Fisheries Management and Ecology

Fisheries Management and Ecology, 2010, **17**, 77–88

Assessing the effects of line capture and barotrauma relief procedures on post-release survival of key tropical reef fish species in Australia using recreational tagging clubs

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Abstract Common coral trout, *Plectropomus leopardus* Lacepède, crimson snapper, *Lutjanus erythropterus* Bloch, saddletail snapper, *Lutjanus malabaricus* (Bloch & Schneider), red emperor, *Lutjanus sebae* (Cuvier), red-throat emperor, *Lethrinus miniatus* (Schneider) and grass emperor, *Lethrinus laticaudis* Alleyne & Macleay, were tagged to determine the effects of barotrauma relief procedures (weighted shot-line release and venting using a hollow needle) and other factors on survival. Release condition was the most significant factor affecting the subsequent recapture rate of all species. Capture depth was significant in all species apart from *L. malabaricus* and *L. miniatus*, the general trend being reduced recapture probability with increasing capture depth. Recapture rates of fish hooked in either the lip or mouth were generally significantly higher than for those hooked in the throat or gut. Statistically significant benefit from treating fish for barotrauma was found in only *L. malabaricus*, but the

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 doi: 10.1111/j.1365-2400.2009.00722.x

lack of any negative effects of treating fish indicated that the practices of venting and shot-lining should not be discouraged by fisheries managers for these species.

KEYWORDS: released fish survival, shotline, tag and release, venting.

Introduction

In recent years, the desire to improve the survival of released line caught fish has been prompted by increasing rates of discarding as a result of fisheries management changes, including commercial catch quota, increased size limits and reduced bag limits (Higgs 1998, 2000; Henry & Lyle 2003; Welch *et al.* 2008). Efforts to improve the release survival have involved the use of different hooks (Diggles & Ernst 1997; Cooke & Suski 2004; Mapleston *et al.* 2008) and fishing methods, as well as the development of codes of handling and release practices (FSG (Florida Sea Grant) 1999; Arlinghaus *et al.* 2007). In many fisheries, barotrauma is also a major issue, particularly for those that take place in relatively deep water (Wilson & Burns 1996; St John & Syers 2005; Parker *et al.* 2006) where pressure change and associated expansion or bursting of the swim bladder can cause catastrophic physiological damage (Rummer & Bennett 2006) and subsequent high release mortality.

To reduce these barotrauma effects and to allow the fish to swim away from the water surface on release, many fishers either vent the fish (St John & Syers 2005) or attach a weight that drags the fish from the surface (shot-lining). Venting or fizzing is a widespread technique that involves puncturing the fish's swim bladder with a sharp object, usually a hollow needle, to release the gas. Shot-line release involves inserting a weighted, barbless hook (attached to a normal fishing line) into the fish's lip and allowing it to drag the fish to an appropriate depth where repressurisation can occur. A jerk on the line releases the hook and the fish swims away. Shot-lining is not as widespread a practice as venting, although in some parts of Australia and elsewhere it is being widely promoted as a method of ameliorating the effects of barotrauma (St John & Syers 2005; Theberge & Parker 2005). There has been recent debate on the efficacy of venting fish (Wilde 2009), although there have been few published studies that have assessed shot-line release as an alternative. One of the ways of investigating the effects of venting and other barotrauma treatments has been capture/recapture tagging studies (Wilde 2009) with recapture rates used as a surrogate measure of survival.

In Australia, recreational anglers maintain extensive databases of catch and release information as part of recreational tagging programmes administered by the Australian National Sportfishing Association (ANSA). At times, these programmes have successfully collaborated with research organisations studying recreational fish species to provide valuable fisheries management information (Sumpton *et al.* 2003; Russell & McDougall 2005; Zischke *et al.* 2009). The database contains information on many species including key tropical reef species such as common coral trout, *Plectropomus leopardus* Lacepède, crimson snapper, *Lutjanus erythropterus* Bloch, saddletail snapper, *Lutjanus malabaricus* (Bloch & Schneider), red emperor, *Lutjanus sebae* (Cuvier), redthroat emperor, *Lethrinus miniatus* (Schneider) and grass emperor, *Lethrinus laticaudis* Alleyne & Macleay. An earlier analysis of ANSA data collected up to 2003 (Sumpton *et al.* 2008) suggested that venting enhanced the release survival of both *L. sebae* and *L. malabaricus,* although only a small subset of anglers used the venting method, barotrauma symptoms were not recorded, shot-lining had not been trialled and there were inconsistencies in the information recorded by anglers. As a result of that analysis, major improvements were made to the data recording protocols and more comprehensive information was recorded.

At the time of these changes, a group of experienced ANSA anglers was recruited to assist researchers in an experiment to tag and administer barotrauma relief procedures to large numbers of key tropical reef fish species. Data collected with the aid of these anglers were used to test whether barotrauma relief procedures (shot-lining and venting) had any long-term impact on subsequent recapture rates. Factors likely to have influenced the survival of these species were investigated with recapture rates of the various treatment classes of tagged fish used as an indicator of relative survival rate. It is acknowledged that many other factors, including differential fishing effort among the species, may play a role in determining final recapture rate. Thus, recapture rate was not used as an indication of interspecies differences in post-release survival, but rather to compare the impacts of various factors within a species.

Materials and methods

A group of ANSA anglers (n = 56) who were experienced in tag and release procedures was recruited throughout Queensland, Australia, to assist researchers in structured experiments to determine the effects of two barotrauma relief procedures (shot-lining and venting) on the long-term survival of line caught tropical reef fish. Fishing was mainly conducted within the Great Barrier Reef (latitude 10°30′ S to 24°30′ S) on the north-east coast of Australia, but extended as far south as latitude 27° S (depth range 1–70 m).

Shot-line devices were constructed using a 450 g lead, tear drop, sinker with an embedded barbless Mustad 8/0 J-style hook. Venting tools were 16 gauge hypodermic needles as recommended by the Florida Sea Grant Program (http://www.flseagrant.org\science\venting\).

Anglers were individually contacted by project staff and trained in the use of the barotrauma relief procedures, although most were already experienced in the use of venting tools and adhered to current best practice fish handling techniques. When venting fish, anglers were advised to insert the needle under a scale at an angle of 45° to the side of the body, directly below the 4th dorsal spine and in line with the top of the pectoral fin. Project staff also maintained regular contact with the recreational anglers, stressing the need to adhere to the experimental protocols when releasing tagged fish.

Between September 2003 and September 2007, over 12 000 *P. leopardus*, *L. erythropterus*, *L. malabaricus*, *L. sebae*, *L. miniatus* and *L. laticaudis* were treated, tagged and released as part of the experiment. All fish were caught by hook and line, and most handled using a moist cloth to minimise injury and stress during hook removal and tagging. Fish were measured (± 1 cm), tagged and released, generally within 30 s of capture. Where fork lengths (FL, mm) were recorded these were converted to total lengths (TL) using morphometric relationships available from previous studies (McPherson & Squire 1992 for the lutjanids, Brown & Sumpton 1998 for *L. miniatus*) and others were taken from unpublished reports and FISHBASE (Froese & Pauly 2006). Location and date of capture were recorded.

Some fish were not treated and these served as controls. Others were treated either by releasing the fish using a shot-line device or venting the swim bladder with a hollow needle. The experimental design required anglers to use each of the treatments and a control on consecutive fish regardless of barotrauma symptoms so that there would be a balanced design across treatments (i.e. approximately equal numbers of shot-lined, vented and control releases). Individually numbered tags marked with the words ‘record date place length’ and a 24-h toll free telephone number, were inserted in the dorsal musculature and locked between the pterygiophores below the dorsal fin rays. Anchor tags (Hallprint™; 75 × 2 mm) and dart tags (Hallprint™, Hallprint Pty Ltd, Victor Harbour, South Australia; 91 × 2 mm) were used, depending on the size of the fish.

Barotrauma symptoms were recorded as one or more of the following categories: (1) no visible sign of barotrauma; (2) swim bladder inflated and stomach hard; (3) gut protruding from mouth and/or anus, exophthalmia (eyes bulging).

Hooking location, bleeding and injury were categorised according to Table 1 and anglers were provided with diagrams to aid in the objective recording of hooking location and injury. The size and type of hook, as well as capture depth were also recorded. Release condition was assessed subjectively as one of five categories according to the following criteria:

- no obvious damage from capture/handling, minimal time out of water (< 30 s), swam away strongly;
- some hook or handling damage, short time out of water, swam away well;
- moderate damage from hooking or handling, moderate scale loss, slow to swim away;
- long time out of water (> 30 s), major scale loss, long recovery time, fish turned upside down;
- no sign of recovery on release, floated away on surface or taken by a predator.

There were many instances where a fish was recaptured several times and released each time. These fish were only assumed to have been caught once in determining recapture rates, subsequent recaptures being excluded from the analyses.

Data analysis

Binomial generalised linear regression models (GLMs) with logit link function were used in GenStat (2007) to test the effect of various factors and covariates on

Table 1. Criteria used by anglers to classify tagged tropical line caught fish on the basis of hooking location, bleeding and injury

Hooking location	Bleeding	Injury
Lip or jaw	No bleeding	No damage
Inside mouth but not as far as throat	Light bleeding	Hooked in eye
Throat or gill hooked but hook visible	Copious dark red blood	Gill damage
Gut hooked with hook not visible		Jaw damage
Foul hooked (not in the mouth or jaw)		Moderate scale loss
		Heavy scale loss

recapture rate, with each fish species analysed individually. Two GLMs are presented for each species. The first (hereafter referred to as the condensed model) was used to test whether release condition and tagger affiliation (ANSA or research) were important contributing factors to the overall recapture rate of tagged fish. Release condition was confounded by the influence of other factors and could be regarded as encapsulating the combined effects of barotrauma, hooking injury and other capture variables. To account for this, a second GLM (hereafter referred to as the expanded model) was run with release condition replaced by contributing factors such as bleeding, hooking location, body size and injury. Two-way interaction terms were fitted in all models but aliasing and lack of data coverage across all categories allowed only main effects models to be analysed for some species. In general, data coverage was too limited to consider higher order interactions. Models were run in a stepwise manner with terms ordered according to their mean deviance and the resultant mean proportions of recaptures were adjusted for the other terms in the model.

Depth was treated as a second-degree polynomial variable in the models, apart from *L. erythropterus*, *L. malabaricus* and *L. miniatus* where data were categorised into two depth classes (< 23 and > 22 m), three depth classes (< 15, 16–30 and > 30 m) and two depth classes (< 21 and > 20 m), respectively because of different depth distributions. All other factors were analysed as categorical variables. In some cases, data were pooled when the number of observations in various categories was low ($n < 5$). These groupings are described for each species in the results that follow but in all cases the barotrauma category of extreme represents the aggregation of all individuals showing signs of exophthalmia and/or gut extrusion from either mouth or anus. Likewise, hooking location was classified into three groups with the aggregation of fish hooked in the mouth and jaw being grouped into a shallow hooking group and the remainder (other than those foul hooked outside the mouth) being grouped as deep hooked. Body size was categorised into two groups, usually on the basis of minimum legal size (MLS). Where an overall treatment effect or interaction was found to be significant ($P < 0.05$), least significant difference testing was used to compare paired means.

Results

Over the 4 years of the experiment, 12 761 fish were tagged and released by researchers and ANSA anglers. The research releases complying with experimental protocols accounted for 21% of the total releases (over 40% of the total *P. leopardus* and *L. miniatus* releases) and 57% of the usable treated releases over all species (Table 2). In some subsequent analyses, these data sets were further restricted to eliminate data from anglers that appeared to have a biasing influence on results because of misreporting, data recording inconsistencies or non-adherence to experimental protocols. For example, data from particular anglers who tagged large numbers of fish in one area and who regularly fished the same grounds or who disproportionately employed one treatment method were eliminated from subsequent analysis.

Lower recapture rates of control (untreated) *L. malabaricus* and *L. erythropterus* in the unadjusted raw data (Table 2) suggest that there may be benefit in treating these species. By contrast, barotrauma treatment may be detrimental to *L. sebae*, as the recapture rate for untreated fish (11.8%) was considerably greater than for either shot-lined (7.3%) or vented (6.8%) fish. The detailed models presented in the results that follow further explore the effects of barotrauma treatment, hooking injury and other factors on recapture rate of each species in greater detail.

All species (apart from *L. sebae*) were predominantly caught in depths < 40 m (Fig. 1), where over 80% of

Table 2. Numbers of tagged fish (T), recaptures (R) and percentage recapture rate (%) of tropical line caught species tagged and treated as part of the long-term release survival experiment between October 2003 and September 2007

Species	Not treated			Shot-lined			Vented			Total		
	T	R	%	T	R	%	T	R	%	T	R	%
Plectropomus leopardus	361	29	8.0	179	17	9.5	422	25	5.9	962	71	7.4
Lutjanus erythropterus	821	116	14.1	171	31	18.1	365	69	18.9	1357	216	15.9
Lutjanus malabaricus	651	65	10.0	99	16	16.2	248	32	12.9	998	113	11.3
Lutjanus sebae	3004	355	11.8	151	11	7.3	191	13	6.8	3346	379	11.3
Lethrinus miniatus	456	5	1.1	153	6	3.9	231	5	2.2	840	16	1.9
Lethrinus laticaudis	1112	51	4.6	18	0	0	58	3	5.2	1188	54	4.5
Total	6591	621	9.5	829	81	9.8	1595	147	9.4	9888	849	9.5

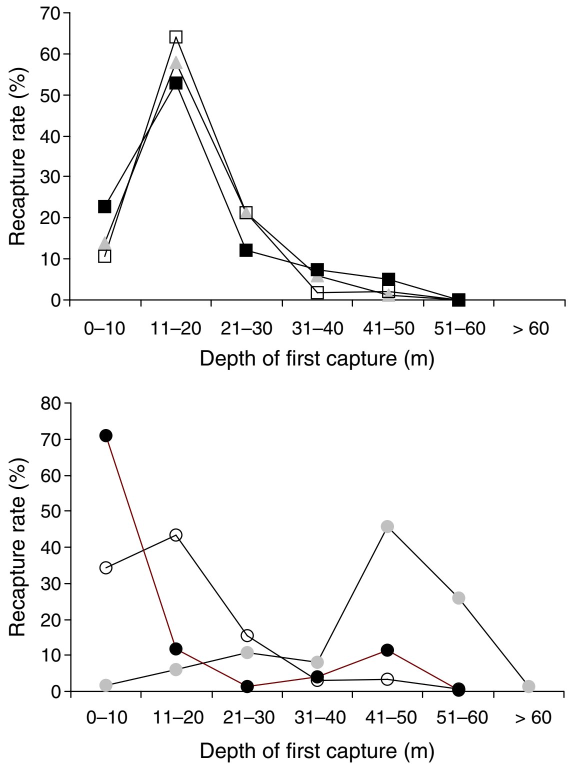

Figure 1. Recapture rate of *Plectropomus leopardus* (▲) (n = 993), *Lutjanus erythropterus* (□) (n = 1245), *Lutjanus malabaricus* (■) (n = 919), *Lutjanus sebae* (●) (n = 3265), *Lethrinus miniatus* (○) (n = 835) and *Lethrinus laticaudis* (●) (n = 1133) captured at a range of different depths and subsequently tagged by researchers or ANSA anglers.

tagging took place. The majority of *L. sebae* on the other hand were caught in depths exceeding 30 m and *L. laticaudis* was the only species caught mainly in water < 10 m deep.

*Common coral trout (*Plectropomus leopardus*)*

The condensed main effects model showed that release condition and barotrauma signs were the only significant factors affecting *P. leopardus* recapture (Table 3). Recapture rates declined with poorer condition of release (Fig. 2a), although fish of release condition 2 had the overall highest recapture rate; a result that was also reflected in the unadjusted summary results (Table 2). Fish with extreme symptoms of barotrauma were recaptured less frequently than those displaying no symptoms or less severe symptoms (Fig. 2b).

In the expanded model, barotrauma treatment was tested as an interaction term with barotrauma signs, as well as body size, but as none of these interactions was significant ($P > 0.1$) they were removed from the final model. *Plectropomus leopardus* were categorised into large and small on the basis of their MLS (38 cm TL). Both water depth and body size contributed significantly ($P < 0.05$) to *P. leopardus* recapture probability with fish above the MLS more likely to be recaptured (recapture rate of large fish = 0.119 ± 0.024 compared with 0.0496 ± 0.014 for small fish). Recapture rates declined at depths greater than 20 m (Fig. 3), but there were no significant barotrauma treatment effects

Table 3. Summary of probability values derived from generalised linear models. Factors significant at the 0.05 level are shown in bold. Missing cells indicate factors that were not included in the models because of aliasing, confounding or insufficient data contrast

	Plectropomus leopardus	*Lutjanus erythropterus*	*Lutjanus malabaricus*	*Lutjanus sebae*	*Lethrinus miniatus*	*Lethrinus laticaudis*
Condensed model						
Release condition	**< 0.005**	**0.005**	**< 0.001**	**< 0.001**	**0.002**	**0.001**
Barotrauma signs	**0.027**	**< 0.001**	**0.003**	0.064	0.080	0.446
Tagger affiliation	0.838	**< 0.001**	**0.001**	0.112	0.425	0.481
Treatment	0.167	0.567	0.397	0.433	0.326	0.869
Signs × Treatment			**0.016**			
Condition × Tagger			**0.001**			
Expanded model						
Depth	**0.021**	**< 0.001**	0.414	**< .001**	0.265	**< 0.001**
Barotrauma signs	0.163	**< 0.001**	**0.014**	0.106	0.207	0.104
Hook removed	0.076			0.646		0.534
Body size	**< 0.001**		0.692	0.430	0.112	0.403
Bleeding	0.232		**0.003**			
Tagger affiliation		**< 0.001**	**0.038**			
Hooking category	0.454	**0.022**	0.818	**0.013**		0.383
Treatment	0.248	0.388	0.585	0.329	0.055	0.337
Depth × Treatment		0.682				
Barotrauma signs × Treatment			**0.045**			

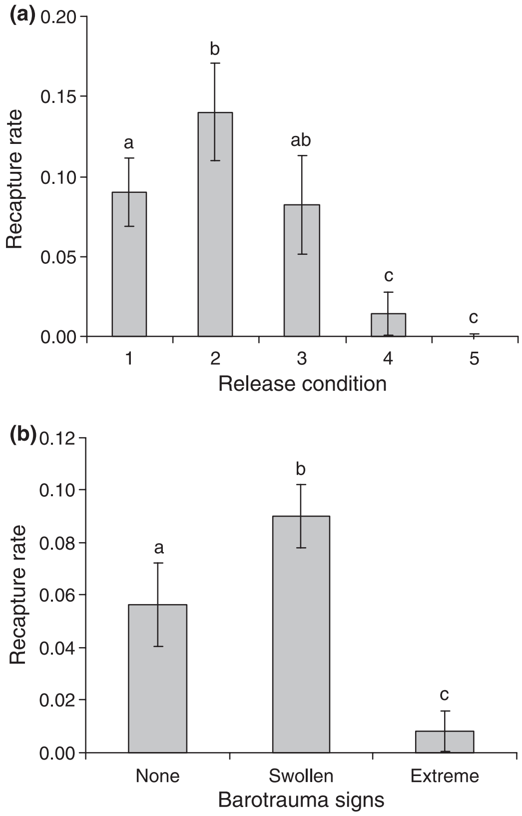

Figure 2. Adjusted mean recapture rate (±SE) of line caught *Plectropomus leopardus* for a range of (a) release conditions and (b) barotrauma signs categories. Bars with a common superscript are not significantly different ($P < 0.05$).

with adjusted recapture rates of 0.10 for untreated, 0.09 for shot-lined and 0.07 for vented fish.

*Crimson snapper (*Lutjanus erythropterus*)*

All factors, except for treatment, included in the condensed model had highly significant ($P < 0.001$) effects on the recapture rate of *L. erythropterus* (Table 3). The interaction between barotrauma signs and barotrauma treatment was also statistically significant ($P < 0.001$), but as these two factors were confounded by the greater application of relief procedures to fish that displayed barotrauma symptoms, the final model presented includes only the main effects. Recapture rate declined dramatically with poorer release condition of fish (Fig. 4a). Fish in the best release condition (condition 1) had more than twice the recapture rate of fish in poorer condition (condition 2, 3 or 4). Unexpectedly, fish displaying the extreme symptoms of barotrauma had significantly higher recapture rates than those that had no obvious barotrauma signs when they were first caught and tagged (Fig. 4b).

The main effects of depth, barotrauma signs, tagger affiliation and hooking location were statistically significant ($P < 0.05$) in explaining some of the deviance in recapture rate in the expanded model (Table 3). *Lethrinus erythropterus* showing symptoms of barotrauma also had higher recapture rates, although the adjusted mean of fish that had no signs was closer to the condensed model adjusted categories

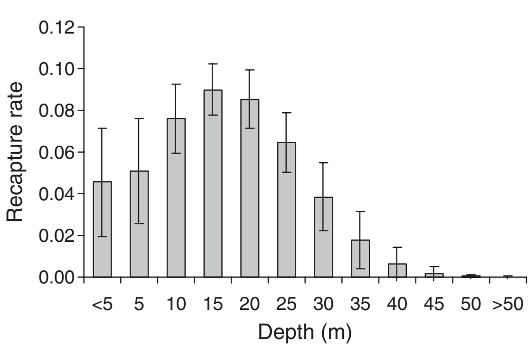

Figure 3. Adjusted mean recapture rate (±SE) of line caught and tagged *Plectropomus leopardus* captured from a range of depths.

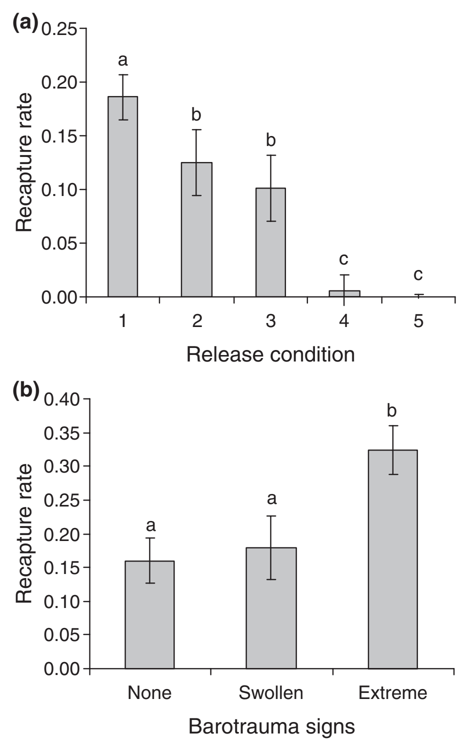

Figure 4. Adjusted mean recapture rate (±SE) for line caught *Lutjanus erythropterus* for a range of (a) release conditions and (b) barotrauma signs. Bars with a common superscript are not significantly different ($P < 0.05$).

than in the raw data (Fig. 5a). Recapture rate of researcher tagged fish was significantly greater than those tagged by recreational anglers (Fig. 5b). The apparent reduced survival of deep hooked *L. erythropterus* was also a feature of this species (Fig. 5c). The recapture rate of fish caught in < 24 m (0.18 ± 0.019) was significantly greater than those caught in deeper water (0.045 ± 0.031) but there were no significant treatment effects (adjusted recapture rates 0.16 for controls, 0.18 for shot-lined and 0.22 for vented fish).

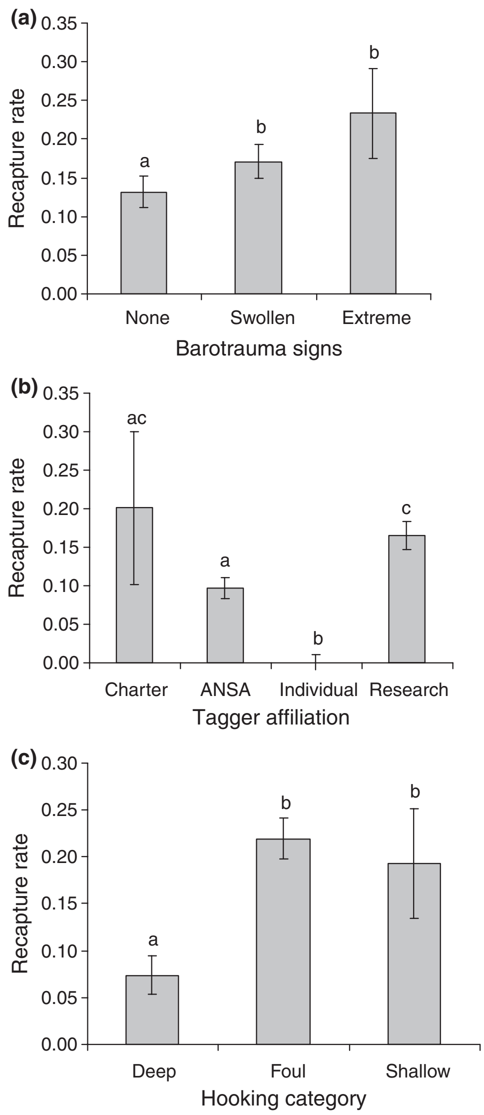

Figure 5. Adjusted mean recapture rate (±SE) of line caught *Lutjanus erythropterus* for a range of (a) barotrauma signs, and (b) tagger affiliation and (c) hooking location categories. Bars with a common superscript are not significantly different ($P < 0.05$).

*Saddletail snapper (*Lutjanus malabaricus*)*

In the condensed model, *L. malabaricus* tagged and released by researchers showed the expected pattern of higher survival with better overall subjective condition on release (Fig. 6a). The recapture rate of fish that had no barotrauma signs was enhanced by venting compared with other treatments, although shot-lining or venting fish that displayed barotrauma symptoms had no significant effect on recapture rate compared with controls (Fig. 6b). Fish with obvious symptoms of barotrauma were more likely to be recaptured if they had been shot-line-released rather than vented.

Lethrinus malabaricus were categorised into size classes on the same basis as *L. erythropterus* (35 cm TL). Of all the species examined, this species had the highest proportion (>10%) suffering the extreme symptoms of barotrauma. Bleeding, barotrauma signs and tagger affiliation were significant main effects in the expanded model (Table 3) and after adjusting for non-significant interactions in the model and including important main effects, only one interaction was

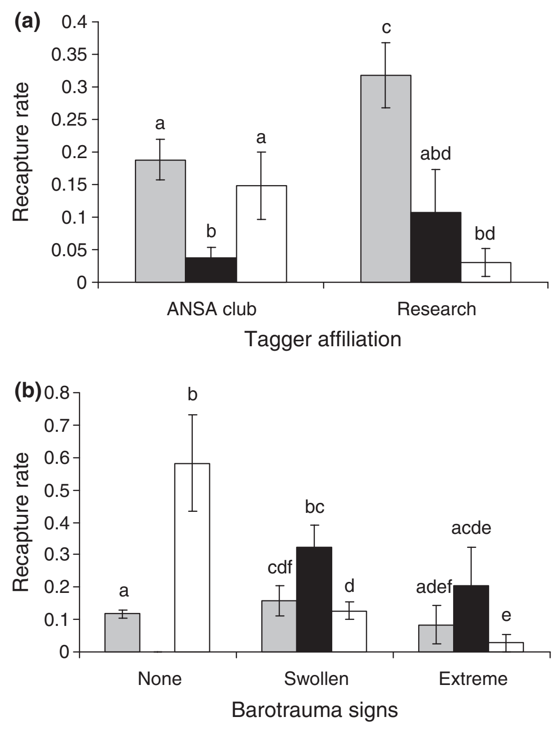

Figure 6. Adjusted mean recapture rate (±SE) of line caught *Lutjanus. malabaricus* for (a) a range of release conditions [release condition 1(▩), release condition 2 (■) and release condition 3 (□)] tagged by researchers and ANSA anglers and (b) treated fish [control (▩), shot-lined (■) and vented (□)] displaying different barotrauma signs. Bars with a common superscript are not significantly different ($P < 0.05$).

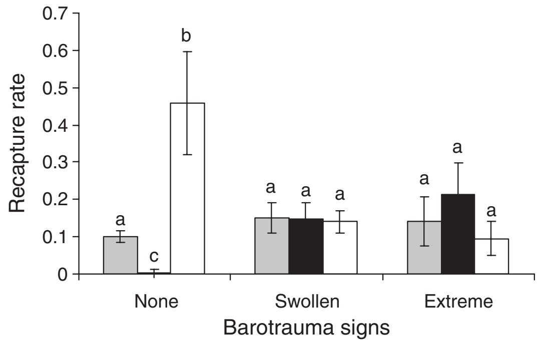

Figure 7. Adjusted mean recapture rate (±SE) for control (▨), shot-lined (■) and vented (□) line caught *Lutjanus malabaricus* showing different barotrauma signs. Bars with a common superscript are not significantly different ($P < 0.05$).

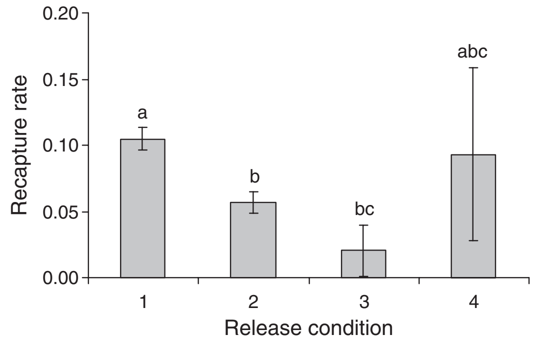

Figure 8. Adjusted mean recapture rate (±SE) of line-caught *Lutjanus sebae* for a range of release condition categories. Bars with a common superscript are not significantly different ($P < 0.05$).

statistically significant (barotrauma signs × barotrauma treatment). Fish that were injured enough to bleed as a result of capture had a significantly ($P < 0.01$) lower recapture rate (5.7%) than fish that were not bleeding (14.7%). Similarly, researcher tagged and released fish had a higher recapture rate (23.8%) than those of non-researchers (14.4%). Plotting the adjusted means of the barotrauma signs × treatment interaction (Fig. 7) highlighted enhanced survival of vented fish that had no signs of barotrauma. The positive effects of shot-lining fish showing signs of barotrauma were not as evident in this model as they were in the condensed model.

*Red emperor (*Lutjanus sebae*)*

The condensed GLM had no significant ($P > 0.05$) two-way interactions but release condition was highly significant ($P < 0.001$) in determining the recapture rate of *L. sebae* (Table 3). The pattern of higher recapture rate for better release condition fish was again evident for this species (Fig. 8).

The expanded model showed two significant main effects: depth ($P < 0.001$) and hooking location ($P < 0.05$) – and no significant two-way interactions (Table 3). While not statistically significant, the modelled treatment effects (recapture rate of 0.11 for controls, 0.08 for shot-lined and 0.08 for vented fish) were in broad agreement with the unadjusted raw results, which also showed a higher recapture rate among control fish than in treated fish. The adjusted mean recapture rates for *L. sebae* showed a declining trend with increasing depth (Fig. 9a). Fish hooked only in the lip or mouth also had a significantly higher probability of recapture than those that were either foul or deep hooked (Fig. 9b).

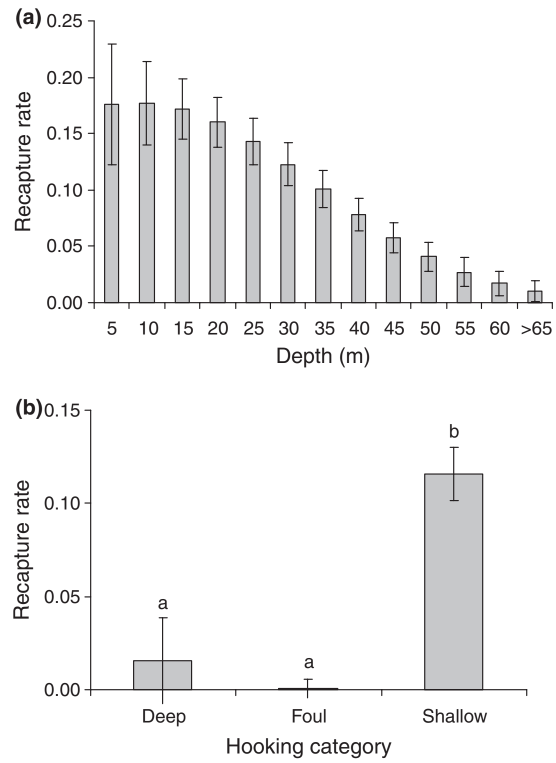

Figure 9. Adjusted mean recapture rate (±SE) of line caught *Lutjanus sebae* for a range of (a) depth of first capture categories and (b) hooking location categories. Bars with a common superscript are not significantly different ($P < 0.05$).

Redthroat emperor (Lethrinus miniatus) and grass emperor (Lethrinus laticaudis)

Numbers of recaptures of both *L. miniatus* and *L. laticaudis* were low (Table 2) and inadequate to model the effects of treatment and other factors on recapture rate accurately, but both species showed the consistent trend of increased recapture probability with better release condition (Table 3). *Lethrinus laticaudis* also had a significant depth effect consistent with the results for other species.

Effect of deep hooking and hook removal on recapture

Fish that were deep-hooked (in the throat or gut) sometimes had the hook removed by anglers, whereas in other cases the hook was left lodged inside the fish's gullet and the line cut prior to release (the current general best practice within the angling community) (Table 4). None of the individual species exhibited a significant effect of hook removal, but when data were pooled for all species the recapture rate of fish that had hooks left in was significantly greater than for those that had the hook removed (χ^2 = 6.31, d.f. = 1, $P < 0.05$).

Discussion

This experiment failed to demonstrate a consistent statistically significant effect of either treating or not treating fish species for barotrauma. The exception was *L. malabaricus*, where there was a benefit in treating for barotrauma prior to release, a result consistent with the findings of Sumpton *et al.* (2008) that suggested that venting enhanced released survival. While barotrauma treatment was not significant for *L. erythropterus* in either study, there may be benefit in treating both *L. erythropterus* and *L. malabaricus* as both species had appreciably higher recapture rates of treated fish relative to the controls than the other species investigated. Anglers have difficulty in distinguishing between these species as they form mixed schools and small specimens below the MLS are very difficult to identify to species level. It is surprising that such closely related species should exhibit such a difference in physiological response to line capture and barotrauma, although differences in barotrauma susceptibility among similar species within the same family have previously been highlighted (Lucy & Arendt 2002; Rummer & Bennett 2005; Hannah & Matteson 2007). Adjusting data for the effects of various factors in the models for both *L. erythropterus* and *L. malabaricus* reduced the differences between each of the treatments and controls compared with the raw recapture results (Table 2). Unadjusted results indicated some benefit in barotrauma treatment as recapture rates of treated fish were sometimes 50% higher than those of untreated fish. For these species, tagger affiliation was particularly significant in explaining some of the variation in recapture rate and it is likely that variation in handling practices among anglers contributed to highly variable recapture rates.

The interaction between barotrauma signs and treatment was not significant in most cases, but this interaction was important as treatment for barotrauma symptoms should have the greatest impact when fish are suffering from its effects. Nonetheless, the lack of significant adverse effects from shot-lining or venting suggests that treatment for barotrauma can be recommended regardless of the ability of anglers to diagnose the condition accurately. For some species (e.g. *L. malabaricus*), the greatest benefit was obtained by venting fish that did not display any barotrauma symptoms suggesting that treatment may have no positive benefit if severe physiological damage has occurred. Conversely, there was some evidence to recommend against treatment of *L. sebae* despite earlier findings to the contrary (Sumpton *et al.* 2008). *Lutjanus sebae* was predominantly caught in depths > 30 m, whereas most other species were caught in shallower water. *Lutjanus sebae* also displayed the least effects of barotrauma of all the species examined. The difference between the earlier and present studies with respect to this species may also be because of unidentified biases in the former study. Sumpton *et al.* (2008) acknowledged problems with data recording practices of anglers and recommended changes to protocols that were implemented in the present study to reduce these biases. When one of the anglers who had earlier tagged large numbers (> 2000) of *L. sebae* (and was identified as a possible biasing tagger in the present study) was removed from the earlier data, reanalysis showed that the effects were no longer statistically significant. Short-term, experimental (3 days) release survival experiments that assessed the effects of barotrauma treatment on *L. sebae* also failed to show any positive

Table 4. Number of tagged and recaptured tropical line caught fish species that were deeply hooked but which either had their hooks removed or were left in on release. Numbers of fish subsequently recaptured are shown in parentheses

	Number tagged and recaptured		Percentage recaptured	
Species	Hook removed	Hook left in	Hook removed	Hook left in
Plectropomus leopardus	33 (1)	17 (3)	3.03	17.65
Lutjanus erythropterus	27 (4)	56 (5)	14.81	8.93
Lutjanus malabaricus	19 (2)	89 (9)	10.53	10.11
Lutjanus sebae	14 (0)	64 (2)	0.00	3.13
Lethrinus miniatus	19 (0)	11 (1)	0.00	9.09
Lethrinus laticaudis	4 (0)	138 (4)	0.00	2.90

benefit of either venting or shot-lining on the survival of that species (Brown *et al.* 2008).

Release condition explained more of the variability in the data than specific factors included in the expanded models, suggesting that this subjective assessment (open to inter-angler variation) of how the fish behaved when it was released to the water was the best predictor of survival. The trend was for all species to have a greater probability of recapture if they had no obvious injury, had minimal time out of water and swam away strongly when they were released. However, other factors were also impacting on the survival of many of these species. The effect of depth was fairly consistent for all species, with the likelihood of recapture generally decreasing with increasing depth, although two species (*L. malabaricus* and *L. miniatus*) failed to show a statistically significant effect over the range of depths tested. This trend is in line with other studies that demonstrated higher mortality or incidence of barotrauma symptoms of fish with increasing depth (St John & Syers 2005; Hannah & Matteson 2007; Hannah *et al.* 2008).

Body size was only a significant factor for one species, *P. leopardus*. Many factors interact when a fish is hooked and subsequently landed by an angler. For some species, larger individuals may take longer to land than smaller individuals because of their greater fighting ability. This could either increase the stress on the fish because of lactic acid build up or other physiological effects (Beggs *et al.* 1980), but it may allow greater time for the fish (particularly physostomes) to self vent as it takes longer to ascend from depth. Alternatively, a quick retrieval of a small fish may cause the swim bladder to burst because of the rapid expansion of swim bladder gases that cannot be quickly compensated for by the fish. Although few fish greater than the current MLS were tagged and released for most species, this does not diminish the value of these results as the size of fish released would be representative of the discards of the recreational and commercial sectors. Commercial fishers are less likely to release fish above the MLS, although they sometimes release large individuals of this species because of quota restrictions and the market premium paid for small live *P. leopardus* (Welch *et al.* 2008).

For most species, there were too few deeply hooked fish to test the effect of hook removal on recapture rate, but overall the results indicated benefit in not removing hooks from such fish, as advocated by best practice of fish handling. Hooking location was a significant factor for both *L. erythropterus* and *L. sebae*, with the expected pattern of reduced survival of deeply hooked fish being evident. Bleeding, as a result of hooking and line capture, which is arguably also a good indicator of injury, was not observed frequently enough in most species to investigate its effect on recapture rate, but in *L. malabaricus* the expected pattern of reduced recapture with bleeding was observed.

The overall poor recapture rate for *L. miniatus* compared with other species should not be interpreted as an indication that it suffers more from the effects of barotrauma or capture stress. Although this species showed some positive effect of barotrauma treatment on recapture rate, there are many factors that could influence its ultimate recapture rate (and indeed all species). Differential tag loss may be responsible for impacting on the recapture rate of some species (McGlennon & Partington 1997) and there is little information on tag loss for any of the species studied. In addition, recreational fishing effort is not uniform across fishing grounds for all species. This observation was most noticeable in *L. erythropterus*, *L. malabaricus* and *L. sebae* data. Each of these species had relatively high recapture rates, because they are heavily fished at well-known and easily accessible fishing locations. Targeting of *L. miniatus* on the other hand is known to be far more wide-ranging as they are far less likely to aggregate. These factors, therefore, preclude any ranking of species susceptibility to release mortality based on recapture rate alone.

Observations by researchers during experiments, as well as comments by many of the ANSA taggers, raised some doubts about the application of shot-lining as a barotrauma relief procedure for more general use among recreational anglers. During tagging experiments, it was common for fish to become detached from the shot-line shortly after their descent from the surface. It was noted that larger and more active fish were capable of violently shaking their head and becoming detached from the shot-line before they reached a depth that would have enabled alleviation of their symptoms. At times, these fish were seen to resurface shortly after treatment. Experience with the technique reduces the probability of malfunction and anglers experienced in using this method reported fewer problems. However, many experienced anglers who participated in the experiment were reluctant to use shot-lining routinely, reporting that it was more time consuming and prone to failure than venting for some species. Despite these difficulties, shot-lining still provided recapture rates comparable with and often better than venting. Venting is a more invasive practice as it involves the puncturing of internal organs leading to the greater probability of infection and organ damage than would be expected by simply threading a barbless hook through the lip. During the course of the experiment, it became apparent that shot-line release was more applicable to larger fish suffering barotrauma and species considered not to respond well to venting.

In conclusion, the results of this study justify the use of shot-lining or venting to ameliorate the effects of barotrauma for the species studied, apart from *L. sebae*. The choice of which treatment to use should be left to anglers' preference because no consistent evidence was found that one technique was superior to the other in promoting post-release survival amongst these species. Many factors interact when a fish is caught and subsequently released, and these complicate the assessment of the relative importance of individual factors (including barotrauma treatment) in determining the fish's ultimate survival. While the value in using recreational anglers in tagging studies of this nature is acknowledged caution should be used when involving large numbers of anglers, particularly when relatively complex experimental procedures are involved. It is vital that experimental protocols and data recording procedures are adhered to by all involved. This becomes more difficult with increasing number of participants in the research.

Acknowledgments

Thanks to the many members of the Australian National Sportfishing Association in Queensland for their contribution to the tagging studies. The assistance of the many recreational, charter and commercial fishers who took part in the experiment is gratefully acknowledged, particularly those that tagged and treated over 150 fish (A. Stewart, R. McArthur, K. Bailey, D. Powell, M. Powell, H. Johnson, J. Macgregor, B. Avery, W. Sullivan, M. Dohnt and W. Ferrington). We are also grateful to a large number of staff from the Department of Primary Industries and Fisheries and the Fishing and Fisheries Research Centre, James Cook University who assisted with the tagging. The cooperation of the many hundreds of recreational and commercial fishers who returned tagged fish is also gratefully acknowledged. This project was funded by the Fisheries Research and Development Corporation (Project 2003/019), the Queensland Department of Primary Industries and Fisheries and James Cook University.

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