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Gear-based characterization of the Gizo, Solomon Islands, inshore commercial finfish fishery

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ABSTRACT

In 2015–2016, a gear-specific assessment of the Gizo, Solomon Islands, commercial inshore fishery was conducted to assist management decision making. The survey identified at least 260 species and 25 families among over 14,000 individual catch- and gear-specific fish photos taken using a digital image capture system. Seventy-nine fishers provided 175 catches during surveys and more than 1,600 fisher and vendor interviews were conducted. More than 75% of all individual fish sampled belonged to nine families that included groupers (Epinephelidae) with 29 species and snappers (Lutjanidae) with 28 species. Groupers, snappers and emperors (Lethrinidae) dominated line-caught fish, while speared catch was composed primarily of parrotfish (Scaridae) and surgeonfish and unicornfish (Acanthuridae). Catch-per-unit effort (CPUE) was 3.9 ± 0.1 kg hr^{-1} $fisher^{-1}$ overall, with the highest CPUE for line fishing at 4.5 ± 1.6 kg hr^{-1} and lowest CPUE for nighttime spearfishing (2.1 ± 0.4 kg hr^{-1}). Gear-specific size distributions and species targeted varied widely, with juveniles dominating most catches for speared fish. Between line-caught and speared catch, only two species were common within the top 25 species. At the time of the study there were no enacted national regulations related to finfish in the inshore fishery in Solomon Islands. Community-based management approaches have been endorsed by government and non-government entities in Solomon Islands, however a greater level of community engagement and voluntary fisher compliance is needed in concert with government enforcement to control potential overfishing, particularly nighttime spearfishing. Ongoing support for precautionary, adaptive management is a recommended course of action to limit the potential for overfishing in Gizo and other coastal areas of high human population density that rely heavily on marine resources.

1. Introduction

Solomon Islands is a tropical Melanesian island nation located within the Coral Triangle, a global center of biodiversity. This high biodiversity includes coral reef fishes, with over 1019 species identified among 82 families and 348 genera (Allen, 2006). The Solomon Islands comprises nearly 1000 islands and islets, atolls and cays, many surrounded by varying areas of reef and often encompassing large lagoons. The country's reef resources are subject to customary marine tenure, whereby traditional reef owners have customarily recognized access rights to certain reefs, and the ability to use existing customary tenure frameworks to manage fishing activities therein. Inshore fisheries are also managed at the national level by the Ministry of Fisheries and Marine Resources (MFMR) who are mandated under the Fisheries Management Act (FMA, 2014). Traditional forms of management have been practiced for generations, however there is some erosion of its effectiveness as a result of economic, political and cultural changes (Hviding, 1998; Aswani, 2002). Nevertheless, this forms the basis of the community-based resource management approach (CBRM) approach supported by the FMA.

The Solomon Islands population is *c.* 615,804 people with a population growth rate between 2009 and 2013 of 3.8%, and a population density of 33 people km^{-2} (Solomon Islands National Statistics Office, 2009). Solomon Islands is spread across 8 degrees of latitude (5°–13°S) and 14 degrees of longitude (155° to 169°E) (Fig. 1), which creates a particular challenge to the national government to effectively manage marine resources solely using centralized fisheries management. The country is resource rich, however, mining, timber and occasional international exports of coastal marine products have impacted both upland and coastal

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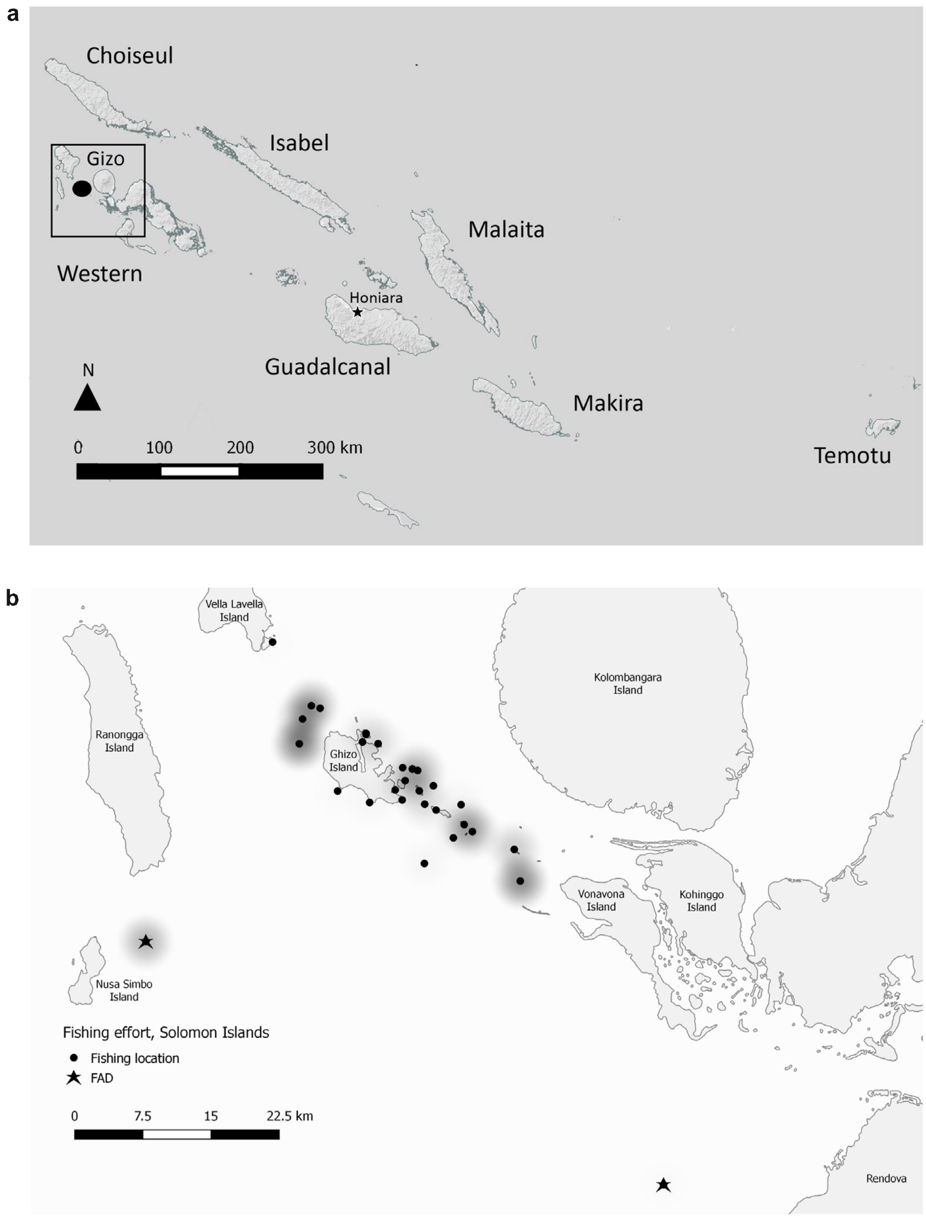

Fig. 1. (a) Map of Solomon Islands listing the provinces and highlighting the study site, Gizo, within Western Province; (b) Heat map of fishing locations identified through fisher interviews during the study.

habitats (e.g. Donnelly et al., 2000), and severely impacted critical habitats for some marine species (Hamilton et al., 2017). The per capita gross domestic income is relatively low (USD$2000), thus Solomon Islanders are heavily reliant on natural resources for daily food and income requirements (Gillett and Lightfoot, 2001; Green et al., 2006).

In Solomon Islands, Bell et al. (2000) reported that fish consumption ranges from 109 to 120 kg person^{-1}, with 64% of fish taken by subsistence fishing, and 90% of all animal-sourced nutrition derived from fish products. There is a projected requirement for fish resources from 25,500 mt in 2020 to nearly 30,000 mt in 2030 to maintain current per capita fish consumption levels. Currently, there are no reliable production figures for the inshore fishery, although various attempts have been made to quantify the contribution the fishery makes to the economy (e.g. Gillett, 2009). Estimates in the 1990s were 1150 mt yr^{-1} (Dalzell et al., 1996) and 3200 mt yr^{-1} between 1988 and 2000 (Gillett and Lightfoot, 2001), which serves as the last approximation of coastal small-scale fisheries production. In order to ensure future food and socio-economic security, there is a need to improve the characterization, monitoring and sustainable management of inshore fisheries resources. Bell et al. (2000) highlighted a number of steps to help Pacific Island Countries and Territories (PICTs), including the Solomon Islands meet future needs, among them: (1) strengthening community-based management; (2) utilizing indicators (e.g. species) and implementing adaptive management to meet sustainable harvest targets; (3) creating incentives for sustainable harvest; (4) implementing national-level regulations, and (5) promoting awareness of the inter-dependence between communities and resources. Such actions reflect regional best practices (MSG, 2015; SPC, 2015) and are accommodated in the FMA (2014), the MFMR (Solomon Islands Ministry of Fisheries and Marine Resources) Corporate Plan 2017–2019 and the Solomon Islands MFMR Strategy 2017–2019. Nevertheless at the time of this study there were no national regulations related to finfish,

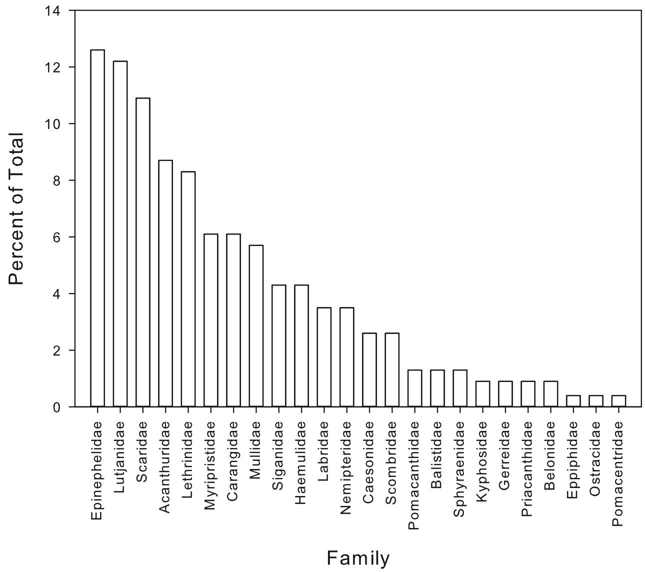

Fig. 2. Percent contributions to total number of species in catch at the family level.

or any related national fishery management plans. In practice, coastal fisheries management is largely in the hands of customary resource owners (Cohen et al., 2012; Abernethy et al., 2014; Sulu et al., 2015) who manage through a variety of mean, including periodic area closures and gear restrictions, as examples (e.g. Cohen and Alexander, 2013).

A number of surveys have been completed on coral reef fish and fisheries in Solomon Islands (e.g. Richards et al., 1994; Donnelly et al., 2000; Allen, 2006; Green et al., 2006; Brewer, 2011; Cohen et al., 2013; Roeger et al., 2016; Hamilton et al., 2017), at different scales and for varying purposes, including a value chain analysis (Brewer, 2011). Cohen and Alexander (2013) described variations in both invertebrate and finfish catch owing to periodical closure through customary marine tenure and report both gear-specific catch-per-unit-effort and the cumulative total of finfish families, however, none has yet reported a comprehensive species-specific characterization of catch within the local (small-scale) commercial fishery. In Solomon Islands, fish markets of varying size and scope operate, with the largest market based in the capital, Honiara. The Honiara Central Market is the only market importing domestic fish from outside its own province (Guadalcanal). Within Gizo, markets are supplied by local fishers selling directly to consumers in most cases by family members. Both local sales and, in some cases, exports to Honiara occur whereby fishers consolidate and ship fish directly to Honiara or fishers' catch is consolidated and shipped by middlepersons (Brewer, 2011). In Gizo, fishers may also sell direct to restaurants, however no such consolidation for domestic export was recorded in Gizo, such that all Gizo market sales are considered a direct fisher to consumer transaction.

This work was undertaken as part of a broader project that had the objective to define the catch, as origin, volumes and species, along with the primary capture methods used within the coral reef fishery that supplies the main market centers of Solomon Islands, including Honiara market (MFMR unpublished data). Herein, we report on the coral reef fishery that supplies the Gizo (Town) market in Western Province. Although data from interviews with net fishers are included, we focus on the two primary gear types used, spear and hook-and-line (hereafter, line) and provide recommendations for management.

2. Materials and methods

2.1. Site description

Gizo Town (Gizo, hereafter), Solomon Islands, is situated on Ghizo Island. Gizo is the provincial capital of Western Province and is the second most populous, hovering around 6000 inhabitants at the time of the survey (Solomon Islands Ministry of Fisheries and Marine Resources Strategy, 2017) (Fig. 1). The area is inhabited by indigenous Solomon Islanders, a small group of expatriates and a comparatively small population of Gilbertese who were relocated to Solomon Islands between 1955 and 1971 from Hull and Gardner Islands in the Phoenix group (Maude, 1952; Bennett, 1987). The Gizo market operates in the town's center next to the seawall, providing easy access for fishers to offload catch. Both pelagic and reef fish are available, along with a variety of invertebrates. Fish are usually displayed openly and sold either by the fishers themselves or by vendors who are typically family members. Fish are either sold individually or in groups (called heaps), with prices varying depending on fish length, species or weight. Fish are captured with a variety of gears and methods, with fishing conducted from motorized boats, dugout canoes or from shore. Captured fish are stored in insulated boxes (referred to locally as eskies) with ice or placed in the bottom of the fishing vessel until landing on shore. The value chain in Gizo is simple and typically limited to direct sales to consumers from fishers (Brewer, 2011).

2.2. Survey methods

Between 25 February 2015 and 17 October 2016, MFMR initiated Gizo market sampling using a team of local fish surveyors (PK, PP, MU, FF). Surveys combined paper-based fisher questionnaires and a digital image capture system (DICS). Prior to and throughout the sampling period, enumerators were provided training in fish species identification, interview techniques and the use of the DICS by the lead author. A number of published (e.g. Myers, 1999; Allen et al., 2015) and online references (e.g. Fishbase: www.fishbase.org) were also made available. All photos used in the current analysis were verified by the lead author and MU, with some validations conducted by leading fisheries experts (see acknowledgments). The questionnaire captured trip-specific information on the number of fishers, gear type(s), means of transport (i.e. vessel or shore-based fishing), hours fished (excluding travel times to and from fishing locations), fisher origin (e.g. village, town, etc.) and fishing location (as reef name or FAD location). Sales prices were recorded for individual fish or groups of fish depending on how fish were being sold. Fishers and fish vendors were haphazardly selected for interviews at the time of landing, regardless of fishing method, sex, or fisher or vendor origin. Catches were examined and photographed using the DICS when interviewees granted permission to access the entire catch. Catches were not examined when full access was not given, i.e. when only partial catches were accessible, or when interviewees declined access entirely. All participants were provided tickets for ice purchase in exchange for interviews. Marketed fish surveyed included catch within the immediate areas around Gizo and pelagic fish taken by trolling in nearby areas, including at nearby fish aggregating devices (FADs).

2.3. Instrumentation and database

The DICS was developed and its proprietary software is owned by J and I Cuetos-Bueno. The DICS is used to record and store digital images of individual fish within a catch, with data stored on an SD card. The system design incorporates a digital pocket camera mounted to a PVC arm that allows the camera to point downward to a standard fish measuring board (60 or 100-cm in length with 1-cm increments) where the fish are placed. The camera is linked to a remote push-button trigger. Fish are placed on the measuring board and photos are taken sequentially of each fish within a given catch. A monitoring code that included the date and fisher is placed on the board to link groups of photos to fisher interviews. At the conclusion of each day, the series of photos was transferred from the SD card to a Microsoft Access database. The database is designed to allow individual fish to be examined, with fields for manual entry of fish species ID both as an abbreviated code and Latin names, fish length (herein, as total length) and the monitoring code. Options are provided to include fish weight where weighing scales are used, a tick box to indicate terminal phase individuals (i.e. for scarids) and to highlight whether the photo needs revision, i.e. 'needs further review'. The Access database is programmed with a series of options and tabs to examine individual fish and combined data for individual species. Among other options, the database compiles thumbnails of individual photos from each species for comparisons and includes a basic photo library for each fish family. Individual fish lengths for each species are automatically added to a size frequency graph. Where length is entered along with known size of maturity parameters, size distribution and the percentage of juveniles, undersized, optimum-sized and mega-spawners (i.e. fish greater in size than the optimal length, or the length when an unfished age group reached its maximum biomass) (Froese et al., 2008) can be viewed graphically as a pie chart. An associated table includes the number of individuals within each size category. In this study, individual fish weights were not taken. Catch volumes, as family weights, was collected using an electronic scale, while size-at-sexual maturity information was either input from peer-reviewed scientific life history studies or from Fishbase, as no specific life history data were available from studies in the Solomon Islands. The combined dataset was then be downloaded as a.csv file for analysis in a range of programs.

2.4. Data analysis

For the current assessment, data was incorporated and analyzed in Microsoft Excel. The paper-based interview data was then be combined with the DICS data for further analysis. From the data, a species list for both combined gear and gear-specific catch was developed, along with catch-per-unit effort (CPUE) as kg fish fisher^{-1} h^{-1} by gear type.

2.5. Fishing methods—descriptions and analysis

Several gears and methods were identified in the Gizo fishery, which are generally common to PITC coral reef fisheries. Line fishing methods in the Gizo fishery include dropline, strikeline, throwline and trolling. Results referring to line-caught fish are combined methods, unless otherwise defined. Dropline fishing is used along reef drop-offs or in open water targeting deepwater fish species, with weighted lines comprised of a series of fishing hooks attached branch lines called snoods. Strikelines (i.e. jigging) use jig (i.e. lure) to target bottom fish and consists of a hook molded within a lead sinker, which is usually covered by a soft body to attract fish. Jigging creates a jerky, up-and-down motion to attract fish. Throwlines (or trotlines) are set horizontally and constructed of heavy fishing line fitted with swiveled snoods and baited hooks attached at intervals. A weight at the middle of the main line is used to sink the hooks. Trolling uses a single line fitted at the end with lures or baitfish that are drawn through the water using a motorized boat or stationary canoe. For canoe trolling, fishers slowly wind the line in a stationary position or sweep the line from side-to-side. Spearfishers in Solomon Islands primarily use a sling spear, a short homemade spear gun, or less commonly, a triple-prong 'Hawaiian sling'. Similar to other type of spear, the barbless sling spear is propelled by a short length of inner tube rubber or surgical tubing. Sling spear rubbers are attached to the middle of a handle with a small loop of wire that is fitted to a notched groove on one end of the spear. Gillnetting is typically done by small-mesh (*c.* 5–8 cm stretch) monofilament nets fitted with floats and weights to position the net on the reef or in the water column. Data was analyzed both for combined gear and as gear-specific. For gear-specific catch composition, effort and fish size, data was first split by gear type and analyzed separately. Where multiple gears were used in a single fishing bout, data were only included in combined gear analysis. For the current survey, net, line and spearfishers were interviewed, however no photos were taken for netted catch. Thus CPUE results for net fishing was taken from interview data combined with family weights taken during the interview process.

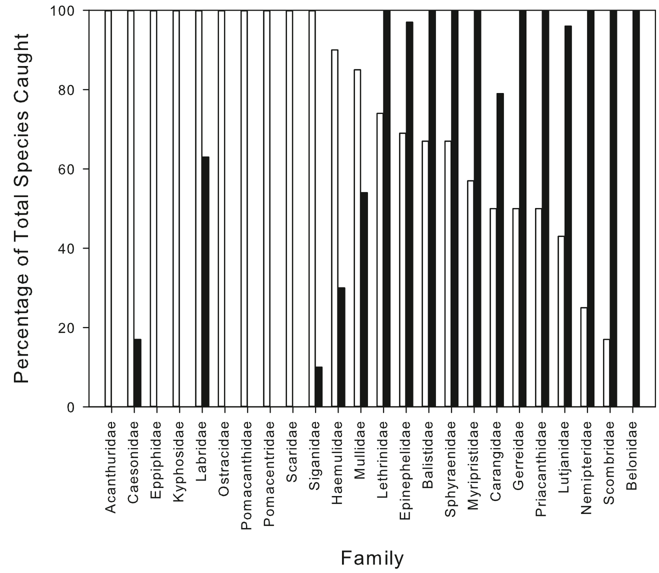

Fig. 3. Gear-specific percentage of total species found in the Gizo fishery within the speared (*white*) and lined (*black*) catch.

3. Results

A total of *c.* 15,000 individual fish photos was taken together with 1682 fisher interviews during the study. Of those, 10,399 photos were used in the current analysis, with discarded photos associated with combined gear use or incomplete or questionable data. While most interviews provided some useful data, only 182 (10.8% of the total) provided complete data fields for catch-specific analyses, with catches from these interviews fully photo-documented. From the photos, a minimum of 260 species from 24 fish families was identified (Supplemental Material). More than 75% of all individuals surveyed belonged to nine fish families (Fig. 2), with groupers (Epinephelidae), snappers (Lutjanidae) and parrotfishes (Scaridae) each represented by more than 25 species and each family representing more than 10% to the total number of species present.

3.1. Family and species contributions to catch

Surveys using the DICS targeted only line-caught and speared catches. Hereafter, netted catch results reflect data captured

Table 1
Top 25 species, relative percentages of totals (T) and mature (M) from each respective gear type. Common species between gears are highlighted in gray. a=Prince (unpubl. data; Prince et al., 2017); b=Taylor and Choat (2014); c=Taylor et al. (2016); d=Taylor et al. (2014); e=Grandcourt et al. (2007); f=Grandcourt et al. (2010).

Spear	T	M	Line	T	M
Acanthurus lineatus[a]	9.7	48.0	*Lutjanus gibbus*[a]	25.0	82.8
Parupeneus barberinus[a]	7.3	49.9	*Lethrinus lentjan*[a]	8.7	86.0
Siganus argenteus[c]	6.7	19.0	*Selar boops*	4.2	
Caesio caerulaurea	5.0		*Sphyraena forsteri*	3.6	
Scarus psittacus[b]	4.0	100.0	*Lethrinus obsoletus*[a]	3.2	81.6
Monotaxis grandoculis[a]	3.6	45.9	*Lutjanus bohar*[a]	2.9	46.8
Scarus niger	3.0		*Lutjanus rufolineatus*	2.9	
Acanthurus nigricauda[a]	2.8	60.9	*Lutjanus quinquelineatus*	2.5	
Scarus dimidiatus[a]	2.5	47.8	*Lutjanus kasmira*	2.4	
Caesio cuning	2.3		*Lethrinus xanthochilus*[a]	2.3	76.8
Hipposcarus longiceps[b]	2.3	47.6	*Lethrinus erythracanthus*	1.9	
Lutjanus gibbus[a]	2.2	75.9	*Lethrinus olivaceus*[a]	1.7	41.9
Naso vlamingii	2.1		*Lethrinus erythropterus*	1.6	
Pterocaesio tessellata	2.0		*Monotaxis grandoculis*[a]	1.3	83.3
Siganus canaliculatus[e]	2.0	100.0	*Sargocentron violaceum*	1.3	
Scarus rubroviolaceus[b]	2.0	13.9	*Lethrinus microdon*[f]	1.2	47.0
Mulloidichthys vanicolensis	2.0	10.6	*Lethrinus atkinsoni*	1.2	
Siganus doliatus[a]	2.0	80.0	*Myripristis adusta*	1.2	
Naso lituratus[d]	1.7	100.0	*Lethrinus amboinensis*	1.1	
Parupeneus crassilabris	1.5		*Euthynnus affinis*	1.1	
Ctenochaetus striatus	1.5		*Myripristis pralinia*	1.1	
Scarus quoyi	1.4		*Caranx sexfasciatus*	1.0	
Scarus oviceps	1.3		*Lutjanus biguttatus*	1.0	
Acanthurus auranticavus	1.2		*Lethrinus semicinctus*	1.0	
Parupeneus cyclostomus	1.0		*Cephalopholis miniata*	1.0	

Table 2
Catch-per-unit-effort for gears used by the Gizo fishery.

Time/Method	Dropline	n	Strikeline	n	Throwline	n	Trolling	n	Spear	n	Net	n
Overall	4.5 ± 1.6	82	4.4 ± 2.2	52	3.1 ± 1.1	298	2.6 ± 1.3	186	2.2 ± 0.4	397	2.9 ± 1.2	161
Day	4.7 ± 2.2	59	4.4 ± 5.0	20	2.2 ± 1.2	103	2.6 ± 1.3	157	2.5 ± 1.3	68	2.9 ± 1.2	142
Night	4.4 ± 2.5	16	4.5 ± 2.3	32	3.5 ± 1.5	178	2.1 ± 0.4	15	2.1 ± 0.4	324	3.1 ± 21.1	11
Canoe	4.5 ± 1.7	77	4.7 ± 3.4	54	3.3 ± 1.6	254	2.7 ± 0.6	14	2.7 ± 0.6	121	4.3 ± 1.7	48
Boat	4.6 ± 8.9	5	3.0 ± 2.4	7	2.3 ± 3.3	43	2.1 ± 0.6	172	2.1 ± 0.6	197	2.5 ± 2.6	103
Shore	na	0	na	0	na	0	na	0	na	0	4.8 ± 4.7	9

solely by interviews. Seventy-five species were common to both line-caught and speared catch, however only two species, Paddletail snapper, *Lutjanus gibbus*, and Bigeye humpnose emperor, *Monotaxis grandoculis*, were common among the top 25 targeted species for both gears, with wide differences in their respective contributions to each gear type (Table 1). For lined catches, *L. gibbus* represented 25% of all individuals sampled numerically, while Lined surgeonfish, *Acanthurus lineatus*, comprised nearly 10% of all speared catches. At the family level, surgeonfish and unicornfish, rabbitfish (Siganidae), parrotfish, boxfish (Ostracidae), rudderfish (Kyphosidae), spadefish (Eppiphidae) angelfish (Pomacanthidae) and damselfish (Pomacentridae) were unique to speared catch, while only needlefish (Belonidae) were unique to lined catches (Fig. 3).

3.2. Catch-per-unit-effort and effort location

Catch-per-unit-effort (CPUE) was calculated from all interviews where gear, the number of fishers, catch weight, and time spent fishing was available. From these interviews, CPUE varied widely among gears for the Gizo fishery, with an overall CPUE of 3.9 ± 0.1 (mean±standard error, hereafter) kg h^{-1} $fisher^{-1}$ (Table 2). From combined interviews, fishing trips averaged 2 fishers $trip^{-1}$ who spent 5.1 h $trip^{-1}$. The highest CPUE was shown for line fishing (Table 2), with dropline the most productive line method overall and higher catches and lower variation during the night. The lowest overall CPUE was for spearfishing. Dropline and strikeline fishing CPUE was higher during daytime than throwline, which had the lowest CPUE among all daytime gears. Line fishing methods were also dominant for CPUE during nighttime, with average CPUE similar between trolling and netfishing, with the latter showing highly variable catch. While dropline CPUE was highly similar between motorized boat and canoe-based fishing, strikeline and throwline fishing yielded higher catch from canoes. Perhaps unsurprisingly, trolling using motorized boats captured more fish weight than canoe-based trolling. For speared fish CPUE, canoe-based fishing was more productive in terms of catch weight than from the use of motorized boat, while shore-based net fishing resulted in the highest CPUE among all methods.

Fishing effort was largely concentrated in the Gizo area, with the exception of fishing at nearshore and offshore FADs (Fig. 1b). Based on interview data, minimum distances from fishing locations (as site distance to market) averaged 7.7 ± 0.9 km for non-FAD trips, 37.9 ± 11.4 km for FADs and 11.3 ± 0.4 km for all trips combined.

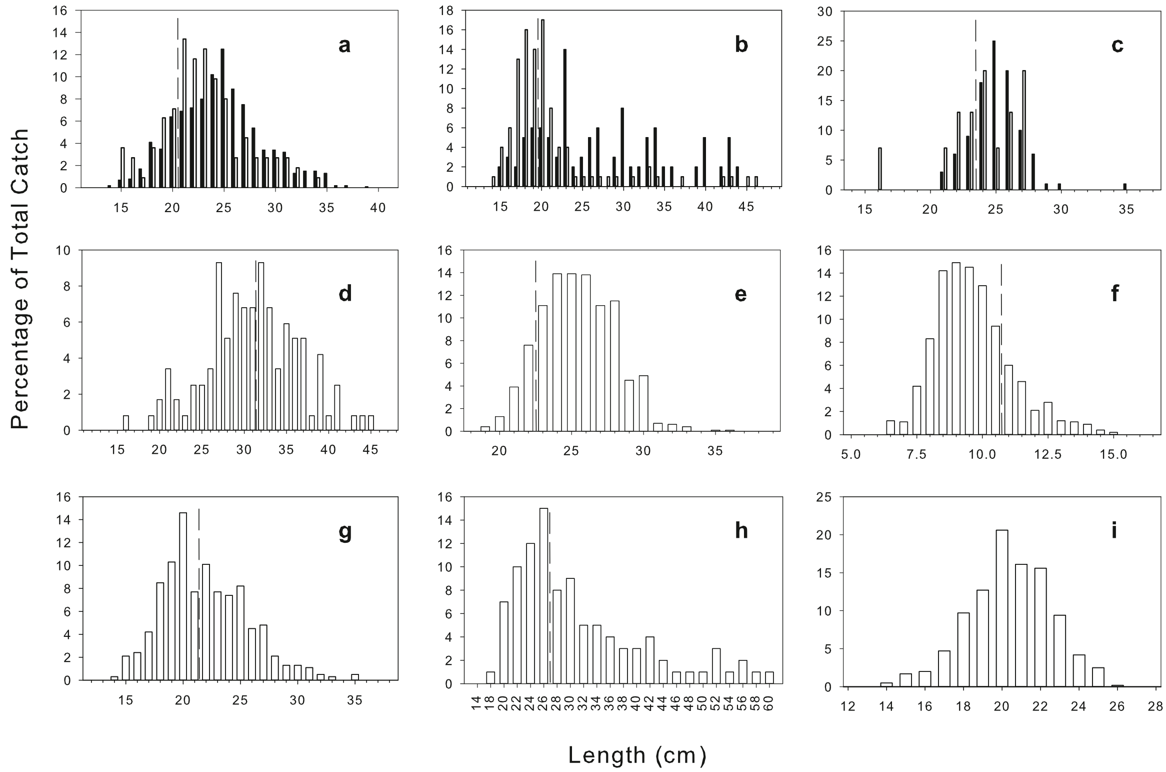

Fig. 4. Gear-specific size frequency distribution for fishes where (1) size-at-sexual maturity data was available or (2) where targeted species were common among gears. (a) Paddletail snapper, *Lutjanus gibbus* (n_{LINE} = 1300; n_{SPEAR} = 112), Speared (*black*), lined (*white*); (b) Humpnose big-eye bream, *Monotaxis grandoculis* (n_{LINE} = 66; n_{SPEAR} = 183). Speared (*black*), lined (*white*); (c) Orange-striped emperor, *Lethrinus obsoletus* (n_{LINE} = 163; n_{SPEAR} = 15). Speared (*black*), lined (*white*); (d) Speared Pacific longnose parrotfish, *Hipposcarus longiceps*, N = 118); (e) line-caught Pink ear emperor, *Lethrinus lentjan* (n = 453); (f) Speared Forktail rabbitfish, *Siganus argenteus* (n = 346); (g) Speared Dash-and-dot goatfish, *Parupeneus barberinus* (n = 377); (h) Two-spot red snapper, *Lutjanus bohar*. Only 2 of 152 *L. bohar* were observed in speared catch (not included). (n = 183); (i) Speared White-spotted rabbitfish, *Siganus canaliculatus* (n = 716). Dashed lines represent size-at-sexual maturity. Note percentage various scales used for the y-axis.

3.3. Gear-specific species size distributions

Among the gear-specific top ten species observed in Gizo catch, seven had peer-reviewed published size-at-sexual maturity information from which to gauge the impacts of the fishery (Table 1; Fig. 4a–i). For others, the proportion of juveniles in the catch was estimated based on size-at-sexual maturity (length at 50% sexual maturity, L_{50}, hereafter) information provided by macroscopic examinations of Gizo market samples done during a separate study (Prince, 2017: based on the methods of Hordyk et al., 2014). (Note: The latter study has not been verified for accuracy and does not account for mature, resting individuals. Management based on these methods should be used with caution.) For common species, the mean individual size of lined catch was significantly greater for lined than speared catch for *L. gibbus* (Fig. 4a) ($mean_{LINE} \pm SE = 23.0 \pm 0.4$ cm TL; $mean_{SPEAR} \pm SE = 24.6 \pm 0.1$ cm TL; T-test: t = 19.02, df = 112, $p < 0.00$), *M. grandoculis* (Fig. 4b) ($mean_{LINE} \pm SE = 27.2 \pm 1.0$ cm TL; $mean_{SPEAR} \pm SE = 20.7 \pm 0.4$ cm TL; T-test: t = 12.4, df = 66, $p < 0.00$) and Orange-striped emperor *Lethrinus obsoletus* (Fig. 4c) ($mean_{LINE} \pm SE = 25.1 \pm 0.2$ cm TL; $mean_{SPEAR} \pm SE = 23.8 \pm 0.8$ cm TL; T-test: t = 3.23, df = 14, $p < 0.01$), the mean individual size of catch was significantly greater for lined than speared catch. For line-caught fish where maturity data was available, adult catch composition ranged from 49 to 86%. Specifically, 86% of lined Pink ear emperor *Lethrinus lentjan* (Fig. 4e), less than 50% of Two-spot red snapper *Lutjanus bohar* (Fig. 4h), 42% of *Lethrinus olivaceus* and 47% of Smalltooth emperor *Lethrinus microdon* (not shown) were mature. The percent maturity for speared catch ranged from 14 to 100% maturity. Speared *H. longiceps* (Fig. 4d) comprised 48% mature fish, while only 19% of Streamlined spinefoot *Siganus argenteus* (Fig. 4f) and just under 50% of Dash-and-dot goatfish *Parupeneus barberinus* (Fig. 4g) were mature. Speared Common parrotfish, *Scarus psittacus,* White-spotted rabbitfish, *Siganus canaliculatus* (Fig. 4i), and Orangespine unicornfish, *Naso lituratus*, were entirely represented by adults in catch. These species each mature and reproduce at small sizes and during the first year of growth (e.g. Grandcourt et al., 2007; Taylor and Choat, 2014; Taylor et al., 2014). For the two species common to line and speared catch, the percent of mature lined *L. gibbus* was 83% and 76% for speared fish. Mature *M. grandoculis* comprised 46% of speared catch and 83% of lined catch, demonstrating greater selectivity for mature fish by line fishing.

4. Discussion

The results presented herein represent the first systematic catch- and gear-specific data for the Gizo nearshore commercial fishery. Prior studies in Gizo include a study of the commercial FAD-based tuna fishery (Albert et al., 2014) and a spawning potential ratio (SPR) assessment of the primary target species of the reef fishery (Prince unpublished data). Within Solomon Islands small-scale fisheries, Cohen and Alexander (2013) have examined variations in CPUE in closed and open section of reefs managed through customary marine tenure, while Roeger et al. (2016) described the small-scale nearshore fishery in Langalanga Lagoon, Malaita Province, following declines in reef resources. For the current study, more than 260 species were identified among 24 fish families being targeted by the Gizo small-scale fishery. Large differences in combined weight were observed among families contributing to catch and although a few of the most highly targeted species were common to both lined and speared catch, there were several fish families (and species) that were unique to one gear type. Where size comparisons were possible, lined catch included a larger percentage of mature individuals than speared catch, suggesting higher selectivity for hook-and-line fishing. Similar to findings from Cohen and Alexander (2013) from parts of Western Province and Nggela Islands (Central Province), gear-specific variations in CPUE were also evident in Gizo, with spearfishing showing the lowest CPUE among gear types, while among the various line fishing methods employed, CPUE was highest for dropline and strikeline fishing. This contrasts with Cohen and Alexander (2013) who reported larger CPUE using spear than line, although values for both gear types in their study locations were well below those observed in Gizo. Specifically, line fishing in Gizo yielded as much as three times greater volume per unit effort than Cohen and Alexander's (2013) reported values, while speared catch in Gizo was only slightly higher. Higher catches using spear were also observed from prior studies of the reef fishery in Pohnpei (Micronesia), with values overall and for specific gear types similar to those from Gizo (Rhodes et al., 2018). These differences may reflect gear preferences and more common use and success in each study site. In Gizo, variations in CPUE were also observed between nighttime and daytime fishing, however these variations did not show a clear pattern among gears. The only large differences observed were for throw-line, with a substantially higher catch during nighttime periods. Surprisingly, canoe fishing was generally demonstrated to have higher CPUE than motorized boat-based fishing with the exception of trolling, which had greater CPUE during daytime. Effort for the Gizo fishery was in close proximity to the market and the population center, which is a known factor in increasing fishing pressure on fish populations and other marine resources in Solomons (e.g. Sabetian and Foale, 2006; Brewer et al., 2009) and elsewhere (e.g. Williams et al., 2015).

A number of nearshore fisheries have been investigated in species-level detail in the PICTs (e.g. Rhodes et al., 2008; McLean et al., 2016; Cuetos-Bueno et al., 2018a,b; Rhodes et al., 2018). Among these, the fish diversity identified within the Gizo fishery appears to be among the highest to date, with 260 species among 25 finfish families targeted by the reef fishery. The number of families in the current study was smaller still than that of Cohen and Alexander (2013) who recorded 36 finfish families. By comparison, only 163 species were identified among 16 families in the Pohnpei, Micronesia, nearshore fishery, while surveys in Chuuk, Micronesia, documented around 100 species over similar sampling durations and sample sizes that also included rare species. In the Commonwealth of the Northern Mariana Islands nearshore fishery, at least 111 species were identified. Prior reports by Richards et al. (1994) suggested 180 species from 30 fish families contributed to shallow-water (inshore) fisheries in the Solomon Islands, with catch dominated by lutjanids, epinephelids, lethrinids, scombrids and carangids. There was no mention of scarids, acanthurids or holocentrids, which currently make up a significant part of the fishery. At the time of the Richards et al. (1994) report, only (undefined) small amounts of reef fish were being sold in Gizo, some domestic exports were being sent to Honiara (Guadalcanal Province) and spearfishing comprised the smallest proportion of effort by gear type (based on figures supplied by Leqata et al., 1990). By 2015, more than 532 mt of nearshore fishes was being exported domestically to Honiara from the outer provinces (MFMR, unpubl. data). Of this, Western Province exported at least 85 mt over a 15-month period (2013–2015) (MFMR unpublished data). The amount supplied from surrounding and nearby Gizo reefs is still unknown, since middlepersons consolidate catch from various reef areas to ship directly to Honiara. Such determinations will require substantially greater effort to identify middlepersons and fished reefs.

In Gizo, the fishery appears to be changing rather rapidly, with indications that greater pressure is being applied to surrounding reefs through commercial fishing both for local consumption and domestic export (e.g. Sabetian and Foale, 2006; Aswani and Sabetian, 2010; Brewer, 2011) and an unknown quantity being supplied directly for subsistence needs. Based on past reports, at least some communities have become more reliant on exporting to domestic markets as a source of income, a trend likely to grow as the population of the Solomon Islands increases (Bell et al., 2000). Some evidence of fisheries impacts can already be observed, including the diminution in abundance of Green bumphead (aka humphead) parrotfish, *Bolbometopon muricatum* (e.g. Sabetian and Foale, 2006; Aswani and Sabetian, 2010; Hamilton et al., 2019), a species that is largely targeted by nighttime spearfishing.

Based on catch location data taken from fisher interviews, fishing effort around Ghizo Island is relatively high, with Gizo fishers already traveling on average 8 to 11 km from Gizo to supply the local market. According to Brewer (2011), which details value chains for Gizo and Honiara markets, a number of fishers also contribute to the Gizo fishery from more distant areas (e.g. Simbo and Ranongga). While the current survey did not look at overall marketed volumes or volumes taken per fisher per annum, Brewer's (2011) surveys indicate that individual fisher's catch may range from 1000 kg to more than 10 mt yr^{-1}. The survey by Brewer (2011) and a previous one that touched on the Gizo fishery (Sabetian and Foale, 2006) both suggested declining mean size and a greater paucity of fish around the immediate vicinity of Gizo Town since the time the interviewed fishers had first started fishing. Based on these reports, fishing pressure appears to be relatively high. Evidence from this study shows that undersized fish contribute substantially to catch, particularly within the spearfishery. Changing fisheries as a result of overfishing are already evident in parts of the Solomon Islands, as demonstrated by Roeger et al. (2016) and Hamilton et al. (2019). In the former case, fishing has shifted in Langalanga Lagoon away from reefs to nearshore environments, with high catch rates. In the latter case, targeted fisheries, poor enforcement and habitat loss were attributed to a 92% decline in Green bumphead parrotfish since the 1980s. These combined studies suggest that unmanaged or poorly managed fisheries in areas of high population density in Solomon Islands may further suffer without some form of intervention.

Globally, nighttime spearfishing has been demonstrated to be an unsustainable fishing technique that is now severely impacting coastal reef resources in many PICTs (Gillett and Moy, 2006). The reasons for these declines are at least in part due to the non-selective use of the gear and the targeting of reef fish that are largely immobile during nocturnal periods. The result of targeting herbivorous and corallivorous species impacts reef ecosystem function (Thacker et al., 2001; Folke et al., 2004; Fox et al., 2009; Bennett and Bellwood, 2011; Bejarano et al., 2013) and diminished the potential for coral recruitment, recovery and persistence (e.g. Hughes et al., 2007) by controlling algal biomass. In the current study, herbivores, which provide key functions on coral reefs, such as acanthurid and scarid, were exclusive to speared catch. For the combined fishery, a large percentage of primary fisheries targets were immature. In Gizo, there was a clear indication that spearfishing is targeting substantially more juveniles than other gear types. Clearly, impacts to fished populations are not exclusive to nighttime spearfishing and there is a need to better understand the life histories of the main target species, including spawning times and maturity schedules. While less certain, providing fishers with size-at-maturity information might motivate them to comply voluntarily with self-imposed size limits (e.g. Hordyk et al., 2014). Regardless, based on the results of Roeger et al. (2016) and Hamilton et al. (2019), stronger management intervention in excess of community-based efforts may be needed if indications of fish population decline in Gizo can be clearly shown.

Throughout many parts of the world, declining catch and fish biomass has been correlated with distance to population centers (e.g. Albert et al., 2015; Cuetos-Bueno and Houk, 2018; Cinner et al., 2013; Maire et al., 2016). While fish biomass estimates have not been assessed for Gizo, size reductions have been reported (Aswani and Sabetian, 2010) and reductions in local spawning aggregations for groupers (Epinephelidae) are also known (Hughes, 2017). For the current study, both line and speared catch is already dominated by juveniles for some key target species. In combination, this information may portend a fishery already being negatively impacted by heavy localized fishing pressure. In nearby Roviana Lagoon, longer fishing times and longer travel distances are already impacting fishers and possibly communities reliant on fish for protein (Albert et al., 2015). Without local and government-supported management initiatives to make adjustments to fishing practices, Gizo fishers may soon be forced to spend longer fishing and travel further to maintain catch (e.g. Hicks et al., 2014).

The Solomon Islands Fisheries Management Act supports community fisheries management initiatives, consistent with regional policy and best practice (MSG, 2015; SPC, 2015) and community-based resource management (CBRM), and builds on customary marine tenure as a core coastal fisheries management approach (MFMR, 2010). Bell et al. (2000) outlined a list of management measures that may be applied to Solomon Islands coastal fisheries in addition to community-based approaches that include size limits, seasonal harvest controls, marine protected areas and gear restrictions. The findings reported herein and in previous reports (e.g. Sabetian and Foale, 2006; Aswani and Sabetian, 2010; Hughes, 2017) support science-based determination of size limits, seasonal harvest controls and gear restrictions that may be used to regulate the fishery at a national level, in support of CBRM. Specifically, the findings shown for Gizo and the regional declines in coastal fisheries highlight the need for government management initiatives in combination with community-based management. For Gizo and the Solomon Islands, future steps to improve management decision-making will include identifying critical habitats and life history phases of key commercial species, and gathering up-to-date information on biodiversity and standing stocks in coastal waters, particularly those affected by commercial fishing. Finally, a more detailed examination of the Gizo fishery is needed to establish long-term trends and examine the impacts of gear use on the sizes and types of fish being targeted.

5. Conclusions

An examination of the Gizo, Solomon Islands, inshore fishery found at least 260 fish species contributing to the fishery. Catch composition between speared and lined fish overlapped, however a number of species and families were unique to a single gear type. While lined catch contained juveniles, a substantially greater proportion of individuals were below the known size at sexual maturity in speared catch, with differences significant for those with known size-at-sexual maturity. In Gizo, inshore fishing effort was limited to areas proximate to markets, suggesting prolonged fishing for commercial purposes is likely to have impacts to ecosystems over time, particularly since much of the catch is derived from unsustainable nighttime spearfishing. Some species, such as Green bumphead parrotfish are already showing signs of decline where they are actively targeted (e.g. Hamilton et al., 2016; Hamilton et al., 2019) and there are anecdotal reports of diminishing size and spawning aggregation density among other target species (e.g. Sabetian and Foale, 2006; Hughes, 2017). Long-term datasets are needed, along with the identification of critical habitats and life history parameters to assist communities, markets and governments in Solomon Islands develop informed management decisions.

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Appendix A. Supplementary data

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