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Research Article

Study on different hook and bait types in the Persian Gulf hand line fishery: optimization and development★

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Abstract – The hand line fishery in the Persian Gulf is considered a sustainable fishing practice. The aims of this study were to estimate catch composition, catch rates, length frequencies, and the percentage of individuals caught below length-at-maturity with two types of hooks, circle and J-style with natural and artificial bait by hand line fishing. Circle and J-style hooks with natural and artificial bait were alternated. Sampling operations were carried out on Qeshm Island, in the North of the Persian Gulf in spring 2015. Catch per unit effort for J-hooks with natural and artificial bait and circle hooks with natural and artificial bait differed significantly ($p < 0.05$); they were 0.9772 ± 0.25, 0.7772 ± 0.26, 0.5688 ± 0.32, and 0.4108 ± 0.23 kg/hook/h, respectively. Thus, the highest catch rates were obtained with J-style hooks with natural bait. Kolmogorov–Smirnov tests showed that the length frequency distributions for *Lethrinus nebulosus*, and *Alectis indicus* differed significantly between treatments ($p < 0.05$), while no significant differences were found for other species ($p > 0.05$). For most species (except *L. nebulosus*), there was no significant difference between circle and J-style hooks for the proportion of individuals smaller than length-at-maturity ($p > 0.05$).

Keywords: Hook / Bait / Length frequency / Catch rate / Hand line / Persian Gulf

1 Introduction

Hand line is one of the most important fishing gears for recreational sectors in the Persian Gulf. In 2016, 1370 small boats landed 12,000 mt caught by handlining around Qeshm Island in the North of the Persian Gulf. Hand line fishing is considered a sustainable fishing practice (Sainsbury, 1996). It is an adaptable fishing method and there are different ways to rig it based on the target species and conditions of fishing. Hand line fishing is used in all seas and oceans, and a substantial part of fish resources is extracted through this method (Bjordal and Løkkeborg, 1996). For example, hand line fishermen land 47,000 mt annually in waters north of Spain (Punzon et al., 2004). Annual landings from hand lines from the Philippines, Vietnam, Thailand, and Cambodia were 24,270, 45,028, 3498, and 15,600 mt, respectively (SEAFDEC, 2001).

Although the hand line fishing method is simple, there are differences in gear structure and operation performance when targeting demersal and large pelagic species. The hand line fishermen from the Iranian waters of the Persian Gulf commonly use two kinds of hooks (circle and J-style) and different baits (natural and artificial). J-style and circle hooks (Woll et al., 2001; Mapleston et al., 2008; Curran and Bigelow, 2011; Pacheco et al., 2011; Hannan et al., 2013) and also natural and artificial baits have been compared in several studies (Løkkeborg, 1990; Alós et al., 2009; Carvalho et al., 2015). According to these studies, changes in the hook type and bait could lead to changes in catch rates, catch per unit effort (CPUE), and catch composition.

Currently, there are not enough accurate statistics and information about hand line fishing in the Persian Gulf to set any rules or management limitations that could guarantee sustainable fishing in this area. Monitoring fishing effort, and estimating catch rates and biological parameters of the caught species are a first step in evaluating the sustainability of fishing in the area (MSC, 2009).

The aims of this study were to estimate catch compositions, catch rates, length frequencies, and the percentage of individuals caught below length-at-maturity (L_m) for two hook types, circle and J-style, with natural and artificial bait in the Persian Gulf hand line fishery.

2 Materials and methods

2.1 Sampling area

Sampling was carried out off Qeshm Island in spring 2015. Fishing was mainly done in the southwest near the city of

★ Supplementary material is only available in electronic form at www.alr-journal.org.

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Qeshm (26°40′ N, 56°07′ E), between 1 and 10 nautical miles from the coast. Fishing depth was between 5 and 100 m and all fishing took place over coastal reefs.

2.2 Data collection

For each sampling event, geographic coordinates (using GPS) and time of day were recorded. Caught individuals were identified using valid identification keys from the literature (Dehghaniposhtrodi and Asadi, 1996; Carpenter et al., 1997). All individuals were then counted and weighed. We recorded total length (TL) to the nearest cm. Catch composition was calculated in weight and in numbers. Four treatments were compared: J-style hook with natural bait, J-style hook with artificial bait, circle hook with natural bait, and circle hook with artificial bait. Natural bait was a piece of squid and artificial bait was a plastic lure looking like a squid. The size of the bait was chosen proportionally to hook size.

CPUE was calculated for each treatment as (Anonymous, 2001):

$$\mathrm{CPUE} = \frac{C}{ND},$$

where C is the catch in weight (kg) and N is the number of hooks, and D is duration of deployment.

Species diversity was calculated using the Shannon index (Shannon and Weaver, 1949):

$$H' = -\sum P_i \ln P_i,$$

where P_i is the proportion of species i in numbers.

2.3 Fishing trials and gear

Handlining is just as its name implies: holding a line in the hand while waiting for a fish to take the bait. If a fish is hooked, it is hauled in by hand. Fishermen raise and lower the line to draw attention to the bait. All operations are done by hand. For the four experimental treatments, a total of 171 deployments were performed. The number of trials with hook sizes of 4/0, 5/0, 7/0, and 8/0 were 42, 43, 43, and 43, respectively; these were equally distributed across J and circle hooks to avoid possible interaction effects. For this, each fisher was randomly assigned one of the four hook sizes at the start of a fishing trip and thereafter followed a sequential order of hook sizes. Two classes of boats were used: 17 and 20 ft. Fishermen carried one hand line set with specific hook and bait types on each trip by each boat. Details of the hand lines are summarized in Table 1.

Fishing trips were carried out daily from dawn until dusk, weather permitting. The duration of each trip varied. Soak time was between 3 and 16 h and depended on fish availability and weather conditions.

2.4 Data analysis

First, the homogeneity of variances and normalization of data were evaluated. We used a randomized complete block design to evaluate the effect of hook sizes on CPUE values. The effect of hook sizes was not significant ($p > 0.05$). An analysis of variance was then carried out to evaluate the effect of hook type, bait type and their interaction on CPUE values and diversity indices, and Duncan testing was conducted with a probability level of 5% to compare means. Mean length by species was compared amongst different treatments with Kruskal–Wallis tests. Using Sturges' formula (Sturges, 1926), individuals were first grouped into length classes, and then length frequency distributions by length class were compared using Kolmogorov–Smirnov tests. Chi-square tests were used to compare the abundance of species and the percentage of individuals caught smaller than the length at first maturation. Analyses of catch composition dissimilarities between treatments were carried out using SIMPER (Clarke, 1993). In order to statistically analyze and store data, Excel, SPSS, and Primer software were used.

Table 1. Characteristics of hand lines used for targeting species in the Persian Gulf.

Mainline	Material: monofilament nylon Dimension: diameter 0.8 mm; length 91.44 m
Snood	Material: wire cable Dimension: diameter 2 mm; length 0.5 m
Hook	J-style: sizes of 4/0, 5/0, 7/0, and 8/0 Circle Mustad: sizes of 4/0, 5/0, 7/0, and 8/0
Bait	Natural: piece of squid Artificial: plastic lure looking like squid
Swivel	Mounting: attached between mainline and snood to connect the hook to the snood Number: two
Sinker	Material: lead Weight: ~2 kg

3 Results

3.1 Catch composition

In total, 1306 fish with a total weight of 3886.95 kg were caught during 171 experimental hand line fishing trips in the Persian Gulf (Table 2). The catch contained 26 fish species belonging to 20 families (Fig. 1). *Scomberomorus commerson* was the most landed species by weight for J-style hooks with natural and artificial baits. For circle hooks with natural bait *Lethrinus nebulosus* was the most abundant species in weight, while it was *Scomberoides commersonnianus* for circle hooks with artificial bait. Two species, *Alectis indicus* and *Sphyraena jello*, were taken by all hook and bait types, while two other species, *Thunnus tonggol* and *S. commersonnianus*, were caught exclusively with artificial bait (Fig. 1).

Species abundances differed significantly between natural and artificial baits (χ^2-test, $p < 0.05$) and also circle and J-style hooks (χ^2-test, $p < 0.05$). The species in the different treatments (pairwise comparisons) that were responsible for the dissimilarity in catch composition in numbers are shown in Table 3. *S. commersonnianus* contributed to differences between natural and artificial bait for both hook types, while it was *S. commerson* for hook types. The largest dissimilarity was found between J-style hooks with artificial bait and circle hooks with natural bait.

Table 2. Main catch data for fishing trips with different treatments.

Catch	Treatment			
	J-hook natural bait	J-hook artificial bait	Circle hook natural bait	Circle hook artificial bait
Number of fishing trips	57	39	47	28
Total fishing time (h)	415	260	140	115
Total number of individuals	423	303	359	221
Total weight (kg)	1985.5	1126.82	405.3	369.33
CPUE (kg/hook/h) ± SD	0.9772 ± 0.25	0.7772 ± 0.26	0.5688 ± 0.32	0.4108 ± 0.23

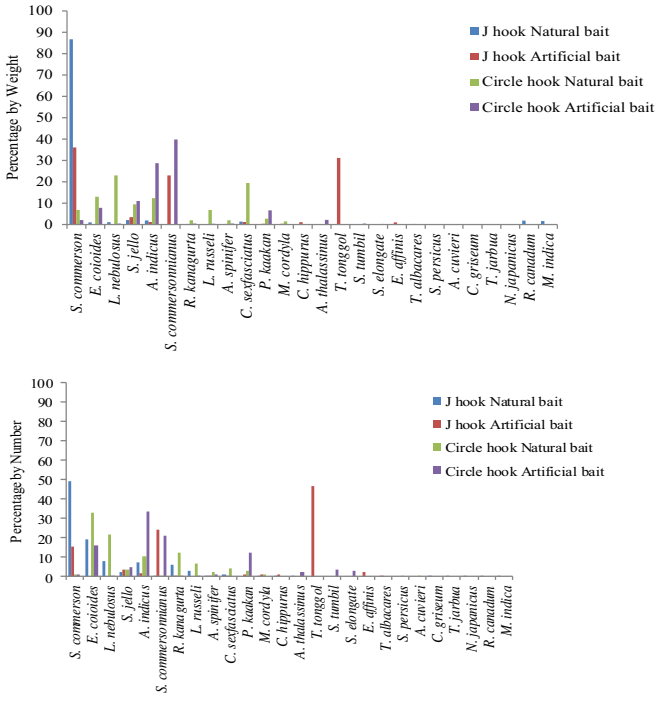

Fig. 1. Catch composition of different treatments by weight and numbers in Qeshm Island, northern Persian Gulf.

3.2 Number of individuals caught below length-at-maturity

The percentage of individuals caught below length-at-maturity (L_m) differed between hook and bait types and ranged from 0 to 100 (Table 4). This proportion could not be determined for some of the species due to the small number of specimens. The results indicated that hand line selectivity was satisfactory for *S. commersonnianus*, *S. commerson*, and *A. indicus* for all four treatments. However, for some other species such as *T. tonggol* and *Epinephelus coioides*, the majority of the caught individuals were smaller than L_m. For *L. nebulosus*, the percentage of individuals smaller than L_m differed significantly between the circle and J-style hooks (χ^2-test, $p < 0.05$) but for other species, the results were not different for different hook and bait types (χ^2-test, $p > 0.05$).

The length frequency distributions of all species were compared between treatments. Larger individuals of *A. indicus* were caught significantly more by J-hooks with artificial bait ($p < 0.05$). In the case of *L. nebulosus*, significantly larger individuals were caught by circle hooks with natural bait ($p < 0.05$). But for other species, no significant differences were observed ($p > 0.05$). Based on the results, J-hooks with natural bait caught the largest individuals of *S. commerson*, compared to other treatments.

3.3 Overall catch rates and diversity

Hook and bait types had significant effects on overall catch rates for all species combined ($p < 0.05$, Table 5) (Fig. 2). There was no significant interaction between hook type and bait type for overall mean CPUEs ($p > 0.05$). Thus, J-style hooks with natural bait gave the highest catches, while circle hooks with artificial bait gave the lowest. The results were somewhat different for diversity.

The greatest species diversity was obtained using circle hooks with natural bait and the smallest for J-style hooks with artificial bait (Fig. 3, $p < 0.05$).

4 Discussion

Many studies comparing J-style hooks with circle hooks have found significant differences in catch rates (Woll et al., 2001; Prince et al., 2002; Skomal et al., 2002; Cooke et al., 2003; Alós et al., 2009; Afonso et al., 2011; Curran and Bigelow, 2011; Hannan et al., 2013), while in several other studies no differences were found (Mapleston et al., 2008; Carvalho et al., 2015). In the present study, J-style hooks also had higher catch rates and CPUEs, compared to circle hooks. According to the results, the best treatment in terms of catch rates was the J-style hook with natural bait.

The large number of species (26) and diverse catch composition of landed fish revealed that fishers seem to consider a large part of their catch as target species. However, no information on discarded fish was collected in this study. Catch compositions were dominated by *S. commerson*, *S. commersonnianus*, *A. indicus*, *L. nebulosus*, and *E. coioides*, which made up about 85% of the landed biomass. This catch composition was consistent with published studies from other tropical areas (Low et al., 1985; Ralston et al., 1986; Ali et al., 2004; Mongeon et al., 2013; Zimmerhackel et al., 2015). Handlining is mostly performed in tropical waters and around coral reefs and related to atolls, which have similar species compositions. In our study, catch composition significantly

Table 3. Pairwise comparison of catch compositions (in numbers) for different hand line hook and bait types (treatments).

Treatment comparison	Dissimilarity (%)	Species responsible for dissimilarity
J-artificial vs. J-natural	48	*S. commersonnianus*, *E. coioides*, *L. nebulosus*, *L. russellii*
J-natural vs. circle-natural	30	*S. commerson*, *P. kaakan*, *A. spinifer*, *L. nebulosus*
J-artificial vs. circle-natural	58	*S. commersonnianus*, *E. coioides*, *L. nebulosus*, *S. commerson*
J-natural vs. circle-artificial	53	*S. commerson*, *S. commersonnianus*, *P. kaakan*, *L. nebulosus*
J-artificial vs. circle-artificial	48	*E. coioides*, *S. commerson*, *A. indicus*, *S. tumbil*
Circle-natural vs. circle-artificial	44	*S. commersonnianus*, *L. nebulosus*, *R. kanagurta*, *L. russellii*

Table 4. Mean length and length range, and percentage of individuals caught below length-at-maturity (%L_m) in Qeshm Island, northern Persian Gulf. L_m values from Froese and Pauly (2015).

Species	L_m (cm)	J-hook natural bait		J-hook artificial bait		Circle hook natural bait		Circle hook artificial bait	
		Mean length; range (cm)	%L_m	Mean length; range (cm)	%L_m	Mean length; range (cm)	%L_m	Mean length; range (cm)	%L_m
S. commerson	85	109.3; 45–215	9.6	106.9; 44–140	10.6	–	–	–	–
S. jello	53	82; 38–119	10	81.3; 40–110	20	67.3; 42–112	46	80.8; 50–110	9
S. commersonnianus	46	–	–	79.25; 63–95	0	–	–	76.9; 50–100	2
A. indicus	32	45.6; 20–62	13	57; 48–73	0	47.8; 25–75	10	47.3; 25–67	9
L. nebulosus	28	31.7; 20–50	39.4	–	–	42.9; 20–61	9	–	–
E. coioides	45	25.4; 15–35	100	–	–	30.6; 15–65	88	38.6; 15–55	57
L. russellii	39	27.5; 18–65	92	–	–	39.6; 20–76	60	–	–
P. kaakan	32	–	–	–	–	42; 33–50	0	40.9; 25–60	11
T. tonggol	73	–	–	42.5; 25–70	100	–	–	–	–

Table 5. Analysis of variance results for the effects of hook and bait type on total CPUE in Qeshm Island, northern Persian Gulf.

	Sum of squares	df	Mean square	*F*	*p*-value
Hook	0.732	1	0.732	10.177	<0.001
Bait	0.015	1	0.015	0.211	0.045
Hook × bait	0.040	1	0.040	0.560	0.46
Error	2.303	32			
Total	18.655	35			

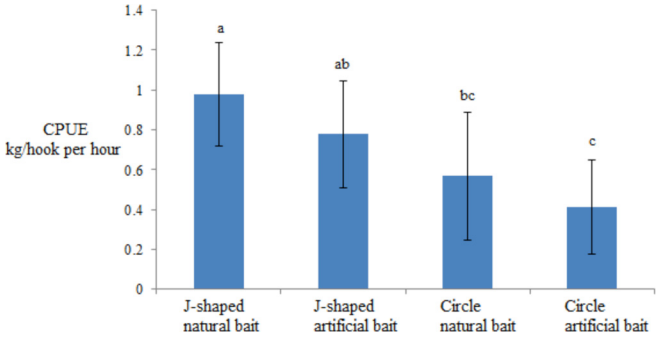

Fig. 2. Comparison between mean CPUEs ± SD for four treatments (J or circle hooks and natural or artificial bait) from experiments carried out in Qeshm Island, northern Persian Gulf. Letters represent pairwise significant differences between treatments. For example, 'ab' means J-hooks with artificial bait were significantly different only with circle hooks with artificial bait.

differed between circle and J-style hooks, and also between natural and artificial baits. Rules specifying permitted bait types have been used as a management tool leading to differences in catch rates, catch composition and CPUE (Løkkeborg and Bjordal, 1992; Broadhurst and Hazin, 2001; Arlinghaus et al., 2008; Alós et al., 2009). The type of bait is an effective factor for influencing species selectivity in hand line fishing because nutritional attractions and stimulants are species-specific (Løkkeborg et al., 2014). In this study, it was observed that some of the species, such as *S. commersonnianus*, were caught exclusively with artificial bait and some other species, such as *L. nebulosus*, were caught mostly with natural bait.

4.1 Length frequency and length-at-maturity

Length frequency distributions did not differ between treatments for most species. Erzini et al. (1997) also found that the type of the bait did not have a significant effect on the length frequency distribution of the caught species. However, in the case of *S. commersonnianus*, artificial bait attracted more individuals. In most fisheries in which small-sized individuals

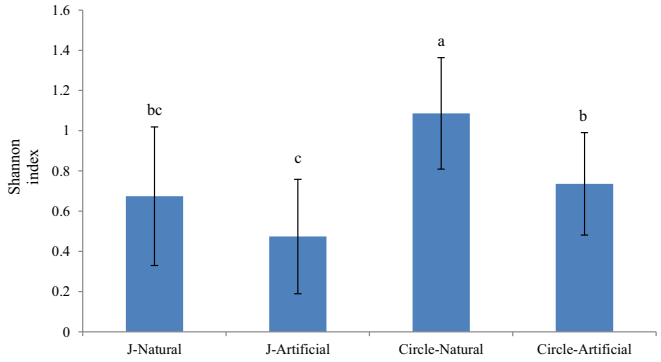

Fig. 3. Comparison of mean Shannon species diversity indices (±SD) amongst treatments (J or circle hook and natural or artificial bait) for experiments carried out in Qeshm Island, northern Persian Gulf. Letters represent pairwise significant differences between treatments.

are caught, it is preferable to use more natural baits. In fact, small-sized species will not bite on artificial baits (Alós et al., 2009).

The mean length of *L. nebulosus*, *E. coioides*, *A. indicus*, *S. commersonnianus*, *Lutjanus russellii*, and *Pomadasys kaakan* caught by pots in Saudi Arabian waters were 32, 35, 32, 46, 35, and 30 cm, respectively (Tharwat and Al-Gaber, 2006). Paighambari et al. (2014) reported that in Hormozgan's waters, most species in the pound net fishery were below minimum landing size. The mean lengths of *E. coioides*, *A. indicus*, *L. russellii*, *P. kaakan*, *S. jello*, and *S. commerson* caught by trawl in Hormozgan waters were 31, 15, 24, 15, 30, and 39 cm, respectively (Eighani and Paighambari, 2013). Erzini et al. (1997), comparing the length frequency of fish caught by monofilament gillnet with those caught with hooks, observed that larger fish were caught with hooks and that fishing with hook reduced the number of immature and undersized individuals significantly. The present results demonstrated significant differences between the size compositions of catches taken by hand line and other fishing gears. The hand line, however, caught fewer individuals that were smaller than length-at-maturity.

In recent years, fishermen have raised concern about unsustainable exploitation of highly vulnerable species by hand line fisheries. *E. coioides* and *T. tonggol* are listed as threatened species by the International Union for Conservation of Nature Red List (IUCN, 2016). The results of this study showed that compared to other species, for *E. coioides* and *T. tonggol*, a larger proportion of individuals were below length-at-maturity (L_m). In multispecies fisheries catching a diverse range of species more than focusing on overall selectivity, it is important to decrease the exploitation of individuals below L_{m50}, as well as endangered species (Gillett, 2011). The simplest and cheapest management tool for reducing catching small individuals is to increase the size of hooks and the bait.

The impact of fishing on elasmobranch (sharks and rays) and sea turtle stocks around the world is currently the focus of considerable international concern. In this study, no elasmobranches or turtles were caught although they occur in the study area. To select the most suitable type of hook and bait for the hand line fishery, in addition to catch rates, other ecological factors such as bycatch mortality and survival rates should be considered. For example, circle hooks have significantly lower mortality rates than J-hooks (Domeier et al., 2003; Horodysky and Graves, 2005; Afonso et al., 2011). Further studies will be required to compare bycatch mortality between circle and J-hooks in the Persian Gulf hand line fishery.

Catch rates, catch composition and length frequency distributions are affected by type and size of the hook (Anon, 1983; Erzini et al., 1999), catch strategy (Bjordal and Løkkeborg, 1996), type and size of bait (Moreno et al., 1992; Bjordal and Løkkeborg, 1996), and the use of various swivels and buoys. Therefore, each of these variables needs to be evaluated separately and monitored in the fishery.

5 Conclusion

The hand line method is performed in Qeshm Island, northern Persian Gulf all year round. Most of the inhabitants of this coastal region make a living through this type of fishing. We tried to optimize the hand line method by comparing two hook types and two bait types. The results showed that J-style hooks with natural bait had the highest catch rates and CPUEs. The commercially most important fish species in the Persian Gulf hand line fishery is *S. commerson* which is caught mostly with J-hooks with natural bait. Length frequency distributions and the percentage of individuals below the length-at-maturity (L_m) showed that the hand line method caught bigger individuals compared to pots (Tharwat and Al-Gaber, 2006), pound nets (Paighambari et al., 2014) and trawls (Eighani and Paighambari, 2013). However, for *E. coioides* and *T. tonggol* for which a large percentage of individuals was below L_m, it is proposed that an increase in hook and bait size should be studied. Once this issue is resolved, the development of hook fishing could be valuable both for the environment and for the fishermen in the region.

Supplementary Material

Supplementary file supplied by authors. The Supplementary Material is available at https://www.alr-journal.org/10.1051/alr/2017007/olm.

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