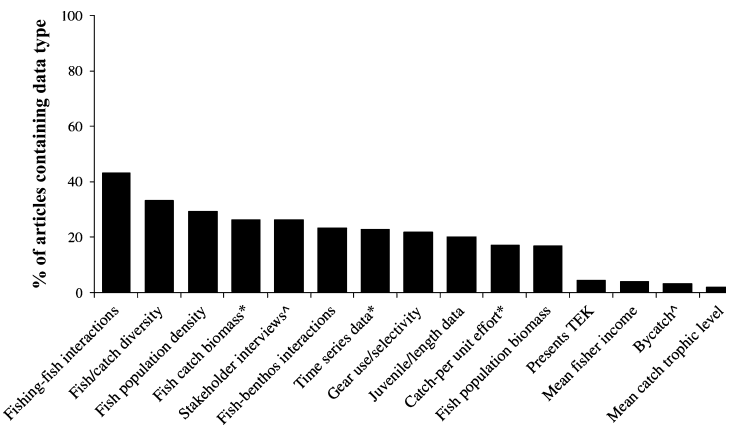


**Figure 3** Absolute frequencies of data categories presented in peer-reviewed artisanal coral reef fisheries articles. TEK abbreviates traditional ecological knowledge. Data types with significantly increasing or decreasing trends in the frequency with which they appear in the literature are denoted by ^ and *, respectively (all $P < 0.05$).

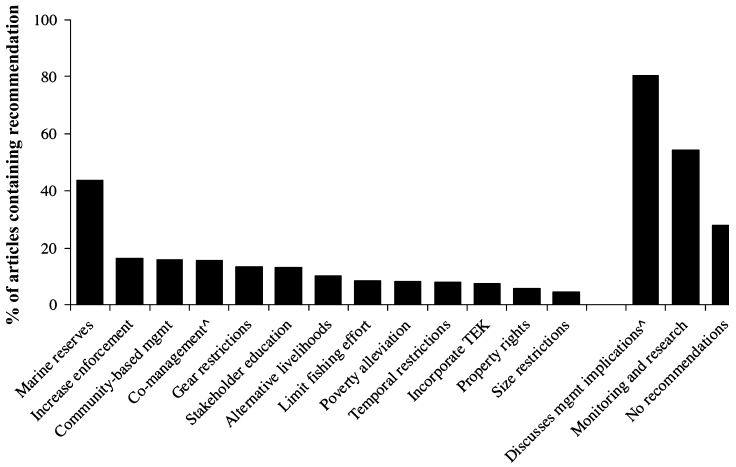


**Figure 4** Absolute frequencies of management (abbreviated as 'mgmt') recommendations presented in peer-reviewed artisanal coral reef fisheries articles. Recommendations with significantly increasing trends in the frequency with which they appear in the literature are denoted by ^ (all $P < 0.05$). There were no significant decreasing trends.

hoods into management plans, <2% discussed the feasibility of real alternatives – aquaculture and direct payment for environmental services were mentioned (Barr and Mourato 2009; Bell *et al.* 2009a). Only 9% of articles explicitly recommended reducing fishing effort (the total catch, number of boats, amount of gear or number of fishers), despite 88% of articles mentioning overfishing as a concern, a concern that has increased over time ($P = 0.002$, $\chi^2 = 8.9$). Mention of climate change, a concern in 12% of articles, has also increased over time ($P < 0.0001$, $\chi^2 = 49.1$). Other concerns commonly mentioned include population and demand growth (33%), development (25%) and food security (22%), none of which had significant temporal trends.

## Future research priorities

Despite a rising number of articles on coral reef fisheries, our literature review identifies several research gaps and trends that are potentially problematic for achieving sustainability. Based on these findings and our collective expertise in a variety of disciplines (i.e. economics, ecology, sociology, anthropology and resource management), we propose nine priority areas for future research into coral reef social-ecological systems that we believe are underrepresented in the literature (Fig. 5) and are necessary to inform better management:

### Ecological effectiveness of management approaches

There are many management options available for artisanal reef fisheries, including spatial, temporal,

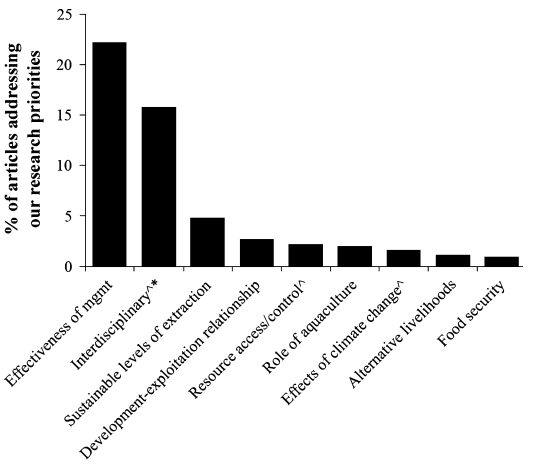


**Figure 5** Absolute frequencies of peer-reviewed artisanal coral reef fisheries articles that address our recommended research priorities. Management abbreviated as 'mgmt'. Recommendations with significantly increasing trends in the frequency with which they appear in the literature are denoted by ^ ($P < 0.05$) and ^* ($P < 0.1$).

effort, gear, species and size restrictions. While often implemented, their effectiveness is rarely tested, with the exception of marine reserves. Examination of the effectiveness of various customary and community-based management frameworks and the potential effects and benefits of gear restrictions is quite limited (McClanahan 2011). Research on management effectiveness has not increased over time.

More studies need to evaluate the relative costs and benefits of effort limitation strategies. Evaluating the political economy and establishing who are the winners and who are the losers of various approaches could greatly facilitate inclusion of

social outcomes in decision-making. Along these lines, the declining trends in absolute number of articles containing time series and CPUE data are a concern because evidence-based management benefits from understanding long-term effects of various interventions. Given the importance to fishery sustainability of minimizing bycatch and the potential usefulness of trophic level trends as an indicator of effective management, the rarity of these data types should be rectified. Additionally, evaluating fishers' responses (i.e. altered fishing and economic behaviour) to management changes and examining the synergistic effects of multiple policies will likely help identify practical solutions (Smith *et al.* 2005). For example, a recent global meta-analysis identified strong leadership as the most important factor for successful fisheries management and co-management as a promising approach when given ample community support (Gutierrez *et al.* 2011). Identifying the leadership and co-management conditions indicative specifically of successful coral reef fisheries management would be informative.

### Ecological thresholds, trade-offs and sustainable levels of extraction

While not all reef ecosystems have the same dynamics, research identifying switch points or thresholds is urgently needed into responses to stressors and second-order, or indirect, effects (Bascompte *et al.* 2005). Linkages across habitats and species should be considered when determining limits to extraction (O'Leary and McClanahan 2010). Research on these topics has not increased over time. Only 22 articles (<5%) addressed the ecological limits to sustainability of multispecies tropical fisheries. Perhaps researchers are not studying these limits, instead focusing on marine reserves, out of a sense that reefs need a reprieve rather than minor adjustments in fishing practices. Or researchers may be reluctant to suggest solutions that may be very context specific or significantly affect the livelihoods of fishing communities.

Future research needs to determine how limiting catch to a proportion of pristine biomass or current productivity may prevent the system from surpassing ecological thresholds and shifting to a state that may not support socioeconomically desirable ecosystems and fisheries (McClanahan *et al.* 2011). Models for optimizing catches from multiple trophic levels can play an important role in determining whether gear selectivity and targeting ratios of trophic groups could reduce the chances of exceeding thresholds and augment fishery productivity and fisher incomes (Kramer 2008; McClanahan and Cinner 2008; Kellner *et al.* 2010).

### Effects of climate change

Climate change attributes such as elevated water temperature, acidification and sea-level rise may alter reproductive biology and growth rates such that classic models of coral reef population and ecosystem dynamics cease to be useful. Climate change will influence ecosystem productivity and species metabolic rates and ranges (Hoegh-Guldberg and Bruno 2010), shift many fisheries poleward (Cheung *et al.* 2010) and decrease growth of calcifying organisms such as corals, bivalves and other invertebrates (Kroeker *et al.* 2010). Although the number of articles mentioning climate change as a concern has increased, we identified only seven articles meeting our search criteria that empirically examined the effects of climate change specifically on reef fisheries.

Further research is needed on the effects of coral bleaching on fisheries (Graham *et al.* 2007), whether gear-based fisheries management could mitigate the effects climate change has on fish communities (McClanahan and Mangi 2004; Cinner *et al.* 2009c) and how changing environmental conditions may facilitate the spread of disease and invasive species (Maynard *et al.* 2011). A group of coral reef scientists consider as a top research priority the relationships between habitat degradation, primarily through loss of coral, and altered food web dynamics (Wilson *et al.* 2010). The effects of climate change on fish recruitment, behaviour and population dynamics, and the potential for management to augment resilience to such changes are also worthy of further research. To date, laboratory studies have not focused on food fish species but rather species whose physiology and growth make them well suited to laboratory research (Munday *et al.* 2009). Efforts to strategically plan for the future will benefit from time series of climate effects and models of predicted environmental change, coupled with laboratory studies focused on commercially important species.

### Food security

Globally, artisanal fisheries play a significant role in food security (Pauly 2006), although regional and local specifics are poorly understood. It is predicted

that even well-managed fisheries will not be able to meet future local demand (Bell *et al.* 2009b). In some cases, heavily fished reefs sustain high yields of fast-growing herbivorous species, contributing to food security (McClanahan *et al.* 2008), but these fisheries can produce fewer monetary benefits than areas with more management restrictions (McClanahan 2010). Although 22% of articles mentioned food security as a concern, <1% address it practically (e.g. Bell *et al.* 2009b) and research in this area has not increased over time. Critical topics for future research include determining the levels of fishing where trade-offs with other ecosystem services become apparent so that food security can be balanced with other ecosystem services and values, examining the difference in market value of the species distributions caught on heavily versus lightly fished reefs and studying the possibility of meeting protein requirements with land-based sources.

### Aquaculture

Heavy reliance on wild fish for food is becoming less tenable in many coral reef countries because of overfishing, a rapidly growing human population and an emerging middle class purchasing more protein. Research on aquaculture has not increased over time, yet, if carefully executed, it may be able to supplement fisheries' catches and increase food security without creating environmental harm. Research has considered the feasibility of grouper aquaculture (Afero *et al.* 2010), the effects of algal farming on fish assemblages (Bergman *et al.* 2001) and whether small-scale aquaculture can actually reduce pressure on wild fish populations (Sievanen *et al.* 2005; Pomeroy *et al.* 2006; Cruz-Trinidad *et al.* 2009). Although many currently used aquaculture techniques have a large environmental footprint, farming species low on the food chain, such as algae, herbivores, filter feeders and detritus feeders, has promise (Duarte *et al.* 2009), with caveats such as ensuring the species is native or unlikely to become invasive. Possibilities for increasing aquaculture efficiency and yields through polyculture remain underexplored in coral reef ecosystems. Polyculture systems farm several species together, potentially reducing the need for inputs and reducing waste.

### Access to and control of fishery resources

Artisanal fisheries around the world face competition from both domestic and foreign industrial fishing boats. Many developing countries now export their fisheries resources, and some even sell off fishing rights to the developed world at greatly undervalued prices (Jacquet *et al.* 2010a). Assigning property rights to artisanal fishers has the potential to increase resource stewardship and thereby fishery sustainability if the rights can be equitably distributed and enforced (Gelcich *et al.* 2010). The literature review identified a few articles that explored successes (Zann 1999; Pollnac *et al.* 2001a; Gutierrez *et al.* 2011) and enforcement challenges (Baticados and Agbayani 2000) of co-management, and the need for legislation to legitimize community-based management and customary resource tenure (Aswani and Sabetian 2010; Clarke and Jupiter 2010). However, the options of excluding foreign fishing and creating priority inshore zones for artisanal fishers (Alcala and Russ 2006; Jacquet *et al.* 2010a) have not been widely researched or implemented.

Property rights can be implemented through various frameworks, including cooperatives, individual transferable quotas (ITQs) and territorial use rights in fisheries (TURFs), and could improve control of resources and improve or stabilize fishers' incomes. Research on these topics is increasing ($P = 0.019$, $\chi^2 = 4.87$); however, further exploration is needed to determine where and how to most effectively allocate and enforce property rights (Gelcich *et al.* 2010) and which approaches produce the greatest ecological and social benefits while encouraging voluntary compliance (McClanahan *et al.* 2006a). There is also a need for research on how the benefits of property rights can be enhanced by employing alternative business structures, such as increased local branding of resources (e.g. Local Catch 2011) and increased vertical integration of artisanal fishers into marketing and processing via cooperatives (Lewis *et al.* 2011). Along these lines, community-supported fisheries [based on the community-supported agriculture (CSA) model], where consumers pay in advance each season for a portion of the catch, are growing in number and sophistication (Brinson *et al.* 2011), and research into their effectiveness should be conducted.

### Relationships between economic development and resource exploitation

Although 25% of articles recognize development as a concern for fishery sustainability, the dynamics of the relationships between poverty, infrastructure,

ease of access to markets and fishing behaviour are just starting to be studied and have not significantly increased over time (Cinner *et al.* 2009b; Schmitt and Kramer 2009; Bene *et al.* 2010). Researchers have examined how resource depletion can be influenced by distance to markets (Brewer *et al.* 2009), transportation infrastructure (Liese *et al.* 2007; Schmitt and Kramer 2009), urbanization (Aswani and Sabetian 2010) and human population size (Stallings 2009). Yet, many of these studies have been statistical correlations, rather than elucidating the causal mechanisms through which development affects the use of coral reef resources.

The ramifications of exporting fish to major markets, versus retaining catches for local and subsistence consumption, is also inadequately studied from the perspective of incentives for overexploitation, compatibility with management, the global redistribution of effort and the types of species targeted. A better understanding is required of how resource conservation in developed countries may result in heavier resource exploitation in developing counties through international demand. It is critical to foster mechanisms that prevent the shifting of environmental footprints from wealthy countries that can afford to implement strict conservation policies to poorer countries with fewer environmental controls (Arrow *et al.* 1995; Cinner *et al.* 2009b).

### Alternative livelihoods

Where sustainability requires reductions in the number of fishermen, it becomes important to consider alternative employment for those who cannot continue to fish. We found only five articles that studied alternative livelihoods. Notably, while it is tempting to consider aquaculture and alternative livelihoods in the same breath, the effectiveness of substituting aquaculture jobs for fishing jobs is variable (e.g. Sievanen *et al.* 2005). There are social, psychological and cultural constraints to adopting alternative livelihoods, and fishing is typically a lifestyle choice in addition to a job (Pollnac and Poggie 2008). Therefore, it is important to understand how the introduction of alternative livelihoods will dampen or reinforce fishing behaviours (Cinner *et al.* 2009a). Alternative income sources may not adequately reduce fishing pressure in the absence of restrictions that limit fishing effort, because formerly professional fishers may continue to fish to supplement their incomes or may become recreational fishers. Furthermore, alternative incomes can create indirect pressures on reef ecosystems through changes to land use and demand patterns. For example, growth of the tourism industry often results in increased coastal development and increased demand for locally caught seafood. Future research should focus on improving our understanding of the non-economic dimensions of dependence on fishing, including identity, tradition, household structure, gender roles and gastronomic preferences (Pollnac *et al.* 2001b; Pollnac and Poggie 2006).

When developing alternative livelihood opportunities, the gender-specific nature of employment in many cultures should be considered. For example, weaving baskets or other jobs in the tourist industry may not be culturally viable alternatives for a fisherman, but could be a means of diversifying household incomes. The role of women or absence of women in the sale of seafood caught by artisanal fisheries and the impact of that role on households (e.g. food security, child education; Chapman 1987; Walker 2001) is poorly understood.

### Integrating ecological and socioeconomic research

If the goal is to find optimal solutions for both the fish and the fishers – which we believe sustainable solutions must strive for – a greater focus on socioeconomic context is required. Based on analysis of the papers presented at the fourth World Fisheries Congress, Chuenpagdee and Bundy (2006) also noted that the majority of the fisheries research was natural science–based. We found only 16% of research used a multidisciplinary approach, but that percentage appears to be increasing ($P = 0.055$, $\chi^2 = 4.0$). The overall quantity of social science research on artisanal reef fisheries has also increased ($P = 0.011$, $\chi^2 = 6.9$). Given how central income effects and incorporation of traditional ecological knowledge are to social palatability, the dearth of studies addressing those topics is a concern.

A broad interdisciplinary perspective allows researchers to consider the socioeconomic drivers of unsustainable fishing (Cinner and McClanahan 2006), the market forces compelling unsustainable levels of consumption (Jacquet *et al.* 2010b), the success of various management approaches (Pollnac *et al.* 2001a; McClanahan *et al.* 2006b) and how applying financial portfolio theory could increase fishery revenues and decrease catch vari-

  

ance (Sanchirico *et al.* 2008). There are win–win opportunities for fishers and reef ecosystems associated with no-take marine reserves (Kellner *et al.* 2010), bycatch reduction (Johnson 2010) and value-added fishery products (Brinson *et al.* 2011), and these should be explored and exploited where they are found. However, such situations are not the norm, making it important for integrated research to explicitly consider the trade-offs between ecological and socioeconomic benefits.

Evaluation of the ecological and economic costs and benefits of various fisheries options is needed. For example, what are the trade-offs between fisheries reliant on a few fast-growing species, fisheries exploiting a more diverse but less productive species assemblage and fisheries that utilize closures? In comparing these approaches, it is important to examine an array of attributes including catch market value, fishing yields, management costs, distribution of benefits and sacrifices among stakeholders, and tourism income (Hicks *et al.* 2009; McClanahan 2010). Note that over-exploitation and declining yields can accompany fisheries well supported by the community (Steneck *et al.* 2011). Consequently, grappling with incentivizing sustainable resource use, enforcing rules and aligning short-term human needs with long-term conservation goals will be critical to moving beyond the preliminary recommendations for success, such as co-management (Wamukota *et al.* 2012).

## Conclusions

There are both ecological and socioeconomic thresholds, trade-offs and limits associated with all management options. We encourage multidisciplinary research initiatives that inform the management process, present the potential ecological, social and economic benefits and costs of regulatory options and take a systematic approach to reporting so that meta-analyses can be conducted and broad lessons learned. However, it is not enough to simply do the research. Researcher expertise and research outputs need to connect with fishers, communities, resources managers and decision-makers at all levels to enable more informed decisions. There is great need for evidence-based management recommendations. From this, a more strategic and collaborative approach, focused on the drivers of fishing, can emerge to guide sustainable management and help ensure the future of coral reef fish, fisheries and artisanal fishing communities.

## Acknowledgements

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