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Spawning potential surveys in Fiji: A new song of change for small-scale fisheries in the Pacific

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Abstract

Catastrophic overfishing of small-scale coastal fisheries through the Pacific poses a major threat to regional food security and biodiversity. Globally, approaches to fisheries assessment and management that were developed for industrial fisheries, are failing small-scale data-poor fisheries. The Pacific Community has called for a complete rethink of fisheries methodologies for the region; a "new song" of change for small-scale coastal fisheries. This article describes the application in Fiji of a new approach to facilitating coastal fisheries management reform. Spawning Potential Surveys (SPS) is a pragmatic multi-disciplinary blend of sciences, that combines a new form of length-based assessment and communication strategies informed by theories of behavior change, nudge and diffusion, that is initiated with programs of citizen science to inform policy development and catalyze broader societal change. Our project successfully coordinated Fiji-based NGOs to work with the Ministry of Fisheries, communities, provincial government and supply chains, to collect the data needed to assess ~90% of the Fijian reef fish catch, conduct the analyses needed to develop new management policies, and build a broad consensus in society to support the ongoing reform process that has now been initiated by the Ministry. This project demonstrates the feasibility and effectiveness of the SPS methodology for informing and motivating coastal fisheries reform in the Pacific, as well as the necessity of a long term and multi-disciplinary approach to achieve the societal change needed.

KEYWORDS

change management, coastal fisheries, coral reef fish, data-poor, fisheries management

1 | INTRODUCTION

Indo-Pacific tropical coral reefs with their assemblages of 100+ fish species are a major repository of biodiversity and a mainstay of local economies. Throughout the Pacific Island countries and territories (PICTs), 49% of the fisheries contribution to GDP comes from reef fish, along with 50–90% of animal-sourced protein in rural areas (Secretariat of the Pacific Community, 2015). With once common species becoming rare and local extinctions spreading (Dulvy & Polunin, 2004; Sadovy et al., 2003, 2013) catastrophic overfishing of reef fish poses a major threat to food security, fisheries livelihoods, reef-based tourism and biodiversity (Newton, Cote, Pilling, Jennings, & Dulvy, 2007; Sale & Hixon, 2015).

Repeated attempts to apply the standard modern methodologies of assessment and management used with commercial fisheries in developed countries, to the coastal fisheries of the PICTs, have failed. As a result, the actual extent of the overfishing remains almost entirely unassessed, and greater than 90% of reef fish stocks are effectively unmanaged (Secretariat of the Pacific Community, 2015). The sheer number of species, being caught by small fishing communities dispersed across a vast region, combined with weak central governance, makes it almost impossible to quantify catch and effort trends, let alone effectively control them in real time, as required for modern fisheries management. Standard assessment methodologies also require detailed biological studies of each species to parameterize the age-based biomass models that interpret decadal long trends in catch, effort and stock abundance. These methodologies are expensive (USD100,000–1,000,000) and technically complex, limiting their applicability to small-scale artisanal fisheries globally (Pauly, 2013; Secretariat of the Pacific Community, 2015). By some estimates they can be applied to less than 10% of fished species (Andrew et al., 2007). Recognizing the rising level of concern for coastal fisheries, the Pacific Community (SPC) worked with Pacific Island leaders and practitioners to develop a new strategy entitled; "A new song for coastal fisheries: Pathways to change," which called for a rethinking of the way fisheries science and management is applied to PICTs (Secretariat of the Pacific Community, 2015).

Since late 2014 the Fiji Ministry of Fisheries (MoF), in partnership with the Wildlife Conservation Society (WCS), World Wide Fund for Nature (WWF), cChange and Biospherics Pty Ltd, have been trialling a new approach to assessing and reforming small-scale fisheries management called Spawning Potential Surveys (SPS). This paper describes its application in Fiji (Figure 1) and how the SPS methodology has been used successfully to

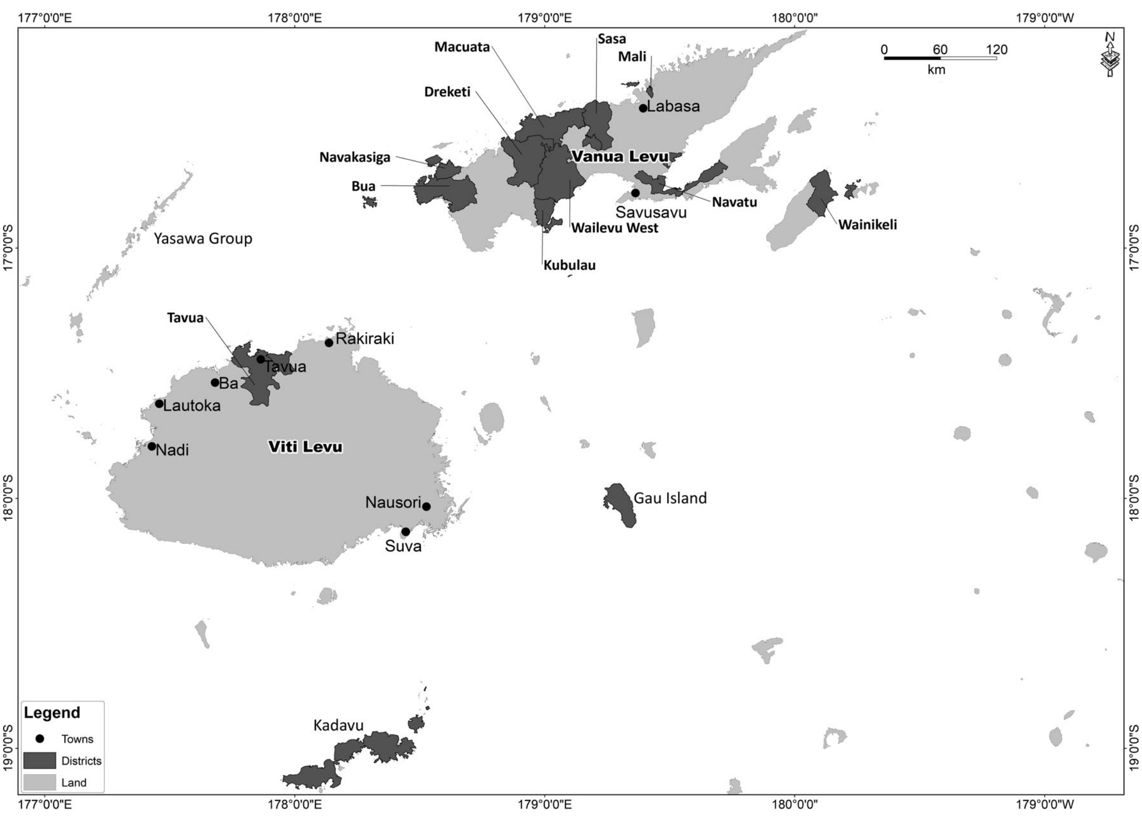

FIGURE 1 Map of Fiji showing key locations for the spawning potential surveys project

assess the status of Fiji's main reef fish stocks, provide the scientific basis for developing new management policies, and create the social impetus needed to begin reform implementation.

2 | BACKGROUND TO COASTAL FISHERIES MANAGEMENT IN FIJI

Fijian law recognizes 410 traditional fishing grounds (*qoliqoli)* which approximately 850 indigenous Fijian (*iTaukei)* communities have constitutional communal rights to fish. Similar to other PICTs communities, indigenous Fijians have a strong connection to their *qoliqoli* and have practiced traditional management of fisheries resources throughout their history (Jupiter et al., 2017); however, the state retains legal control and the majority of ownership rights over them (Sloan & Chand, 2016). The MoF administers the Fisheries Act of 1942 which regulates coastal fisheries in Fiji (Sloan & Chand, 2015). Updated in 1979 and supplemented by the Offshore Fisheries Management Act of 2014, the Act provides for the licensing of users trading in coastal resources and a wide range of management strategies, including the prohibition of fishing methods, fishing in prescribed areas, minimum mesh sizes and lengths for some species, and the declaration of moratoria.

Despite the legal framework and regulations, there has been little effective management of coastal resources. In PICTs it is challenging to maintain the skills and resources required to support the data collection and research programs needed to inform management. Prior to our project the Coastal Fisheries Program (CFP) within the MoF's Research Division had responsibility for monitoring, control and surveillance of coastal fisheries. The CFP endeavored to monitor catch trends through market surveying, and since 2002, ran a program aiming to collect socio-economic and visual fish census data for every reef with the ambitious, but unfulfilled, aim of formulating management plans for every *qoliqoli*. Prior to our SPS project there were no quantitative assessments of any reef fish species, and the basic biology, such as size of maturity, had been documented for only three species (Lasi, 2003). Consequentially, many of the existing regulations, were scientifically ill-informed or outdated.

While the power to enforce national regulations is vested in the MoF, in practice due to limited human resources, communities exercise a large degree of de facto control over their own *qoliqoli* areas with local fish wardens being appointed under law to assist with local compliance and enforcement issues (Sloan & Chand, 2015). Following from this de facto control the practical reality is that: (a) local communities will almost always have to lead the day-to-day implementation of coastal fisheries management; and (b) the influence of Government's laws, policies, and initiatives declines the further one travels from the centre of Government in Suva (Sloan & Chand, 2015). A property law analysis of *qoliqoli* shows that the sharing of ownership rights between the state and traditional communities provides support for government policy and traditional management objectives to align for the best fisheries management outcomes (Sloan & Chand, 2016).

In this context, there is general agreement that cooperative management is needed for long term solutions. Over the last 15–20 years, various NGOs and academic institutions have been working with communities to this end. The Fiji Locally Managed Marine Area (FLMMA) Network has been the most enduring and far-reaching of these initiatives. Working with, and through traditional community processes, FLMMA has worked with some 466 coastal communities to implement local management plans for their *qoliqoli* areas (website: https://www.fijimarinas.com/flmma-fiji-locally-managed-marine-protected-area-network/). However, in general, fish stocks continue to decline and broad-scale co-management has not yet been achieved (Clements, Bonito, Grober-Dunsmore, & Sobey, 2012; Jupiter et al., 2017; Sloan & Chand, 2016). In recent years a public awareness program called "4FJ," run by the behavioral change organization cChange, has advocated for the public to avoid buying or selling grouper during their spawning season and successfully built support for seasonal bans on grouper fishing. Through these combined efforts over the last few decades, a generalized concern about the status of Fijian coastal resources has risen, however the decline of coastal resources has continued (Mangubhai et al., 2019).

3 | METHODS

3.1 | Spawning potential surveys

The SPS approach builds on a simplifying break-through in data-poor fisheries assessment called length-based spawning potential ratio assessment (LBSPR) which enables cheap snapshot stock assessments to be made and turned simply but quantitatively into management advice (Hordyk et al., 2015, b; Prince & Hordyk, 2018; Prince, Victor, Kloulchad, & Hordyk, 2015). An additional advantage of the technique is that it is easily communicated to, and understood by, artisanal fishing communities.

The LBSPR methodology estimates spawning potential ratio (SPR) which provides an index of a fish population's risk of recruitment failure (Mace & Sissenwine, 1993; Walters & Martell, 2004). Unfished stocks complete their full life span and fulfil their natural reproductive potential (i.e., 100% SPR), fishing shortens life spans and reduces reproductive potential to some ratio of the natural level (i.e., <100% SPR). The level of 20% SPR is internationally recognized as the "replacement level" (Mace & Sissenwine, 1993), akin to the human reproductive index of 2.1 children per couple surviving to adulthood. Below 20% SPR the supply of young fish (recruitment) is expected to decline and 10% SPR is referred to as SPR_{CRASH}, because stocks held below this level are likely to be in steep decline.

The data inputs required for LBSPR are catch size composition and local size of maturity, which are interpreted using estimates of life history ratios (LHR) that are characteristic for families, genera and species. The first two of these data inputs are measured in situ, while generic values for the LHR can be estimated from the literature (Holt, 1958; Prince, Hordyk, et al., 2015; Prince, Victor, et al., 2015). The software for LBSPR assessment can be accessed freely at: http://barefootecologist.com.au.

3.2 | Theory of change

Developed with the aim of reforming small-scale fisheries management, rather than research, the SPS approach purposefully combines LBSPR assessment with aspects of behavioral science, including change management (Kotter, 1996), communities of change (Wenger, McDermott, & Snyder, 2002), citizen science (Druschke & Seltzer, 2012), adult education (Knowles, 1977), nudge (Thaler & Sunstein, 2008), and diffusion theory (Rogers, 2003).

Consistent with theories of change management (Kotter, 1996), communities of change (Wenger et al., 2002), and diffusion (Rogers, 2003), we assume that societal change requires the simultaneous and coordinated facilitation of top-down and bottom-up processes (Figure 2). For this purpose, we begin the SPS process in a country with programs of citizen science conducted with selected communities in which staff of local collaborating NGOs and governmental agencies are embedded. The communities were selected based on their dependency on fish, their past experience of working with NGO partners and their interest in, and potential for, managing their own local resources. The aim of the citizen science projects is both to assess the status of local resources, and develop teams of local change champions that span across communities, government and NGOs. Local champions are a critical part of engineering social change as they can lead broad shifts in social norms (Kotter, 1996; Rogers, 2003; Wenger et al., 2002), unlike international experts.

There are too many communities in Fiji, let alone across the PICTs, to think that change can be achieved by providing individualized training and citizen science

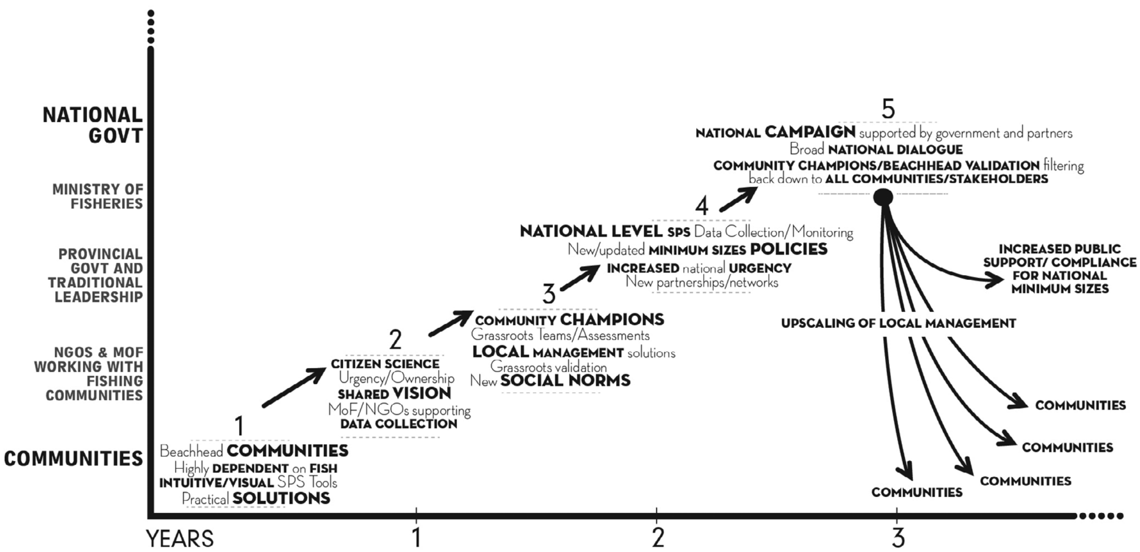

FIGURE 2 An illustration of the theory of change which the Spawning Potential Surveys methodology is based upon. The *y*-axis is indicative of levels of society and the *x*-axis indicates the time-scale over which our Fijian project progressed. The Spawning Potential Surveys process is initiated with a few beach head communities (1) conducting programs of data gathering community science (2). Engagement in the community science programs develops a team of change champions (3) to support national adoption of the management policies developed on the basis of the data gathered by the community science programs (4). Finally, with national government adoption an on-going program of national implementation can be planned and implemented (5)

projects to all of them. Rather, by working initially with a few communities, our aim is to start by establishing initial "bases" or "beachheads" from which broader nationwide processes of change can be advanced (Figure 2). Through the medium of establishing and conducting the citizen science programs all partners gained in-depth training and experience with overfishing, its solutions, data collection, analysis, stock assessment and fisheries management. Our theory of change (Figure 2) being that the knowledge, capacities and champions created through the citizen science programs diffuse through the communities of practice formed by fishers, supply chains, government agencies and NGOs (Wenger et al., 2002), and subsequently more broadly through governmental processes, social and mass media to establish new societal norms (Rogers, 2003).

3.3 | Communicating for change

Aspects of the behavioral theories listed above informed the conduct of the citizen science projects and the communication materials developed to support them. In particular Kotter's (1996) change management theory identifies eight stages through which successful change proceeds; with communities first seeing and feeling the compelling need for change, then trialing and testing change in a step-wise process that builds broader support, further capacity for change and transparent processes for monitoring and evaluating progress. Laying the foundation for successive cycles of adaptation to improve the performance of initial reforms. The first four of Kotter's (1996) eight steps all focus on communication to: (a) inspire people to change by increasing their sense of urgency, and making the objectives real and relevant; (b) build a guiding team of emotionally committed people with the right mix of skills and social levels; (c) establish the right shared vision to focus the emotional, creative and organizational energy needed to drive change; and (d) create buy-in, by engaging as many people as possible, by communicating essentials as simply and effectively as possible and appealing to people's needs.

Based on our previous experience (Prince, Victor, et al., 2015; Prince, 2018; Prince et al., 2020), we developed highly visual communication materials with minimal text which were intended to move beyond sharing information to facilitating discussion. Commonly copious amounts of scientific information are presented with the aim of raising awareness. Believing dialogue is essential to creating ownership and support for solutions, we minimized the material, aiming to contextualize the issues for local audiences with simple illustrations to foster discussion. We envisage our material as facilitation rather than awareness raising tools. We used the same material in a longer format in the community training workshops that initiated the citizen science programs, and in shorter formats as we progressively reported results to our partners, and briefed traditional, provincial and national leaders, MoF policy makers, fish sellers, local resource management committees, and also national and subnational fisheries forums.

3.4 | Heuristic thinking about fishing

Thaler and Sunstein (2008) propose that many cumulative societal impacts result from attitudes and choices that are largely instinctive and emotionally motivated rather than being explicitly rational or logical. These largely subconscious patterns of thinking and behaviour (heuristic frameworks) are absorbed as communal standards with little introspection and serve to save mental energy by making everyday choices automatic. To successfully achieve change, heuristic frameworks should be understood and explicitly addressed, otherwise reform is undermined as communities continue to think and act "instinctively."

We now have experience using these techniques in Chile, Fiji, Indonesia, Kenya, Mexico Palau, Papua New Guinea, Peru, Sri Lanka, and the Solomon Islands (Prince, 2018; Prince, Victor, et al., 2015; Prince et al., 2020). Our experience suggests that in general artisanal fishing communities are deeply aware of, and concerned about, declining local resources, but commonly do not consciously connect the decline with the impact of their own fishing. Like air and water, fish and fishing have been constants in their lives for generations, and are not consciously conceived of as needing management. This heuristic thinking is encapsulated by a seemingly ubiquitous saying used in Pacific communities, but probably inherited through missionary influences, which is that, "God will always provide". The implication being that, because the fish have always been there, they presumably always will be. In an example of the "shifting baseline" syndrome (Pauly, 1995), our experience is that most community members are unaware of how much modern fishing gears, the cash economy, and the ability to preserve and transport fish to market, have changed traditional fishing practices and increased fishing pressure. Prior to our workshops, communities generally associate observed declines with other environmental changes they see, or hear about; sedimentation from road building in Palau, unsustainable forestry practices in the Solomon Islands, mangrove cutting, destructive fishing practices, climate change and coral bleaching. All of these factors clearly contribute to the decline of coastal fisheries, but the international and national policy frameworks for managing those drivers of decline are weak, remote and difficult for communities to influence. While the cause of decline that communities can most directly address, and which our results suggests is the biggest single factor, remains almost totally unrecognized.

In our broad experience of artisanal fishing communities, their heuristic thinking about fish primarily relates to the imperative of not wasting food, basically "waste not, want not." This is encapsulated by the saying, "the smallest fish have the sweetest meat," a version of which we have found in all the artisanal fishing communities we have experience with. Like the European saying that, "the sweetest meat is closest to the bone," which is used to exhort children not to throw away half-eaten bones, in fishing communities this saying exhorts children not to waste good meat just because a fish is small and bony. The consequence of this heuristic way of thinking is that no small fish is ever willingly allowed to escape to finish growing and start breeding; because that would be a nonsensical waste of good meat. This then is the behavioural challenge we face in confronting overfishing.

Our materials use simple direct imagery to create a sense of urgency, build consensus and make their current heuristic thinking explicit. Initially by identifying the changes being observed by communities (fish becoming smaller, travelling further to maintain catches, fishing down the food web [Pauly, Dalsgaard, Froese, & Torres, 1998], less catch per unit effort and serial depletion) as unrecognized symptoms of their own overfishing. Next, the reasons overfishing is occurring now are depicted; modern fishing gear, population growth, increasing incentives to fish driven by cash-based consumer society and growing access to distant markets through modern transport and technology to keep fish cold. Toward the end of the first morning of a village training workshop we divide attendees into small groups to discuss: (a) which of their species are changing the most in terms of fish size, needing to travel further to catch them, declining catches and catch rates? and (b) which species are most important to retain? This provides participants with an opportunity to apply what they have learnt to their own experience, affirm it with others and internalize it; essential elements of adult education (Knowles, 1977). The report back sessions afterward reveal the extent to which local food webs have been fished down, and inevitably a sober appreciation of the overfishing crisis facing each community begins settling in.

3.5 | Developing a simple vision for change

After the report back session, we crystallize the insights gained by participants with a series of images portraying fishing down the food web with the main reef fish species on plates, the number of plates diminishing in successive images as they are rhetorically asked; what their future holds? The last image simply portraying a tin of fish sitting on a plate (Figure 3). At this point, communities invariably begin asking about solutions, which we use to directly challenge the existing heuristic mind set by pointing out that the beginning of a solution is to change the old way of thinking and behaving (Hardin, 1968); that "the smallest fish have the sweetest meat." Our material highlights the contradiction between their heuristic framework for fish, and the way they sustain productivity in their gardens by nurturing small plants and animals. These simple images always work powerfully and we invariably see participants opening their eyes wide, nodding their heads and murmuring affirmation, as our imagery makes explicit the contradiction between gardening which nurtures small organisms, and fishing which retains even the smallest fish for eating.

3.6 | Citizen science

The gardening analogy brings us naturally to the question of, how much breeding is enough for sustainability? We address this by introducing the SPR concept referred to simply as "spawning" and explain it using the human reproductive index analogy used above. This in turn leads naturally to the question of how much spawning is occurring in local stocks, and whether the community is willing to participate in a program of citizen science to find out. Upon receiving their affirmation, we teach community members how to measure fish length and macroscopically gauge maturity. To our surprise, this is almost invariably new information for participants and, by allowing them to see for themselves how many of the fish they catch are immature, is commonly transformative for their understanding of overfishing. In keeping with the principals of adult education (Knowles, 1977) our experience in all the countries we work is that, regardless of how much data community members go onto collect, these hands-on activities consolidate and validate their conceptual understanding of overfishing and the need for management.

4 | RESULTS

4.1 | Data collection

In 2014, WWF introduced SPS to the local reef management committee (*Qoliqoli* Cokovata Management Committee) they had been working with for some years in

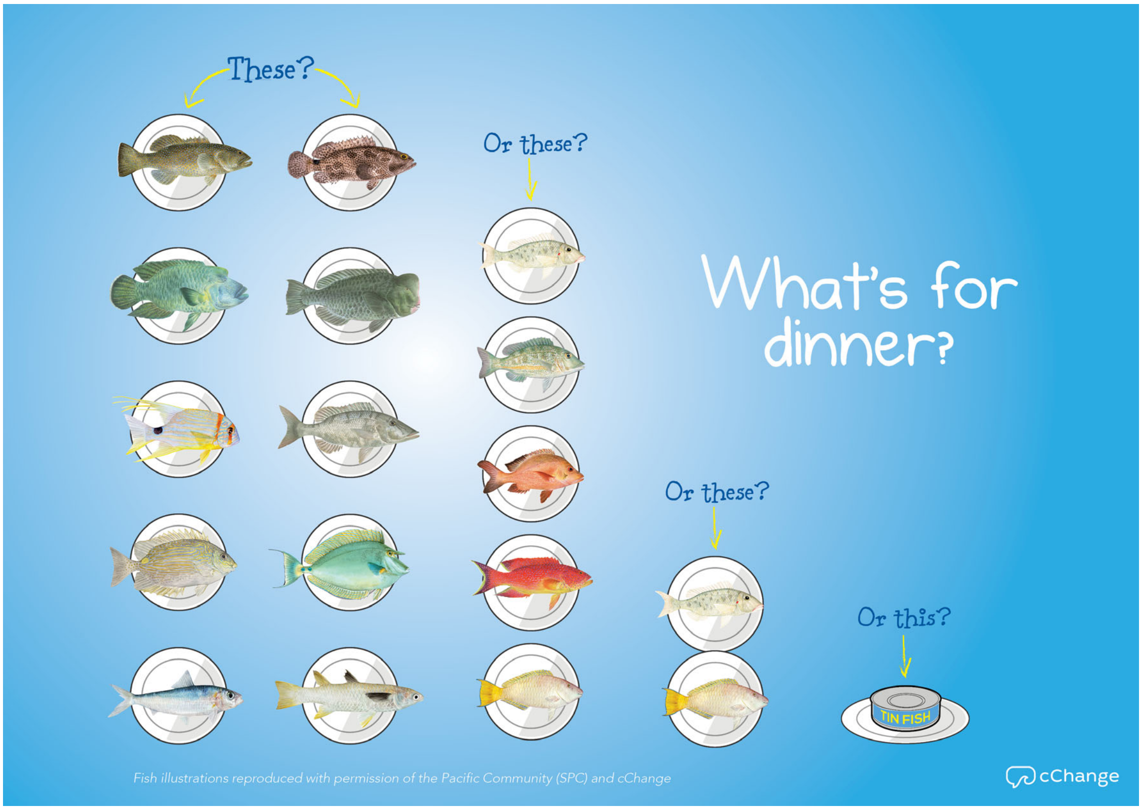

FIGURE 3 Example of the communications material developed to support the spawning potential surveys methodology. This series of images is used to consolidate the concept of fishing down the food web and challenge workshop participants to envisage a future with depleted local reef fish stocks. Image courtesy of cChange

Macuata Province (Dreketi, Macuata, and Sasa districts) along the north coast of Vanua Levu (Figures 1 and 2). Two trainings were provided for leaders and representatives from 12 communities and provincial government and MoF staff, resulting in an initial network of community-based data collectors being established. Additional trainings were provided in Suva in 2015 to the staff of NGO partners, MoF, and University of the South Pacific students. In 2016, community-based data collection programs were expanded to the provinces of Ba (Tavua District), Bua (Bua, Kubulau, Navakasiga districts), Cakaudrove (Wailevu West, Navatu, Wainikeli districts), Kadavu and Lomaiviti (Gau Island). To increase the number of fish being sampled WCS and Biospherics sampled the Labasa market selling fish caught along the north coast of Vanua Levu. Having had their staff participate in briefings and trainings since the inception of the project, senior MoF managers decided during 2015 that their research staff should conduct SPS and included it in their budgetary cycle. In 2016 the MoF trialed the SPS methodology by giving training and data sheets to fishers in three villages close to the capital Suva (Rewa Province), but collecting only limited data, during 2018 their staff began sampling catches in the three main Fijian fish markets. By March 13, 2018 datasets had been compiled containing 16,404 records for 180 species of reef fish.

4.2 | Scientific results

Throughout the data collection phase, progressive results were fed back regularly to project partners so they could become familiar with the type of data being collected, how they would be used, and the likely results. To facilitate discussions preliminary LBSPR assessments were completed for several species for communities in Macuata and Tavua districts in 2016 and 2017, respectively. In March and August 2018, project partners met in Suva for analytical workshops to generate final size of maturity estimates, LBSPR assessments and a system of minimum size limits. These results provided the scientific basis for oral and written policy briefings subsequently provided to the senior MoF management.

For most of the 180 recorded species sample sizes were too small ($n < 50$) to be useful for any other purpose than revealing their relative importance in current landings. Some 14,641 records could be used to generate size of maturity estimates for 47 species (Prince et al., 2018) three of which had pre-existing estimates (Lasi, 2003), and to assess the status of 29 species comprising by number ~ 90% of the sampled landings (Prince et al., 2019). More than half of the species (17) assessed were estimated to have <20% SPR, 14 of which have <10% SPR. Five species are estimated to have 20–30% SPR and 7 were estimated to have 30–76% SPR levels. All the species estimated to have <20% SPR are primarily caught by subsistence fishers using gillnets or spearguns at night. Species estimated to have >20% SPR are predominantly caught by commercial fishers using hook and line. This suggests that night-time spearfishing and gillnetting are currently the greatest threat to reef fish sustainability in Fiji. Both methods have in common: (a) they fish heavily on nursery grounds, in the case of night-time spearfishing, the shallow coral reef flats, and gillnets in shallow seagrass beds and (b) both are very effective at catching small immature fish. By contrast the hook and line fishery primarily focusses on adult grounds in deeper water outside the reef.

5 | POLICY DEVELOPMENT

5.1 | Rationale for Size-Based management

Controls on fishing effort and catches are widely used to manage fisheries, but few of the PICTs have developed the administrative capacities necessary for enumerating, let alone directly managing either catch or effort in coastal fisheries, so that fishing pressure cannot be effectively managed at this time. In recent decades marine protected areas (MPAs) have been widely advocated for managing small-scale and data-poor fisheries (Clements et al., 2012; Lubchenco, Palumbi, Gaines, & Andelman, 2003) and have become the most preferred form of management for study (McClanahan, 2011). While clearly capable of building fish biomass and sizes within effectively enforced sanctuaries (Lester et al., 2009) their effectiveness for sustaining fisheries outside remains unsubstantiated (Clements et al., 2012; Hilborn, 2006; Kearney & Farebrother, 2014; Lester et al., 2009). Locally managed marine areas with traditional *tabus* (i.e., periodically harvested closures) have been widely implemented in Fiji but their maintenance is becoming increasingly challenging as continuing decline of the surrounding fishing grounds erodes community support and levels of noncompliance (poaching) increases (Jupiter et al., 2017). In this context the simplest effective way to sustain reef fish stocks is to manage the size at which fish are caught to ensure they complete at least the 20% SPR needed to replace themselves (Prince & Hordyk, 2018). Minimum size limits (MSL) are widely applied to coral reef fish through the United States and Australian jurisdictions, and many of the countries now recognized as global leaders in fisheries management, began with size-based management. Prince and Hordyk (2018) argue that the example of beginning simply and incrementally developing more complex management capacities, should be emulated by countries seeking to develop their capacity for management and demonstrate that setting MSLs at ~1.2× size of maturity provides a simple “rule of thumb” for preserving >20% SPR and making fisheries resilient to heavy fishing while optimizing sustainable yields.

We also arrive at size-based management through our interest in social change and the simplicity of the messaging required. We think the simplicity of communicating the need for more larger fish reproducing for longer on fishing grounds, as opposed to the abstract benefits of biodiversity and spill-over, is a key reason for the successful uptake of the SPS concepts by communities. Our methodology empowers fishers to self-assess sustainability and the effectiveness of management with the size of the fish they handle on a daily basis. From the standpoint of behavioral change this is a huge strength that enables an ongoing process of changing social norms.

5.2 | Multi-Species minimum size limits

The reef fish catch of the PICTs commonly comprises 100 + species so that species-specific MSLs will be impracticable to implement and enforce, making it necessary to cover groups of species with the same MSL. Reviewing Fiji’s 1942 MSL regulations in the light of the catch size composition data collected and the 46 size of maturity estimates developed, revealed that besides missing a number of important species, and lumping species with disparate body sizes into the same family based MSLs, the regulated MSLs tended to be much smaller than the size of maturity and many were smaller than the smallest fish in the market, so that even if implemented successfully they would have been ineffectual.

To inform the development of new MSL regulations we developed a novel multi-species yield-per-recruit model (MSYPR) to evaluate the trade-offs involved in alternative groupings of the species assemblage into a few MSLs (Prince et al., 2018). Without size limits the MSYPR model estimates that 82% of the potential yield of reef fish would be obtained if fishing pressure could be managed in the long-term at low to moderate levels ($F = 0.3$), but even then, 9 of the 74 species in the modelled assemblage will be prone to extinction. Under the more likely heavy fishing scenario ($F = 0.9$) potential yield falls to ~42% and

38 large and medium bodied species (which must obtain the largest sizes at maturity before they begin reproducing) will be prone to local extinction. The MSYPR analysis suggests that a system of just six MSLs set at 25, 35, 45, 55, 70, and 90 cm can prevent species extinctions and sustain ~93% of the potential yield (Prince et al., 2018).

5.3 | Initial steps towards coastal fisheries reform

In concert with the data collection, analysis and policy development outlined above, our reporting of progressive results back to stakeholder groups accompanied by our reiteration of the core SPS messages, built societal support for coastal fisheries reform.

5.4 | Community based initiatives

On the basis of initial assessments, and independently of the MoF, the local reef management committees, in Macuata and Tavua districts, decided to instigate local management trials which were then endorsed by their respective paramount regional chiefs. In late 2016 the province of Macuata declared a ban on the harvest of camouflage grouper (*Epinephelus polyphekadion*) during 2017, with the aim of implementing an MSL in 2018. And through 2018 the community in Tavua District trialed an MSL for thumbprint emperor (*Lethrinus harak*). Implementation and compliance with these voluntary measures was best in the most remote communities where traditional structures are strongest, but almost nonexistent in communities most easily accessed by market vendors actively seeking product to sell. Never-the-less experience with these trials was instructional for communities, provincial government, and the partnering NGO and MoF staff. It graphically illustrated the need for new government regulation to support the reform process, and effective enforcement in the markets. As well as the importance of communicating about the overfishing issue directly with fish market vendors, and not just with the fishing communities. A communication program to that effect was subsequently developed and delivered. The trials continued raising the profile of the inshore overfishing issue, providing the MoF and their Minister with tangible signals that there was community support for reform.

5.5 | National government adoption

By 2016 the MoF, up to and including the Minister, had embraced the SPS approach and in 2017 began proactively implementing new management policies for coastal fisheries. A new Inshore Fisheries Management Division (IFMD) was established to take over responsibility for coastal fisheries management from the old CFP which had been a section of the Research Division. The IFMD recruited 10 staff, re-allocated from other Divisions and activities of MoF identified as having lower priority, and trained them in reef fish identification and fish measuring, taking over and making permanent, the catch size composition monitoring program in the three main fish markets. In June 2018, following the success of the 4FJ campaign the Minister also announced a national ban on the catching and sale of grouper through the June to September spawning season.

After reviewing the 1942 MSLs regulations in the light of the policy briefings developed through the analytical workshops in 2018, the MoF committed to replacing it with a new system of six multi-species MSLs. The new system was branded “Set Size” for the Fijian propensity to use the word “set” in the way “OK” might be used elsewhere. The new “Set Size” system will be phased in over some time period, as in most places the current size of fish is so small that immediate implementation for all species would be socially challenging and wholesale noncompliance the likely result. A 2-year consultation program was developed to gauge and develop support for some form of progressive implementation, and is being rolled out through community meetings, newspapers, TV, radio and national and subnational forums during 2020 and 2021. In preparation for implementing “Set Size,” with the support of NZAID through 2019, the MoF geared up and began enforcing the existing MSL regulations. Legal issues, which previously were thought to necessitate MoF compliance officers finding a policeman to enforce MoF regulations in markets, have been resolved, allowing MoF enforcement officers to enforce their own regulations, and officers have been trained in species identification.

In 2019, the Minister directed that the SPS methodology should start being applied to a broader range of coastal species, starting with the three main species of spiny lobsters, and a market sampling protocol was developed and implemented.

6 | DISCUSSION

6.1 | The relative achievements of the SPS methodology

The real proof of the SPS methodology’s effectiveness in Fiji will be the eventual recovery of coastal fish stocks, but too little time has elapsed since the project commenced in 2014, for the management policies developed by the project to be fully implemented and take effect. Nevertheless in comparison to the general lack of progress on coastal fisheries management through the region (Secretariat of the Pacific Community, 2015) we can still point to some unparalleled achievements. A sound scientific foundation has been laid upon which the first steps toward reform are proceeding. Our project has successfully filled the scientific void which previously existed in Fiji around the biology and status of the reef fish stocks, adding 44 new estimates of size of maturity where three previously existed, and developing 29 stock assessments for species comprising ~90% of landings, where previously there were none. The process of conducting the assessments and their results have successfully galvanized all levels of Fijian society, from the fishing communities with their traditional leadership, through to the Minister of Fisheries and National Government. Fishing communities in two regions have been motivated to conduct their own trial management reforms, and broad support for government-initiated reforms has been generated. Responding to the coordinated concern of communities the MoF has adopted the science-based policies developed by our project, establishing and equipping a new division to take responsibility for the on-going implementation of the size-based management policy produced by this project. Adopting the SPS protocols a permanent system of catch size composition monitoring has been established, and expanded beyond the reef fish we focused on. This new capacity of MoF will provide "the transparent process for monitoring and evaluating the progress of change," that Kotter (1996) maintains is the final essential element of successfully change management. It should also eventually provide the basis for evaluating the long term "in-the-water" effectiveness of SPS in Fiji.

6.2 | The challenging future of coastal fisheries reform

The achievements of this SPS project to date are clearly good first steps in a longer-term process of reforming Fiji's coastal fisheries management, but in the context of the existing "waste-not-want-not" heuristic way of thinking about fish, the difficulty of changing current social norms and eventually succeeding, should not be underestimated. Although this change was achieved in countries like Australia and New Zealand between the 1960s and 1990s, we encounter Pacific islanders who doubt it can be replicated in the PICTs. Frankly, if this simplest form of management cannot be successfully implemented, we see little hope for the sustainability of coastal fisheries resources in the region. On the other hand, successful implementation of size-based management could stabilize resources and buy the time needed to develop the more complex capacities required to also manage fishing pressure.

The successful implementation of Set Size, if possible, should go a long way to stabilizing and recovering Fiji's reef fish resources, however, not all fish and fisheries are amenable to management with MSLs alone. Some fishing practices are inherently difficult to make size selective. Sustainably managing fishing practices that cannot be made size selective requires effective controls on fishing pressure, which in turn requires real-time monitoring and periodic adjustment of management settings (adaptive management). Governmental capacities that PICTs are likely to have difficulty developing in the foreseeable future. Consideration, therefore, will need to be given to prohibiting some types of fishing, or at least heavily restricting them to limit their impact and make them more size selective.

Theoretically at least, fishing with spearguns and hook-and-line in shallow water can both be size selective as small fish can be avoided or released alive. In practice though fishing with spearguns at night catches large numbers of very small fish, and is widely blamed for driving fish depletions, an accusation our results support. Many *iTaukei* communities have previously instituted bans on night time spearfishing, but as with the MPAs, compliance with these bans has declined as fish stocks have been depleted. If night time spear fishers cannot learn to comply with MSLs, communities and government may need to reconsider implementing and/or enforcing bans, although given the history this would probably be controversial. A different form of regulation used in New Caledonia to achieve a similar effect could potentially be more acceptable. There fishers may catch fish at night with spearguns to feed their own families, but speared fish cannot be sold in markets (Gillett & Moy, 2006). This limits spearfishing pressure, while reserving a part of coastal fisheries resources for local food security. In revisiting the issue of making spearfishing sustainable in Fiji, this form of policy deserves discussion.

The size of fish caught by each type of fishing gear and method catches can also often be improved by regulating the time and place they are used (e.g., not fishing in nursery areas). Gillnets used on the diverse reef fish assemblage are relatively indiscriminate in the size of fish they catch and the fish caught are unlikely to survive if released. Gillnet fishing can be made more selective with the proper regulation of mesh sizes, times, and locations of fishing, to limit the mix of species caught. For example, with the right mesh size and used just to target mullet over sandy bottom, gillnetting could be made sustainably selective. Such regulations need to be developed with a deep knowledge of local geography and fish habitats, and can only be effectively implemented and enforced with the support of local communities. While there is a clear role for the national government in establishing regulations regarding minimum size limits and legal types of fishing gear, spatial and temporal regulations that help make fishing more size selective will need to be developed and implemented through local management committees, which it is hoped the results of this SPS project can help inform.

7 | CONCLUSION

Much of the conservation science conducted in the PICTs is conducted within silos, focusing entirely on either the biological or sociological aspects of an issue. With the SPS approach, we applied a practical multi-disciplinary blend of sciences with the aim of informing coastal fisheries reform and facilitating societal change. Education and facilitated dialogue supported by relatively simple scientific analysis, successfully created, motivated and coordinated a collegiate approach towards initiating the reform of Fiji's coastal fisheries management. Working in partnership with MoF, fishing communities and fish sellers, the various NGOs successfully plugged the information gap that plagues data-poor fisheries globally, collecting data from 16,000+ fish, enabling 43 new estimates of size of maturity to be added to the three previously existing, and the assessment of the status of 29 species comprising ~90% of landings. By quantifying the gravity of the threat to food security posed by overfishing, our simple SPR assessments galvanized the attention of all levels of society, creating the realization that coastal fisheries are in serious need of management reform, and that previous resources and methodologies have been insufficient to confront the challenge. All societal levels embraced the SPR concept and engaged with the process of challenging previous heuristic conceptions of reef fish simply as food that should not be wasted no matter how small, with the idea that the growth and reproductive potential of fish must be managed. The data gathered and the analyses they supported were sufficient to develop new science-based policies for size-based management and design a system of multi-species MSLs for the Indo-pacific reef fish assemblage, that have been adopted by government for implementation.

Of course, the eventual proof of this project's success will be in the rebuilding of the Fijian reef fish stocks, but insufficient time has elapsed for full implementation, let alone its effect to be observed. But the concrete steps taken by the MoF towards full implementation bode well. Kotter's (1996) eight step recipe for successful change management ends with the development of transparent processes to monitor and evaluate the progress of change, so that the process of reform can become on-going and adaptive. With the creation of the new IFMD and its recruitment and training of staff making permanent an expanded version of the SPS catch size composition monitoring program, the MoF has completed this final step of successful change management, institutionalizing the capacities needed to monitor the progress of "in-the-water" reform and adapt policies as required to achieve the change Fijian society now wants.

This relative success demonstrates the feasibility and effectiveness of our SPS methodology for informing and motivating coastal fisheries reform through the PICTs, as well as the necessity of a practical multi-disciplinary approach to achieve societal change. This of course required a long-term source of funding for a coordinated suite of multi-disciplinary projects, and a determination by the funder to ensure its grantees actively collaborated. Resources and conditions which are all too often lacking in the PICTs.

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AUTHORS CONTRIBUTIONS

Jeremy Prince: Funding acquisition, Conceptualization, Development of communications materials, Project supervision, Methodology, Data analysis, Writing—original draft, review & editing. Stuart Green: Funding acquisition, Conceptualization, Team Co-ordination, Writing—review & editing. Sangeeta Mangubhai: Funding acquisition, Project & staff supervision, Writing—original draft, review & editing. Watisoni Lalavanua, Jone Tamanitoakula, Laitia Tamata, Epeli Loganimoce, Tevita Vodivodi, Kalisiana Marama, Pitila Waqainabete, Frank Jeremiah, Diana Nalasi, Mosese Naleba, Waisea Naisilisili, Uraia Kaloudrau, Lepani Lagi, Kalisiana Logatabua, Rosemary Dautei, Rahul Tikaram; Community facilitation, Data collection, supervision, analysis, Writing—review & editing. Scott Radway: Funding acquisition, Development of communications strategy & materials, Visualization, Writing—review & editing. James Sloan: Funding acquisition, legal advice, team co-ordination, Writing—review & editing.

ETHICS STATEMENT

All community members, collaborators and authors gave informed agreement to their participation in this project and were fully conversant with the results and outcomes before contributing to the development of this manuscript.

DATA ACCESS

The data, or some parts of the data, may be available upon request.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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