Identifying management options and effectiveness in Solomon Islands fisheries using traditional ecological knowledge

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Abstract

While most fish spawning aggregations are targeted by fishers in Solomon Islands, very little is still known about spawning aggregation locations and the timing of aggregations for different species. We collected traditional ecological knowledge from 102 fishers residing around Munda, as well as the Roviana and Marovo Lagoons in Western Province to inform community-based management of fish spawning aggregations, and to provide recommendations for adapting current government regulations for the management of aggregating grouper species. Fishers identified 31 separate fishing locations and 26 possible aggregation areas, validating findings from earlier surveys while also highlighting new areas for verification and management. Collated traditional environmental knowledge, integrated with spawning information derived from past studies, pointed to regional variations in spawning times among individual species, specifically groupers, that lessens the effectiveness of the current nationwide seasonal ban and suggests that finer-scale management is warranted at the site level.

Introduction

For many coral reef fishes, reproductive life history includes the formation of fish spawning aggregations (FSAs) that are typically characterised as seasonal events that occur ephemerally within one to several months of the year, depending on the species. At the population level, FSAs represent the sole means of replenishing populations, many through self-recruitment (Jones et al. 1999). At the ecosystem scale, FSAs serve as biological hotspots that provide food and nutrients to marine organisms across a wide trophic spectrum (Nemeth 2012). FSAs are often multi-species and may comprise thousands of individuals, thus representing substantial increases in biomass and nutrient flow. During these events, FSAs attract not only fishers, but also a wide variety of organisms, ranging from planktivores, detritivores, egg-eating fish and invertebrates, and marine megafauna, including manta rays, whale sharks and requiem sharks (Mourier et al. 2016; Rhodes et al. 2019). Thus, their loss can have substantial impacts not only to fisheries, but also to ecosystem dynamics and function.

In the western Pacific, multi-species FSAs form at spatially and temporally predictable sites that attract fishers because of the high catch rates and fish volumes they can obtain over brief periods of time. The timing and location of FSAs is common knowledge among fishers who traditionally depend on them for subsistence and, more recently, small-scale commercial purposes (Hamilton and Kama 2004; Hamilton et al. 2012; Rhodes et al. 2019). Continuing human population growth and an expanding cash economy have, however, intensified FSA fishing, placing FSAs under increasing threat. Indeed, an expanding number of FSA-forming species are now listed among the IUCN Red List's higher threat categories.[4]

To adequately protect these important events and the marine resources dependent on them, resource managers and conservationists worldwide are calling for FSAs to be incorporated into fisheries management (Erisman et al. 2015). Among the most commonly used management methods are area protection, and harvest and sales bans. However, both require information on the spatial and temporal nature of these events, as well as finding the appropriate mechanisms and means for effective monitoring and enforcement.

In Solomon Islands, fishing has heavily impacted FSAs, with density decreases recorded for FSAs near population centres and extirpation where FSA fishing is intense (Hamilton and Kama 2004; Hughes et al. 2020). The Solomon Islands Ministry of Fisheries and Marine Resources (MFMR) developed specific regulations protecting FSAs published in the Solomon Islands Gazette (Fisheries Management [Prohibited Activities and Amendments] Regulations 2018), with a harvest and sales ban from October to January. The regulations also include size limits on key FSA-forming species of groupers and on two other FSA-forming species, green bumphead parrotfish (*Bolbometopon muricatum*) and humphead wrasse (*Cheilinus undulatus*), the latter listed under the Convention on International Trade in Endangered

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Species of Wild Flora and Fauna (Gillett 2010). Yet, across Solomon Islands, scientific and anecdotal evidence have identified a broad range of spawning seasonality, with FSA-based reproduction occurring in all months of the year for three confirmed locations in Western Province where there are some monitoring data (Hamilton et al. 2012; Hughes et al. 2020). Furthermore, almost nothing is known of their composition or status, and little is known about other potential FSA sites.

Our study was designed to address these knowledge gaps by combining a comprehensive review of published records of the timing of FSAs for key targeted species in Western Province, Solomon Islands, with local knowledge collected from fisher interviews. This information is being used to inform local site-based community management of FSAs, as well as to provide recommendations for modifications to the current broad seasonal ban.

Methods

Study area

We focused on filling in information gaps on FSAs from Western Province, Solomon Islands, from the published literature and by collecting traditional ecological knowledge (TEK) from local fishers. Solomon Islands is an island nation of over 600,000 people spread across eight degrees of latitude (5°–13°S) and 14 degrees of longitude (155°–169°E). Located within the Coral Triangle, Solomon Islands boasts some of the highest biodiversity on the planet, with 1019 species of coral reef fishes and 494 species of corals, many of them endemic (Green et al. 2006). These ecosystems form the basis of the fisheries that Solomon Islanders rely on for food and economic security. Solomon Islanders' fish consumption is high, ranging from 30 to 40 kg per person, with 64% of of all fish taken by subsistence fishing, and 90% of all animal-sourced nutrition derived from fish products (Bell et al. 2009). This level of consumption is projected to be unsustainable without effective management and conservation of marine resources.

In Marovo and Roviana lagoons in Western Province, numerous FSA sites are known and nearly all known sites are fished for subsistence and commercial purposes, including domestic export to the capital, Honiara (Brewer et al. 2009; Hamilton et al. 2011). Only one FSA (Uepi) is actively monitored and enforced in Marovo Lagoon, while the species composition, seasonal occurrence and (spawning) population status are unknown for all but two locations in Roviana Lagoon, Shark Point and Njari (Hamilton et al. 2012; Hughes et al. 2020).

TEK Interviews

In May 2019, fisher interviews were carried out in Munda, Western Province, and around Roviana and Marovo lagoons in January 2021. Interviews were conducted using a combination of structured surveys and informal talks with key informants, with a focus on guiding future fisheries management within the region and at the community level (as community-based fisheries management, CBFM), and developing locally managed marine areas (LMMAs). In Munda, 29 surveys were carried out in 16 villages, while 34 interviews across 8 villages were conducted in Roviana Lagoon and 39 interviews across 11 villages around Marovo Lagoon. Surveys focused on obtaining information relevant to identifying location, use and impacts to fish populations in general, and more specifically, the timing and location of FSAs. Surveys also provided information on gear use, target species, and site visitation, with a view to deriving information that would confirm prior findings of FSA sites and times collected through earlier interviews (i.e. Johannes and Lam 1999; Hamilton and Kama 2004; Hamilton et al. 2012). All but a few of the interviews were with patriarch fishers who each had, on average, more than 30 years of fishing experience. Interviewees were asked to provide information on perceived declines in catch and views toward management effectiveness and management options, including but not limited to area and seasonal closures around perceived spawning times. We received ethics approval from the Wildlife Conservation Society (WCS)'s Internal Review Board to conduct this research.

Results and discussion

TEK shared through fisher interviews provided valuable information that has increased our understanding of Solomon Island fisheries and fish life histories in Western Province. Interviewees provided information and suggestions for improving management and LMMA development, particularly by identifying previously unknown spawning sites and verifying sites identified through earlier interviews.

Most fishing trips are reportedly carried out by dugout canoes, with exclusive use of motorised boats comprising only 3% of use in Marovo. Use of canoe and motorised boats varied between 10% (Munda) and 41% (Marovo) across sites (Fig. 1a). As is typical of most tropical Pacific countries and territories (e.g. Dalzell et al. 1996), catch methods varied, with various handline techniques the most common method, followed by spearfishing, including both daytime and night-time spearfishing. Net fishing and trolling were found to be relatively uncommon (Fig. 1b).

Fishers identified 31 separate fishing locations and 26 possible aggregation areas. Results also validated findings from earlier surveys of FSA locations and times using both underwater visual census and fisher knowledge (Table 1). While a few of these sites have been explored and confirmed by previous researchers as spawning sites, most have been unexplored and represent avenues for new research and possible management. Many of the fish species named as aggregation-forming species have not been investigated, although they occur within families known to aggregate when they spawn (Table 1). The derived information is being actively used by Wildlife Conservation Society staff to conduct in-water verification and monitoring of newly recorded FSAs. An evaluation of these sites may not only confirm additional spawning sites, but can also act to provide baseline information on the impacts of fishing on fish stocks and guide future management development.

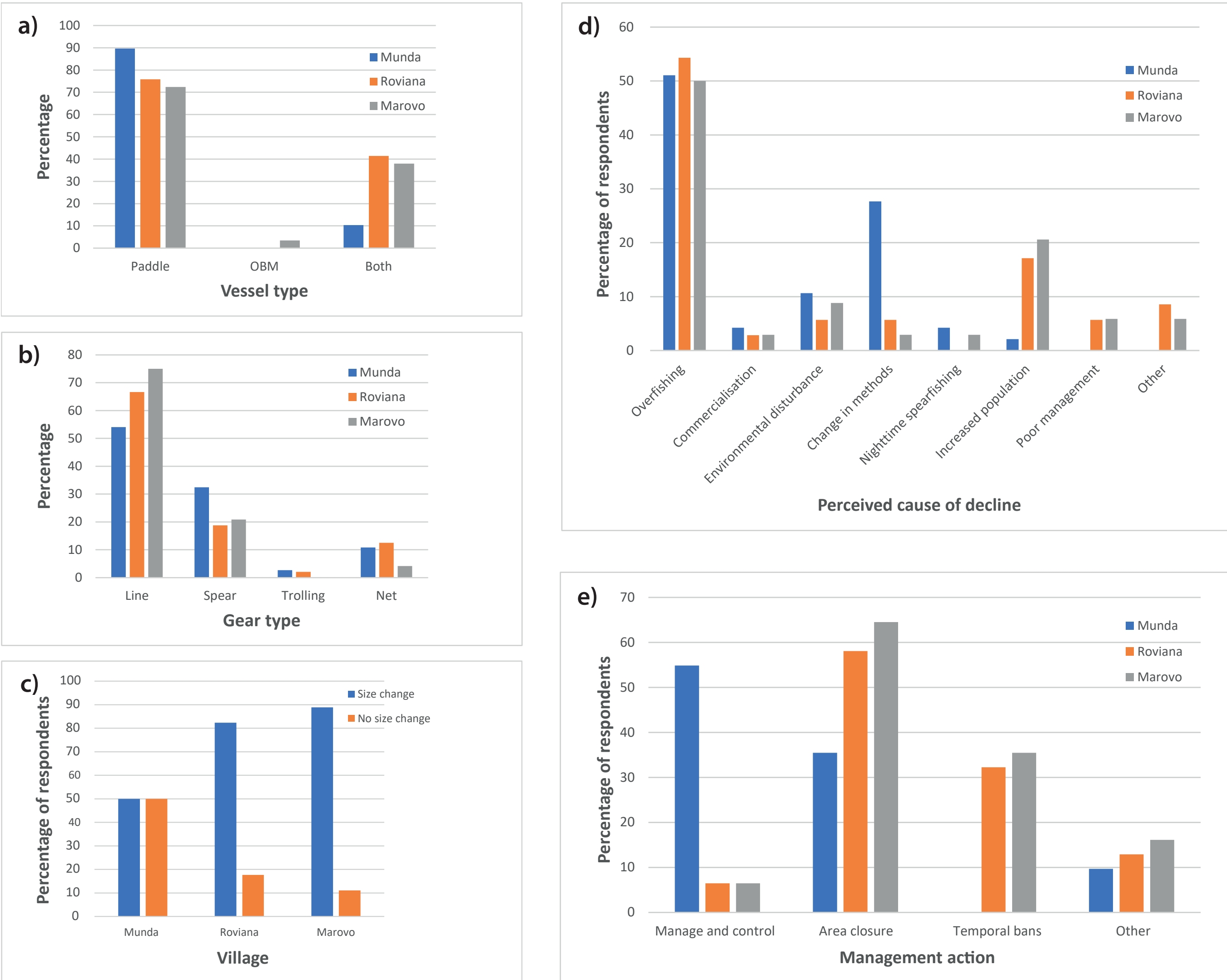

Figure 1. a) Vessel type used across sites, where "paddle" is paddled outrigger canoes and "OBM" is outboard motors; **b)** Reported use of most common fishing gear; **c)** Percentage of respondents who perceive changes in sizes of aggregating species over time; **d)** Perceived cause; **e)** Management action.

Table 1. Species-specific spawning seasonality for fishes identified through current and prior studies in the Solomon Islands. Site names have been coded to maintain confidentiality. Several of the listed species are known to form spawning aggregations (e.g. two-spot red snapper, *Lutjanus bohar*; brown-marbled grouper, *Epinephelus fuscoguttatus*), while others have yet to be confirmed as aggregation-forming species (e.g. three-spot grouper, *Epinephelus trimaculatus*). Direct evidence is confirmation from underwater visual census surveys, while indirect evidence is based on fisher knowledge.

Species	Location	Seasonality	Evidence	Reference(s)
Epinephilidae				
Epinephelus polyphekadion	Western Province A	February–June	Indirect	Johannes and Lam 1999
	Western Province B	October–January	Indirect	Johannes and Lam 1999
	Isabel Province E	June–July	Indirect	Johannes and Kile 2001
	Western Province C	February–March	Direct	Hamilton et al. 2012
	Western Province D	March–August	Direct	Hughes et al. 2020
	Solomon Islands (unspecified)	October–January	Indirect	Hamilton 2003
E. fuscoguttatus	Western Province A	February–June	Indirect	Johannes and Lam 1999
	Western Province B	October–January	Indirect	Johannes and Lam 1999
	Isabel Province E	June–July	Indirect	Johannes and Kile 2001
	Western Province C	November–March	Direct	Hamilton et al. 2012
	Western Province D	January–August	Direct	Hughes et al. 2020
	Solomon Islands (unspecified, multiple)	October–January	Indirect	Hamilton and Kama 2004
	Western Province B	November–January	Indirect	Roviana Fisher Surveys 2021
E. ongus	Solomon Islands (unspecified)	November–January	Indirect	Hamilton and Kama 2004
	Western Province B	November–July	Indirect	Roviana Fisher Surveys 2021
E. spilotoceps	Solomon Islands (unspecified, multiple)	June	Indirect	Hamilton 2003
E. trimaculatus	Solomon Islands (unspecified, multiple)	June	Indirect	Hamilton 2003
E. melanostigma	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019
E. coeruleopunctatus	Western Province B	November–December	Indirect	Roviana Fisher Surveys 2021
Plectropomus areolatus	Western Province A	February–June	Indirect	Johannes and Lam 1999
	Western Province B	October–January	Indirect	Johannes and Lam 1999
	Isabel Province E	June–July	Indirect	Johannes and Kile 2001
	Western Province C	Monthly	Direct	Hamilton et al. 2012
	Western Province D	Monthly	Direct	Hughes et al. 2020
	Solomon Islands (unspecified, multiple)	October–January	Indirect	Hamilton and Kama 2004
	Western Province B	Monthly	Indirect	Roviana Fisher Surveys 2021
P. leopardus	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019

Lethrinidae				
Lethrinus erythropterus	Solomon Islands (unspecified)	March–May, October	Indirect	Hamilton 2005
	Western Province B	n/a	Indirect	Munda Fisher Surveys 2021
L. ornatus	Western Province B	Monthly	Indirect	Munda Fisher Surveys 2019
	Western Province B	Monthly	Indirect	Roviana Fisher Surveys 2021
	Western Province B	September – January	Indirect	Roviana Fisher Surveys 2021
L. obsoletus	Western Province B	Monthly	Indirect	Munda Fisher Surveys 2019
	Western Province B	n/a	Indirect	Roviana Fisher Surveys 2021
L. harak	Western Province B	Monthly	Indirect	Munda Fisher Surveys 2019
L. atkinsoni	Western Province B	Monthly	Indirect	Munda Fisher Surveys 2019
Lutjanidae				
Aphareus rutilans	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019
Lutjanus rivulatus	Western Province A	February – May, September–December	Indirect	Johannes and Hviding 2000
	Solomon Islands (unspecified)	January – March, October–December	Indirect	Hamilton 2003
L. bohar	Western Province A	June–July	Indirect	Johannes and Hviding 2000
	Solomon Islands (unspecified)	Monhtly	Indirect	Hamilton 2003
	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019
L. gibbus	Solomon Islands (unspecified)	Monthly	Indirect	Hamilton 2003
	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019
L. argentimaculatus	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019
L. adetii	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019
L. carponotatus	Western Province B	n/a	Indirect	Munda Fisher Surveys 2019
L. vitta	Solomon Islands (unspecified)	n/a	Indirect	Hamilton 2003
Symphorichthys spilurus	Western Province A	August–January	Indirect	Johannes and Hviding 2000
	Western Province B	October–December	Indirect	Roviana Fisher Surveys 2021

Perceived declines in catches were the most commonly identified impact from FSA fishing, as mentioned by around two-thirds of fishers, which was more pronounced than in other studies in Solomon Islands (e.g. Ensor et al. 2018). Size change was mentioned by 50% or more of interviewees, with nearly 90% of Marovo fishers mentioning reduced sizes of fish (Fig. 1c). Perceived cause of decline varied widely, but overfishing associated with changing methodology and fisher population increase was most notable among all sites (Fig. 1d). Although only sometimes specifically mentioned, nighttime spearfishing was raised as a cause of decline, which has been documented in other studies (e.g. Rhodes et al. 2019). Among management options listed, area closures received the most positive response, with temporal controls that include seasonal closures during spawning times specifically mentioned by Marovo and Roviana fishers (Fig. 1e). Only two respondents failed to suggest a management option. Information derived from fisher interviews and past studies (Johannes and Lam 1999; Johannes and Hviding 2000; Johannes and Kile 2001; Hamilton 2003; Hamilton and Kama 2004; Hamilton 2005; Hamilton et al. 2012; Hughes et al. 2020) identified regional variations in spawning times among individual species, specifically groupers, that lessen the effectiveness of the current nationwide seasonal ban (Fig. 2) and support the need for finer-scale management at the site level.

Fisher interviews also identified key target species (Table 2), with 91 individual species mentioned. For all species, snappers (Lutjanidae) were the most mentioned (n = 131 mentions), emperors the second most commonly mentioned (n = 105), while trevallies (Carangidae) were mentioned 64 times and groupers (Epinephelidae) were mentioned 63 times (Table 3).

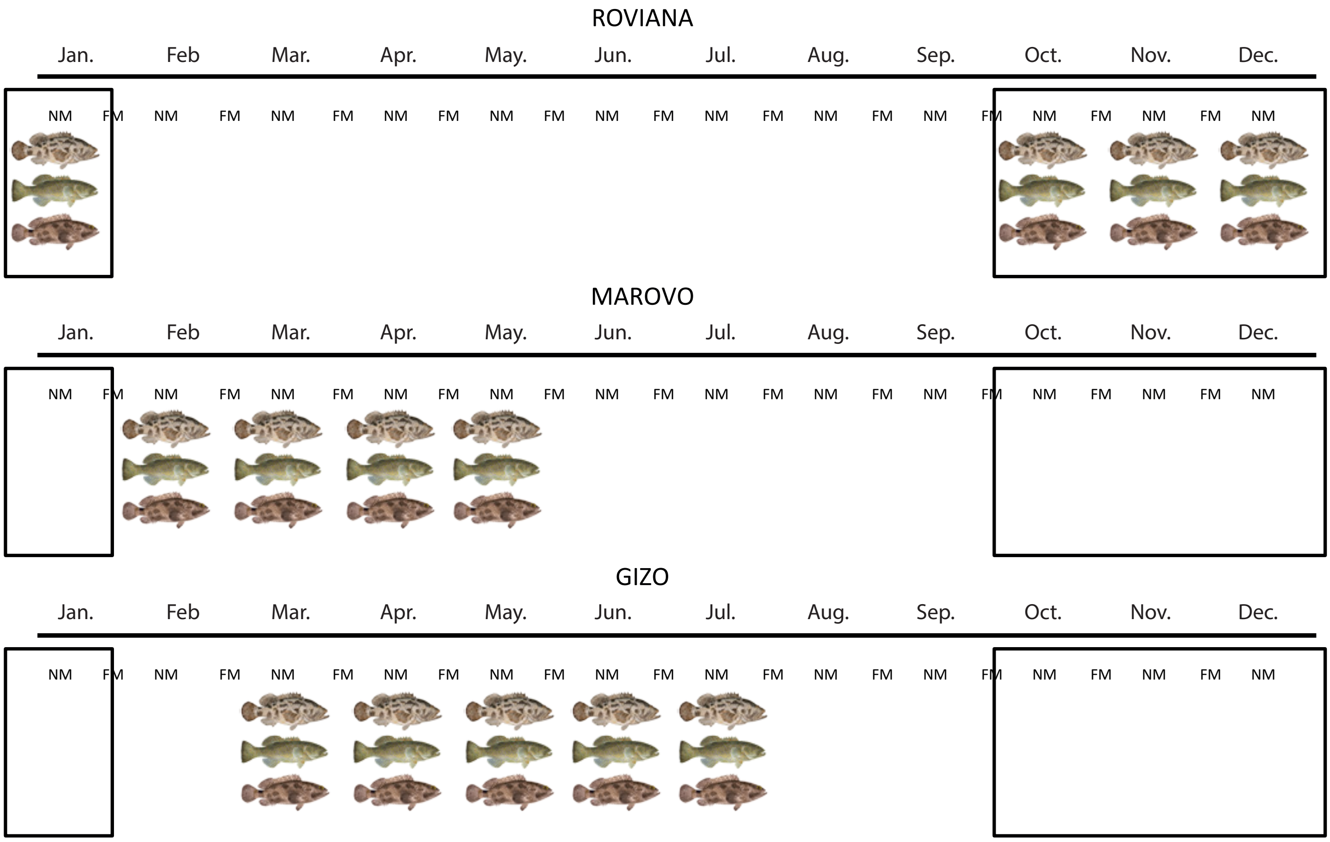

Figure 2. Calendar representation of the timing of spawning for three grouper species. From top to bottom (for each locale) are brown-marbled grouper (*Epinephelus fuscoguttatus*), squaretail coralgrouper (*Plectropomus areolatus*) and camouflage grouper (*Epinephelus polyphekadion*) taken from traditional ecological knowledge (TEK) surveys. These three species are known to aggregate and spawn during variable seasons within Solomon Islands. For these species, aggregations form and persist in the days leading up to new moon phases (NM) during the months indicated in each location. Boxes represent months of the current national sales ban.

Table 2. The 20 target species most mentioned in fisher interviews. Lethrinids (emperors) and lutjanids (snappers) dominate the list of target species.

Common name	Scientific name	Family	Mentions
Longface emperor	*Lethrinus olivaceus*	Lethrinidae	33
Humpback red snapper	*Lutjanus gibbus*	Lutjanidae	29
Two-spotted red snapper	*Lutjanus bohar*	Lutjanidae	22
Spanish mackerel	*Scomberomorus commerson*	Scombridae	18
Mangrove red snapper	*Lutjanus argentimaculatus*	Lutjanidae	13
Rusty jobfish	*Aphareus furca*	Lutjanidae	12
Giant trevally	*Caranx ignobilis*	Carangidae	10
Longfin emperor	*Letrinus erythropterus*	Lethrinidae	8
Blackfin barracuda	*Sphyraena qenie*	Sphyraenidae	8
Thumbprint emperor	*Lethrinus harak*	Lethrinidae	7
Orange-striped emperor	*Lethrinus obsoletus*	Lethrinidae	7
Five-lined snapper	*Lutjanus quinquelineatus*	Lutjanidae	7
Yellowmargin triggerfish	*Pseudobalistes flavimarginatus*	Balistidae	7
Bluefin trevally	*Caranx melampygus*	Carangidae	6
Three-striped whiptail	*Pentopodus trivittatus*	Nemipteridae	6
Striped monocle bream	*Scolopsis lineata*	Nemipteridae	6
Great barracuda	*Sphyraena barracuda*	Sphyraenidae	6
Lined surgeonfish	*Acanthurus lineatus*	Acanthuridae	5
Rainbow runner	*Elagatis bipinnulata*	Carangidae	5
Brown-marbled grouper	*Epinephelus fuscoguttatus*	Epinephelidae	5

Table 3. Number of times that individual species were mentioned in fisher interviews by fish family. Lutjanids and lethrinids dominated the list, while the order of mentions generally reflects fisher preference in marketed catch.

Family	Mentions
Lutjanidae	131
Lethrinidae	105
Carangidae	64
Epinephelidae	63
Scombridae	34
Balistidae	30
Sphyraenidae	25
Acanthuridae	19
Scaridae	14
Nemipteridae	12
Haemulidae	7
Caesonidae	6
Mullidae	6
Holocentridae	4
Pomacentridae	3
Siganidae	3
Labridae	2
Mugilidae	2
Priacanthidae	2
Gerreidae	1
Terapontidae	1

Based on the information derived from these interviews, Wildlife Conservation Society (WCS) is developing a list of recommendations for the Solomon Islands MFMR to enhance the current ban on FSA fishing. WCS is also working closely with local community leaders and fishers to enhance awareness about the impacts to key commercial fish populations from FSA targeting and for the development of resource management plans and LMMAs. In addition to awareness presentations and community-level discussions, WCS has also developed a series of awareness posters and playing cards to expand passive efforts to raise awareness. The aim of these activities is to protect and prolong Solomon Islanders' economic and food security for this and future generations.

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