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Effect of changes in hook pattern and size on catch rate, hooking location, injury and bleeding for a number of tropical reef fish species

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Abstract

The Queensland Great Barrier Reef line fishery in Australia is regulated via a range of input and output controls including minimum size limits, daily catch limits and commercial catch quotas. As a result of these measures a substantial proportion of the catch is released or discarded. The fate of these released fish is uncertain, but hook-related mortality can potentially be decreased by using hooks that reduce the rates of injury, bleeding and deep hooking. There is also the potential to reduce the capture of non-target species though gear selectivity. A total of 1053 individual fish representing five target species and three non-target species were caught using six hook types including three hook patterns (non-offset circle, J and offset circle), each in two sizes (small 4/0 or 5/0 and large 8/0). Catch rates for each of the hook patterns and sizes varied between species with no consistent results for target or non-target species. When data for all of the fish species were aggregated there was a trend for larger hooks, J hooks and offset circle hooks to cause a greater number of injuries. Using larger hooks was more likely to result in bleeding, although this trend was not statistically significant. Larger hooks were also more likely to foul-hook fish or hook fish in the eye. There was a reduction in the rates of injuries and bleeding for both target and non-target species when using the smaller hook sizes. For a number of species included in our study the incidence of deep hooking decreased when using non-offset circle hooks, however, these results were not consistent for all species. Our results highlight the variability in hook performance across a range of tropical demersal finfish species. The most obvious conservation benefits for both target and non-target species arise from using smaller sized hooks and non-offset circle hooks. Fishers should be encouraged to use these hook configurations to reduce the potential for post-release mortality of released fish.

Keywords: Circle hooks; Reef line fishery; Hook location; Post-release survival; Great Barrier Reef

1. Introduction

Hook and line fishing gear are commonly used in many tropical reef finfish fisheries worldwide. The Great Barrier Reef (GBR), off the east coast of Australia, is the largest coral reef ecosystem in the world and supports important commercial, recreational and charter line fisheries. The commercial fishery has an annual value of about AU$60-100 million, primarily supplying common coral trout (*Plectropomus leopardus*) for the live food fish trade in Asia. The commercial sector each year harvests around 3000 tonnes (t) of demersal reef fish, with large quantities also harvested by recreational (2000 t) and charter (300 t) sectors (Begg et al., 2005). The main target species for all sectors of the fishery are common coral trout (*Plectropomus leopardus*) and redthroat emperor (*Lethrinus miniatus*), with the importance of other species such as red emperor (*Lutjanus sebae*), saddle tailed and crimson snapper (*L. malabaricus* and *L. erythropterus*) and serranids other than coral trout varying among sectors and regions (Mapstone et al., 1996; Higgs, 2001). This multi-sector, multi-species fishery is regulated through a variety of management strategies including spawning closures, minimum and maximum size limits for all sectors, total allowable

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commercial catches, and recreational and charter bag limits. Fish caught by recreational and commercial fishers are not always retained, either because of fisheries regulations (i.e. quotas, size and bag limits), poor eating quality, damage caused by attacks from other fish or sharks during capture, recreational catch-and-release fishing and/or ethical reasons. The number of fish released by recreational fishers as a proportion of the total catch varies between species (e.g. red emperor, 68.1%; coral trout, 35.3%; Henry and Lyle, 2003). The number of fish released by the commercial sector varies between regions and species, and may be influenced by high-grading, particularly in the live food fish fishery for common coral trout. An important goal identified by managers and stakeholders of line fisheries in Australia is to increase the survival of released fish (McLeay et al., 2002). One factor contributing to injuries and mortality of released or discarded fish from line fishers is hook type (Diggles and Ernst, 1997; Ayvazian et al., 2002; Falterman and Graves, 2002; Bacheler and Buckel, 2004). A number of recent studies have investigated differences in catch rates, hooking location and rates of injury when using circle hooks and J hooks for both recreational (Prince et al., 2002; Skomal et al., 2002; Cooke et al., 2003) and commercial line fisheries (Falterman and Graves, 2002; Bacheler and Buckel, 2004). These studies have been prompted on the basis of the perceived conservation benefits of using circle hooks, which include reduced post-release mortality, fish frequently hooked in the jaw facilitating easier hook removal, reduced gut hooking, and reduced catch of non-target species. Although some evidence supports these claims, the effectiveness of circle hooks is not consistent across all fisheries or species (Cooke and Suski, 2004). The wide variety of sizes and configurations produced by hook manufacturers adds to the difficulty of making general statements about the effects of hooks. Hook size has been found to be important when considering issues such as selectivity and hooking location (Ralston, 1990; Otway and Craig, 1993; Bacheler and Buckel, 2004), and variation in the degree of offset (deviation of the hook point relative to the shank) can also alter the effectiveness of circle hooks (Prince et al., 2002; Ostrand et al., 2005).

Our objective was to determine the effect of circle hook configurations on the sustainability of the GBR line fishery. Circle hooks have provided conservation benefits through reduced deep hooking and reduced mortality for a number of other fisheries. The applicability of circle hooks for the GBR line fishery has not previously been tested and the effects of popular hook types currently used in the fishery on factors affecting mortality are not known. Empirical data, therefore, are needed to determine the potential value of using circle hooks within this fishery as a strategy to reduce hook-related mortality. We examine catch rate, hooking location, incidence of bleeding and injury for six commonly used hook types including three patterns and two sizes for each pattern, across a range of target and non-target tropical fish species.

2. Materials and methods

Between 14 January and 19 October 2005 we conducted 19 dedicated fishing trips aboard fisheries research vessels to four separate locations off the east coast of Queensland (Fig. 1).

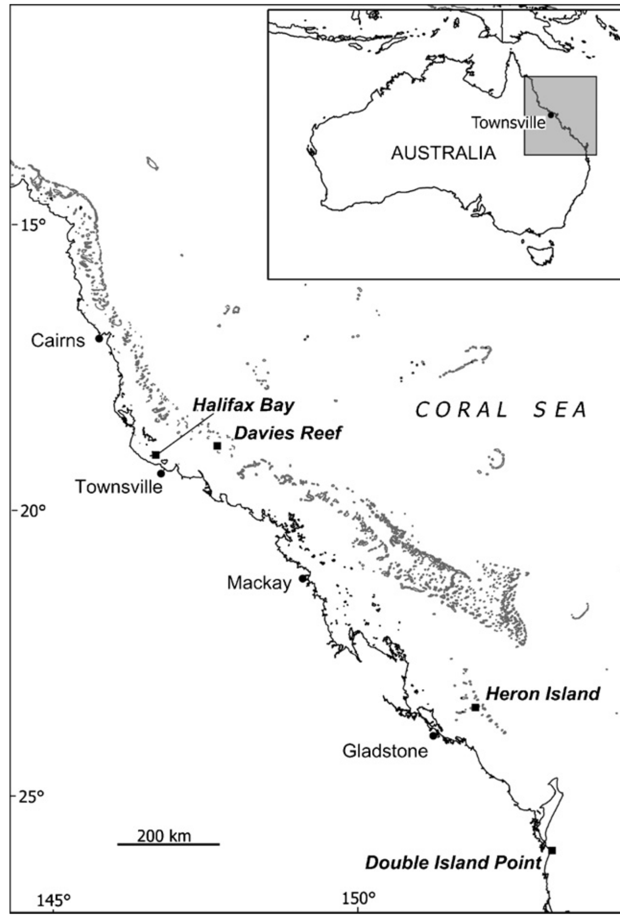

Fig. 1. Map of fishing locations for hooking studies.

Suitable fishing locations were chosen following analysis of commercial and recreational catch records and consultation with local fishers regarding areas where consistent catches of harvested finfish species could be expected. Common coral trout were targeted at Davies Reef in the central GBR in depths from 9 to 29 m. Crimson snapper and saddletail snapper were targeted from a submerged wreck in Halifax Bay, in the central GBR at a depth of 20 m. Redthroat emperor were targeted offshore from Heron Island in the southern GBR at depths from 8 to 20 m. Red emperor were targeted offshore from Double Island Point in southern Queensland in depths from 45 to 50 m. Included in the catch were a number of non-target species of which the three most abundant species or species group have been included in the analysis. These include blue spotted rock cod (*Cephalopholis cyanostigma*), blackblotch emperor (*Lethrinus semicinctus*) and a number of species of trevally (Family Carangidae) which have been aggregated into a single group for the purpose of analysis.

Fishing gear used for the hooking experiments included a rod (Penn Mariner medium action spin rod) and reel (Penn Powerspin 7000) spooled with 15 kg monofilament line and handline (Seahorse® 200 mm Professional Caster Extra Strength) spooled with 25 kg monofilament line. These fishing gears were typical of those used by recreational and commercial fishers targeting demersal reef fish in the study areas. Commercial fishers typically use larger size (∼8/0) J hooks with handlines and monofilament line (∼25–30 kg). In contrast recreational and charter fishers use a greater diversity of hook sizes and patterns and are more likely to fish with rod and reel. For the purpose of our study a total of six hooks were used: size 4/0 and 8/0 J (both J hooks were Mustad 4190); 5/0 and 8/0 12° offset circle hooks; and 5/0 and 8/0 0° offset circle hooks. Except the modified 0° offset circle hooks, each hook pattern was recommended by recreational or commercial fishers and was available from local tackle shops. Recreational fishers preferred Gamakatsu Octopus circle hooks which are manufactured with thin-gauge wire and a 12° offset. For the purpose of this study the offset was removed by bending the hooks with pliers. The gape widths of the J hooks and circle hooks were similar within the small and large size classes. Fishing rigs consisted of a single hook tied to the end of the line with one or two size 4 (27 g) or 5 (65 g) running ball sinkers. These rigs are consistent with those used by both recreational and commercial fishers targeting demersal reef fish.

Research staff supervised between two and five fishers during each of the fishing trips. Fishing was structured so that each hooking trial equated to a 3 h fishing session. Each fisher was randomly assigned one of the six hook types at the start of a fishing session and thereafter followed a sequential order. Fishing time was standardised to 30 min per hook type, which was termed a 'hang' as the vessel was anchored in one spot during this time. Each fishing session was divided into six half-hour hangs. The vessel was moved to a new location at the end of a 30 min hang if no fish were caught or catch rates were low. Frozen pilchards (*Sardinops* sp.) were used as bait (∼150–170 mm total length) and baits were cut to be proportional to the size of the hook. When fish were landed the following information was recorded: (1) species; (2) fork length (mm); (3) either anatomical hooking location (lip, mouth, throat, gut, eye), or foul hooked if the hook lodged outside the mouth; (4) injuries sustained (pierced eye, damage to either the gills or jaw); and (5) bleeding (yes, no). Injury data were aggregated into two categories (injured or not injured), and hooking location was aggregated into three categories for analysis (shallow, lip and mouth; deep, throat and gut; other, eye and foul hooked). The grouping of hooking location is consistent with other studies which have shown a correlation between mortality and deep hooking in the gills, oesophagus or throat (Muoneke and Childress, 1994; Diggles and Ernst, 1997; Millard et al., 2003). Fish were unhooked using pliers or de-hookers, then tagged with unique identifiable dart tag and released. If a fish was gut-hooked, the hook was left *in situ* by cutting the line close to the fish's jaw.

Table 1
Target and non-target species included in the analysis and number caught

Common name	Scientific name	Total
Target species		
Crimson snapper	*Lutjanus erythropterus*	403
Common coral trout	*Plectropomus leopardus*	161
Saddletail snapper	*Lutjanus malabaricus*	136
Redthroat emperor	*Lethrinus miniatus*	53
Red emperor	*Lutjanus sebae*	49
Non-target species		
Trevally	*Carangid* spp.	95
Blackblotch emperor	*Lethrinus semicinctus*	83
Blue spotted rock cod	*Cephalopholis cyanostigma*	73

Data were analysed under the generalized linear model framework (McCullagh and Nelder, 1989), using GenStat (2005). Binary responses (proportions of fish injured or bleeding) were analysed assuming the Binomial distribution with the logit link, and count data (catch rates and aggregate hooking locations) were analysed with the Poisson distribution and a log link. In both models, the dispersion was estimated from the residual mean deviance. Model terms included trip and fisher (as fixed main effects), hook pattern and hook size along with their interaction, and fish size. Common coral trout were divided into two size classes on the basis of their minimum legal size (MLS) of 380 mm TL (total length), while the remaining species were divided into two size classes on the basis of their sample median sizes. The resultant mean proportions and rates were thus balanced and adjusted for all the other terms in the model. Where the overall treatment effect was shown to be significant ($P < 0.05$), least-significant difference (LSD) testing was conducted between the respective means. These analyses were conducted for each species separately, as well as for all species aggregated.

3. Results

3.1. Catch statistics

Following 25 fishing sessions, 1053 fish representing the five target species and three non-target species were captured

Table 2
Mean catch rates (per half-hour hang) by hook pattern and size for individual species and aggregated data including all species

	Hook pattern			Average S.E.	Hook size		Average S.E.
	Offset circle	J	Non-offset circle		Large	Small	
Common coral trout	1.11	1.68	1.06	0.29	1.39	1.18	0.27
Redthroat emperor	0.42	0.27	0.24	0.07	0.34	0.28	0.06
Crimson snapper	2.27	2.04	2.62	0.32	1.87[a]	2.74[b]	0.27
Saddletail snapper	0.88	0.6	0.82	1.31	0.74	0.79	1.31
Red emperor	0.95	0.57	0.78	0.31	0.65	0.9	0.31
Blue spotted rock cod	0.85	0.96	0.7	0.22	0.73	0.77	0.17
Blackblotch emperor	1.15[a]	0.39[b]	1.41[a]	0.26	0.54[a]	1.42[b]	0.23
Trevally	0.73	0.58	0.9	1.27	0.62	0.85	1.26
All species	2.54	2.28	2.81	0.18	2.18[a]	2.90[b]	0.14

Significant differences are indicated by superscripts – within rows and hook treatments, means with the same superscript are not significantly different ($P < 0.05$).

Table 3
Percentage of fish caught which were injured, by hook pattern, hook size and fish size for individual species and aggregated data including all species

	Hook pattern			Average S.E.	Hook size		Average S.E.	Fish size		Average S.E.
	Offset circle	J	Non-offset circle		Large	Small		Large	Small	
Common coral trout	4.56	4.69	2.56	2.71	8.44[a]	0.00[a]	1.66	4.50	2.30	2.13
Crimson snapper	14.4[a]	13.28[a]	4.69[b]	2.66	14.60	8.82	2.40	9.82	11.87	2.21
Saddletail snapper	0.00[a]	0.00[a]	8.42[b]	1.23	6.20	1.00	2.05	2.42	4.07	2.05
Red emperor	3.25	0.57	0.00	73.05	3.22	0.00	49.24	0.00	2.44	37.30
Blue spotted rock cod	4.75	7.16	4.52	4.61	9.35	2.03	3.59	2.93	7.35	3.55
Blackblotch emperor	0.00	5.08	0.00	1.39	4.27[a]	0.00[b]	1.75	0.00	2.60	1.08
Trevally	0.00	14.67	0.00	2.62	5.50	2.87	3.15	3.70	4.71	3.24
All species	6.90[a]	7.81[a]	3.69[b]	4.58	8.98[a]	3.91[b]	0.95			

Significant differences are indicated by superscripts – within rows and hook treatments, means with the same superscript are not significantly different ($P < 0.05$).

in sufficient numbers to be included in the analysis (Table 1). All of the red emperor (average fork length 314 ± 40 mm S.D.) were below the MLS of 550 mm TL and more than 98% of the catch of crimson snapper and saddletail snapper (fork length 305 ± 29 and 326 ± 29 mm, respectively) were below the MLS of 400 mm TL. 23% of the common coral trout landed (fork length 406 ± 71 mm) and 11.54% of the redthroat emperor (fork length 419 ± 62 mm) were below the MLS of 380 mm TL. There are no size limits for trevally (fork length 391 ± 127 mm), but all of the blue spotted rock cod (total length 245 ± 21 mm) and 6.1% of the blackblotch emperor (fork length 245 ± 13 mm) were below the MLS of 380 mm TL and 250 mm TL, respectively.

3.2. Catch rates

When data were aggregated across hook types the greatest number of fish of any one species landed during any hang was 24 crimson snapper (mean 7.75 ± 6.11 S.D.). The maximum number of individuals of any of the other seven species landed in any hang ranged from 5 to 12 (mean 2.81 ± 2.21). The effect of hook size on catch rate was significant for only crimson snapper ($P < 0.001$) and blackblotch emperor ($P < 0.001$), with small hooks producing higher catch rates than large hooks. In addition, hook pattern had a significant effect on catch rates of blackblotch emperor ($P = 0.003$) but none of the other species (Table 2). Catch rates were higher when using smaller hooks except for common coral trout and redthroat emperor (Table 2). When the data were aggregated across species it was apparent that hang ($P < 0.001$), fisher ($P < 0.001$) and hook size ($P < 0.001$) all had a significant effect on catch rates. There was no significant effect of hook pattern when data were aggregated ($P = 0.075$).

3.3. Injury and bleeding

Hook-related injuries were observed in 6% of the fish captured. Of these injuries, 42% were associated with the hook piercing the eye, 33.3% with torn flesh around the jaw and 24.7% with damage to the gills. These categories were aggregated for analysis into injured or not injured. Hook pattern had a significant effect of on injury rate in crimson snapper ($P = 0.012$) and saddletail snapper ($P = 0.008$). Offset circle and J hooks were more often associated with injuries than non-offset circle hooks (Table 3). Hook size had a significant effect on injury rates of common coral trout ($P = 0.003$). Larger hooks consistently caused more injuries than smaller hooks for all species, except trevally (Table 3). Except for common coral trout, small fish were more likely to be injured than large fish. When data were aggregated across species, hook pattern ($P = 0.023$) and size ($P < 0.001$) had a significant effect on injury rate.

Overall, 8.5% of fish landed were bleeding as a result of hooking. Bleeding was more often associated with shallow hooking (71.7%) than deep (14.2%) or other hooking (14.2%). Hook size affected bleeding for saddletailed snapper ($P < 0.001$), with larger hooks causing more bleeding. Larger hooks consistently caused more bleeding in all species (Table 4).

Table 4
Percentage of fish caught displaying bleeding, by hook pattern, hook size and fish size for individual species and aggregated data including all species

	Hook pattern			Average S.E.	Hook size		Average S.E.	Fish size		Average S.E.
	Offset circle	J	Non-offset circle		Large	Small		Large	Small	
Common coral trout	2.36	11.18	11.85	3.69	12.79	4.85	3.11	10.53	2.75	2.75
Redthroat emperor	7.10	0.00	0.00	2.07	6.53	0.00	2.84	0.00	7.10	3.08
Crimson snapper	15.41	14.89	16.98	3.18	16.73	15.21	2.72	17.31	14.34	2.59
Saddletail snapper	11.29	8.95	10.79	4.64	20.62[a]	2.72[b]	3.74	11.17	9.72	3.80
Red emperor	2.81	0.00	0.47	46.71	2.96	0.00	59.47	3.25	0.00	65.42
Trevally	4.37	9.99	4.36	4.53	2.35	9.80	9.23	6.66	5.34	3.97
All species	7.77	8.79	8.91	1.31	10.08	7.34	1.10			

Significant differences are indicated by superscripts – within rows and hook treatments, means with the same superscript are not significantly different ($P < 0.05$).

3.4. Hooking location

Fish were more likely to be shallow hooked (88.0%) than deep hooked (3.9%) or hooked at 'other' locations (8.1%). For the eight species, deep hooking ranged between 2.0% and 9.6% (Table 5). Hook size was a significant factor affecting hooking location for crimson snapper ($P < 0.001$) and blackblotch emperor ($P = 0.011$) small hooks being more often associated with shallow hooking and larger hooks with 'other' hooking locations (Fig. 2). When data were aggregated across species there was a significant effect of hook size ($P = 0.019$) on hooking location (Fig. 3). Small hooks were more likely to be associated with shallow hooking and larger hooks with hooking in 'other' locations. There was no effect of hook pattern on hooking location.

Table 5
Hook location data for each species, showing the percentage of records within each category

Species	Hook location		
	Deep	Other	Shallow
Common coral trout	5.00	4.38	90.63
Redthroat emperor	5.66	9.43	84.91
Crimson snapper	4.77	10.30	84.92
Saddletail snapper	4.41	3.68	91.91
Red emperor	2.04	6.12	91.84
Blue spotted rock cod	9.59	5.48	84.93
Blackblotch emperor	2.41	7.23	90.36
Trevally	2.20	5.49	92.31

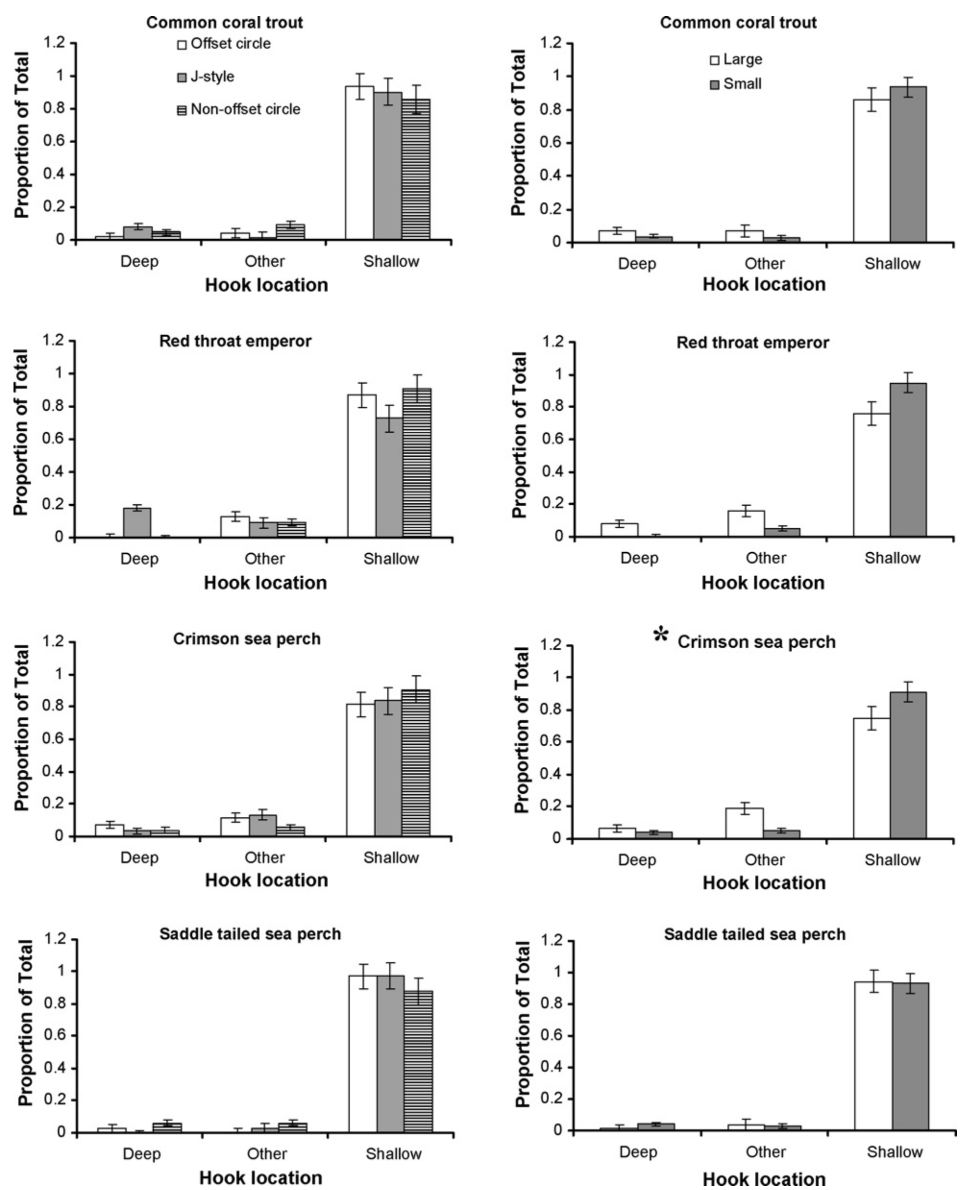

Fig. 2. Proportion of records for each hooking location for hook patterns and hook sizes for each species. Asterisks highlight species where differences in hooking locations between hook treatments were significant ($P < 0.05$).

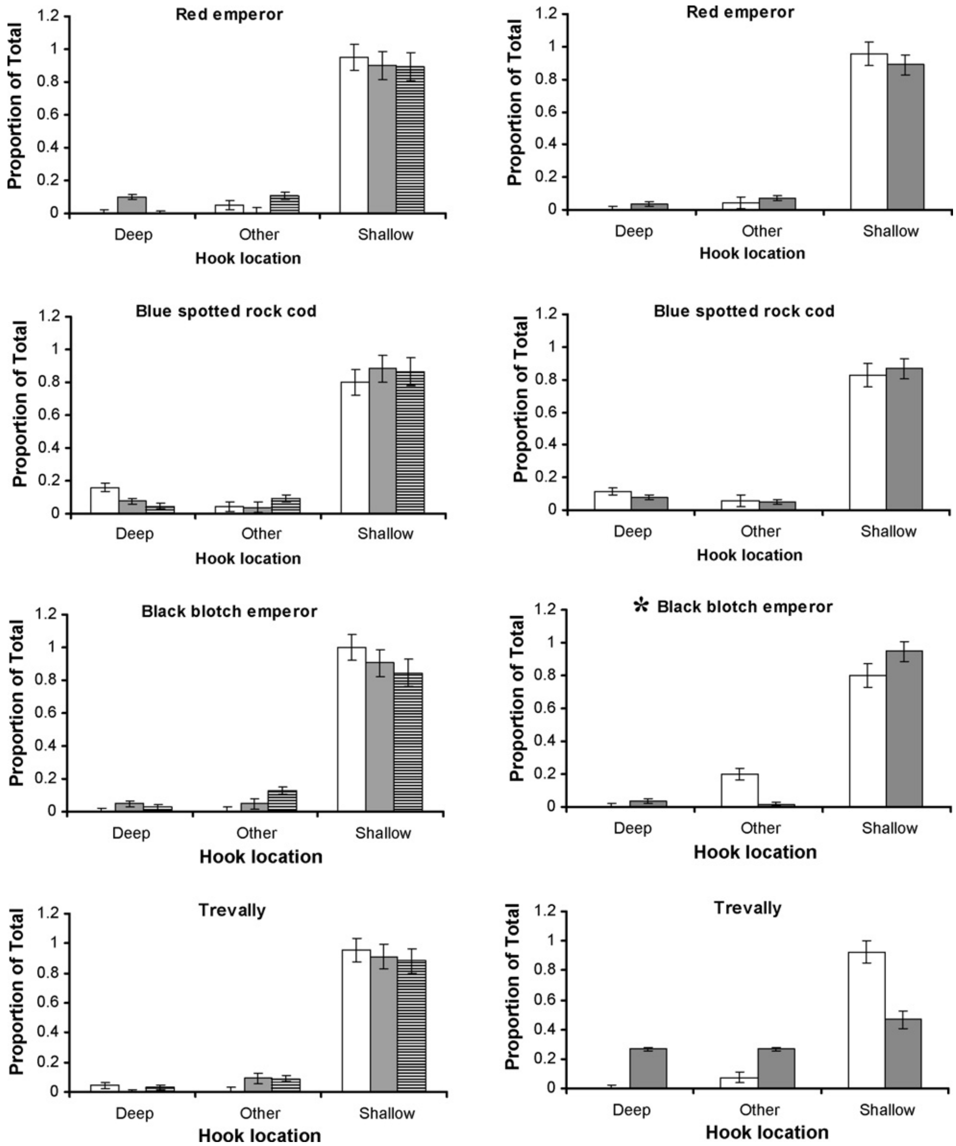

Fig. 2. (*Continued*).

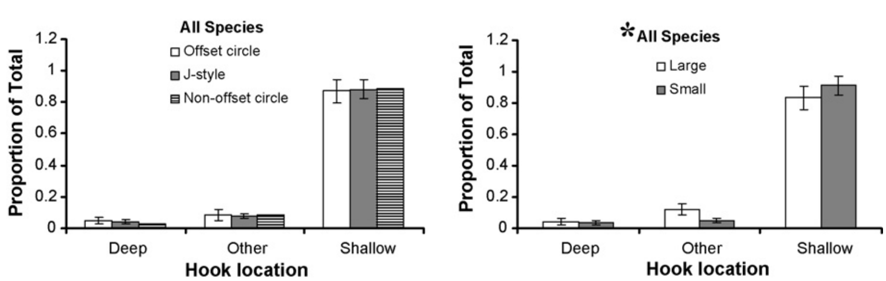

Fig. 3. Proportion of records for each hooking location when data were aggregated for all species included in the study. Asterisks highlight hook characteristics which resulted in significant differences in hooking location ($P < 0.05$).

4. Discussion

4.1. Catch statistics

The species included in our study represent a broad range of target and non-target species caught in the GBR line fishery. The results highlight the variability in effectiveness of different hook types within a multi-species fishery and provide some evidence for the promotion of smaller hooks and non-offset circle hooks as a means of reducing hook-related mortality. The majority (>98%) of saddle tailed and crimson snapper caught were below the MLS, as were all of the red emperors. All of these lutjanids share a similar life history, with juvenile fish schooling inshore and migrating offshore to deeper water with increasing age and size (Newman and Williams, 1996). For these species, fishing location will invariably affect the average size of fish caught, with more undersize fish likely to be caught on inshore grounds than offshore areas. Inshore grounds such as the one fished in our study are heavily utilised, particularly by recreational anglers either targeting these species or other species which use the same habitats. Therefore, the number of fish released from the catch may be very high for these species (Henry and Lyle, 2003).

4.2. Catch rates

There were few differences in the influence of the three hook patterns (non-offset circle, J and offset circle) or hook sizes (small 4/0 or 5/0 and large 8/0) on catch rates. No consistent trend was evident in the catch rate of any hook pattern for either the target or non-target species. Circle hooks did not always have the highest catch rates for target species. In fact J hooks caught the most common coral trout, the primary target species of the fishery, and for some species offset circle hooks out-fished non-offset circle hooks. Results from our study as in other studies, have shown that the effects of circle hooks on capture efficiency are not consistent across species (Cooke and Suski, 2004).

In only two species (crimson snapper and blackblotch emperor) was there an effect of hook size on catch rate, with smaller hooks yielding higher catch rates. However, the majority of crimson snapper and blackblotch emperor were small fish, which could have affected the efficiency of the larger hooks. The smaller gape size of crimson snapper and blackblotch emperor may also explain why hook size was a factor affecting the catch rates for these species. The relationship between gape size and hook efficiency appears to be important for both of these species, with larger hooks also being more likely to foul-hook fish or hook fish in the eye suggesting that the larger hooks were not working effectively.

Currently, larger J hooks are more commonly used by commercial line fishers targeting common coral trout within the GBR line fishery. Results from our study indicate the use of larger J hooks within the commercial sector may be maximising the catch of common coral trout, but not limiting the harvest of non-target species such as blue spotted rock cod. These two serranids are not gape limited, being able to easily swallow the largest hooks used in this experiment. Similar results with regard to hook size have been reported for other serranid groupers caught in North Carolina (Bacheler and Buckel, 2004) and for hapuupuu (*Epinephelus quernus*) from the Hawaiian deep-sea handline fishery (Ralston, 1982). In both studies changes in hook size did not affect the number of serranids caught. Catch rates of blue spotted rock cod and other large-gape non-target species within the GBR multi-species line fishery are therefore unlikely to be affected by moderate changes in hook size.

4.3. Injury and bleeding

There was a consistent trend for larger hooks to cause more injuries for all species. Except for trevally, larger hooks were also responsible for a higher incidence of bleeding. When data were aggregated, J hooks and offset circle hooks were more likely to cause injuries than non-offset circle hooks. Both bleeding and injury are reliable predictors of post-release mortality in a number of fish species (Ayvazian et al., 2002; Malchoff et al., 2002; Domeier et al., 2003). The use of larger J hooks within the fishery, particularly by fishers targeting common coral trout, could be contributing to a greater rate of injury and bleeding among undersize and non-target fish being caught and released. There appears to be a trade-off, between the slight increases in catch rates of coral trout by using larger J hooks, and the substantial increase in injuries and bleeding for undersize and non-target species when using these hooks. The results from our study suggest that to maximise the conservation benefits for the fishery the use of smaller sized hooks will provide the greatest gain.

Injuries were more likely to occur to smaller fish which are likely to be released due to MLS regulations. There is a need to focus on reducing the rate of hook-related injury of smaller fish, particularly for the lutjanid species as discard rates for these species can be high (>50%) (Henry and Lyle, 2003). The discard rates for the three lutjanid species included in our study (>98%) are probably indicative of the inshore grounds which are fished primarily by recreational fishers either targeting these species or catching them as bycatch when targeting other species. The use of smaller hooks or non-offset circle hooks should be encouraged when fishing these grounds to reduce the incidence of injury and bleeding as well as foul hooking for these species.

4.4. Hooking location

There was a great deal of variation in the hook location across the different fish species, with no consistent trends for either target or non-target species. The results from our study contrast with other studies which have shown a clear relationship between circle hooks and hooking location, particularly for pelagic species such as billfish and tuna (Prince et al., 2002; Domeier et al., 2003; Kersetter and Graves, 2006). It is likely there is a relationship between hooking location, hook type and the techniques and gears used in the fishery. Typically within recreational billfish fisheries there are specific techniques associated with the use of circle hooks. Prince et al. (2002) noted that J hooks were set by jerking the rod vertically, while circle hooks were set by simply reeling the line tight as the fish swam away from the boat increasing the resistance to allow the hook to rotate and set. Within the GBR reef line fishery the application of this hook setting technique, particularly while fishing on or around reefs where there is an abundance of structure for fish to swim into and snag gear, may not be applicable given the current gear and targeting behaviour. Where the fishery operates in more open water the use of circle hooks should be encouraged, as the associated hook setting techniques may be more applicable.

Diggles and Ernst (1997) concluded that hooking location was the most important factor affecting mortality of two small reef fish species, wire netting cod (*Epinephelus quoyanus*) and yellow stripey (*Lutjanus carponotatus*) caught from the GBR. Hook location has also been a significant factor affecting survival of striped bass (*Morone saxatilis*) and chinook salmon (*Oncorhynchus tshawytscha*), with deep-hooked fish more likely to die than lip-hooked fish (Grover et al., 2002; Millard et al., 2003). The rates of deep hooking observed in our study varied between fish species, hook patterns and hook sizes. Although non-offset circle hooks resulted in a reduced rate of deep hooking when data were aggregated, this was not always the case for individual species. If shallow hooking is considered a positive outcome, with regard to hook location, there were no instances where non-offset circle hooks out performed the other hook patterns. This highlights the variability in the effectiveness of circle hooks across different species within this fishery.

Bacheler and Buckel (2004) reported that, compared to J hooks, circle hooks reduced the rate of gut hooking for grouper. However, results from our study showed no trend in the rate of deep hooking among similar serranids. The highest deep-hooking rates were associated with J hooks in common coral trout and offset circle hooks for blue spotted rock cod. For both these species there was a reduction in the rate of deep hooking when using non-offset circle hooks, although there was a higher rate of non-offset circle hooks lodging in ‘other’ hooking locations. The fishing gears and techniques used in our study were different to those used by Bacheler and Buckel (2004), and this could have reduced the effectiveness of circle hooks and contributed to the high incidence of ‘other’ hooking.

Hook size had an effect on hooking location for both crimson snapper and blackblotch emperor, with small hooks more often associated with shallow hooking and large hooks with ‘other’ hooking locations. These results are similar to those for catch rates where smaller hooks resulted in a higher catch rate for both species. It is likely that the smaller gape size of these species reduce the effectiveness of larger hooks leading to a greater rate of foul hooking or hooking in the eye. Other studies have shown that there is a strong correlation between hooking location and hook size with larger hooks more likely to hook fish in injurious locations. Cooke and Suski (2004) make the point that to work correctly, the entire circle hook needs to be ingested by the fish prior to setting the hook. Results from our study suggest that within a multi-species fishery such as the GBR line fishery it is more beneficial to use smaller sized hooks which will be more effective across a wider size range and for a greater number of species. The relationship between hook size and gape size appear to be important considerations when optimising the performance of hook patterns for conservation benefits (Cooke et al., 2005).

4.5. Conclusions

The rate of discarding and possibility of hook-related mortality remain a key concern for stakeholders in the GBR line fishery. Our results highlight the variability in performance of six hook types for a range of target and non-target demersal reef fish species, using gear and techniques consistent with the recreational and commercial fishery. The most consistent and obvious conservation benefits for the fishery resulted from using smaller hooks and non-offset circle hook patterns. As has been shown in other studies, there appears to be little benefit in promoting the use of offset circle hooks with no evidence of any beneficial effects for the sustainability of the fishery over and above those of non-offset circle hooks. However, recreational fishers preferred to use a circle hook pattern which has an offset. Fishers should be encouraged to use other circle hook patterns which do not have an offset, or alternately the hook can be bent to remove the offset prior to fishing.

We have shown that using smaller hooks could provide a positive benefit across the fishery by reducing the incidence of injury and bleeding of released fish for a number of target and non-target species. The conservation benefits of non-offset circle hooks within the GBR line fishery although apparent are not as clear as they have been for other fisheries and this is likely to be related to the gear and targeting behaviour of the fishers. The techniques used when setting circle hooks are different from those employed when using J hooks. Within the GBR line fishery there may be situations, other than targeting common coral trout and redthroat emperor in shallow waters around reefs which will suit the application of these hook setting techniques and circle hooks more readily.

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