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[Note]

Effect of Hook Removal on Recapture Rates of 27 Species of Angler-Caught Fish in Australia

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Abstract.—We used data from a cooperative angler tagging program to assess the potential benefit of leaving hooks in fish captured and released by anglers. We assembled 248,010 records of angler catches of 27 species of Australian fish. Hooks were left in only 1.1% of released fish, and the overall recapture rate was 8.8%. We used relative risk, that is, the probability of an event (recapture) in a treatment group (those with hooks not removed) divided by the probability of that event in a control group (those with the hook removed), to assess the potential effects of leaving hooks in released fish. Relative risk ranged from 0.30 to 7.6 and differed from 1.0 in only 3 of the 27 species studied. Thus, there was little evidence that hook removal affected recapture probability. Similarly, there was no evidence of any difference in relative risk among fish species grouped by habitat type. Pooling results across all species and habitats yielded an overall relative risk of 1.18 (95% confidence interval, 1.02–1.36), which suggests that the recapture rate of fish from which hooks were not removed before release was 18% greater than that for fish from which the hooks were removed. Overall, our results indicate that not removing hooks benefits recapture rate, which can be considered as a surrogate measure of the survival of released fish.

Catch-and-release fishing has been practiced for over 100 years (Wydoski 1977; Policansky 2002) but has recently become common. This has occurred because many anglers release fish as a voluntary conservation effort and because fishery managers have increased their use of restrictive length and bag (creel) limits, which often require anglers to release fish of certain sizes or those in excess of a bag or possession limit. A substantial and growing number of studies (see reviews in Barnhart 1989; Muoneke and Childress 1994; Bartholomew and Bohnsack 2005; Arlinghaus et al. 2007) have examined factors affecting survival of fish that are captured and released by anglers. Survival is related to anatomical hooking location (Pelzman 1978; Hulbert and Engstrom-Heg 1980; Butcher et al. 2007), water temperature (Nuhfer and Alexander 1992; Schisler and Bergersen 1996; Wilde et al. 2000), type of gear used (Shetter and Allison 1958; Cooke et al. 2001; Mapleston et al. 2008), and other factors including salinity, depth of capture, and playing time (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005). Possibly the single best predictor of postrelease survival is whether a fish is hooked deeply in the esophagus or stomach (Schisler and Bergersen 1996; Aalbers et al. 2004; Van der Walt et al. 2005; Wilde and Pope 2008). To promote survival and minimize additional injury to deeply hooked fish, a number of studies have examined the potential benefit of leaving hooks in place versus removing them (Mason and Hunt 1967; Warner 1979; Hulbert and Engstrom-Heg 1980; Schill 1996; Schisler and Bergersen 1996; Lucy and Holton 1998; Aalbers et al. 2004; Van der Walt et al. 2005; Broadhurst et al. 2007; Butcher et al. 2007; Grixti et al. 2008). These studies conducted by, or under the direction of, fishery biologists generally have shown that survival of deeply hooked fish is enhanced if hooks are not removed. The practice of releasing fish with hooks left in place is increasingly common among anglers. However, only anecdotal information is available on the potential survival benefits of not removing hooks from fish captured, handled, and released by anglers.

The Australian National Sportfishing Association (ANSA) of Queensland and the Queensland Department of Primary Industries collaborate in a cooperative tagging program, Suntag, in which anglers capture, tag, and release fish. The primary purpose of this program is to provide information for use by fishery researchers. Data from various ANSA projects have been used to describe movement, migration, stock structure, growth, mortality, and other population characteristics of a number of Australian fishes (e.g., Pollock 1982; Morton et al. 1993; Begg et al. 1997) and to study factors affecting recapture rates of angler-caught-and-released fish (Pollock 1984; Brown et al. 2008; Sumpton et al. 2008). In this paper, we use Suntag tagging records to assess the effect of hook removal on the survival of released fish. Specifically, we test the

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TABLE 1.—Summary statistics and relative risk ratios (with 95% confidence intervals [CIs]) for 27 species of Australian fish. The 95% confidence intervals are asymmetrical because they were calculated for the $\log_e$ transformed relative risk and then converted back to a linear scale.

Species	Number captured	Recapture rate (%)	Hooks not removed (%)	Habitat	Relative risk	95% CI
Blue threadfin *Eleutheronema tetradactylum*[a]	2,262	3.67	0.84	Estuarine	0.70	0.04–10.85
King threadfin *Polydactylus macrochir*	2,214	8.54	0.86	Estuarine	0.31	0.02–4.88
John's snapper *Lutjanus johnii*	2,344	8.45	4.61	Estuarine	1.37	0.78–2.41
Sand whiting *Sillago ciliata*[b]	2,459	7.40	7.20	Estuarine	1.02	0.58–1.77
Dusky flathead *Platycephalus fuscus*	2,535	11.01	1.07	Estuarine	2.37	1.20–4.69
Speckled javelin *Pomadasys argenteus*	4,381	2.31	7.51	Estuarine	0.86	0.39–1.88
Malabar grouper *Epinephelus malabaricus*	5,588	14.87	0.27	Estuarine	1.21	0.39–3.77
Pikey bream *Acanthopagrus berda*[c]	9,165	4.20	1.94	Estuarine	0.62	0.25–1.55
Barred javelin *Pomadasys kaakan*	14,351	2.70	1.40	Estuarine	1.23	0.57–2.63
Orangespotted grouper *Epinephelus coioides*	13,751	14.26	0.83	Estuarine	1.72	1.20–2.44
Mangrove jack *Lutjanus argentimaculatus*	20,234	7.62	0.39	Estuarine	1.16	0.56–2.43
Yellowfin bream *Acanthopagrus australis*[d]	22,211	4.79	3.53	Estuarine	0.96	0.69–1.34
Barramundi *Lates calcarifer*[e]	67,596	11.80	0.43	Estuarine	1.02	0.73–1.42
Silver perch *Bidyanus bidyanus*	1,175	8.60	1.96	Freshwater	0.78	0.16–3.72
Golden perch *Macquaria ambigua*	10,607	10.06	0.23	Freshwater	1.09	0.34–3.55
Australian bass *Macquaria novemaculeata*	29,668	9.23	0.03	Freshwater	1.97	0.46–8.51
Bigeye trevally *Caranx sexfasciatus*	1,189	3.11	0.17	Inshore pelagic	5.45	0.43–69.78
Queenfish *Scomberoides commersonianus*[f]	1,993	3.36	0.75	Inshore pelagic	0.95	0.06–14.65
Giant trevally *Caranx ignobilis*	4,390	4.53	1.14	Inshore pelagic	1.13	0.33–3.80
Swallowtail dart *Trachinotus coppingeri*	4,409	5.69	0.68	Inshore pelagic	0.30	0.02–4.66
Bluefish *Pomatomus saltatrix*[g]	4,779	2.20	0.13	Inshore pelagic	3.30	0.23–48.08
Saddletail snapper *Lutjanus malabaricus*[h]	1,124	12.10	3.20	Reef	0.37	0.08–1.77
Crimson snapper *Lutjanus erythropterus*	1,241	12.81	2.34	Reef	1.02	0.38–2.77
Bar-cheeked coral trout *Plectropomus maculatus*	1,981	6.92	0.10	Reef	7.76	2.47–24.34
Red emperor *Lutjanus sebae*[i]	3,008	22.87	2.06	Reef	0.98	0.58–1.66
Grass emperor *Lethrinus laticaudis*	4,944	6.13	0.73	Reef	1.17	0.35–3.89
Snapper *Pagrus auratus*	8,411	7.67	0.19	Reef	0.41	0.03–6.33

[a] Also known as fourfinger threadfin.
[b] Also known as sand sillago.
[c] Also known as river bream.
[d] Also known as surf bream.
[e] Also known as barramundi perch.
[f] Also known as talang queenfish.
[g] Known as tailor in Australia.
[h] Also known as Malabar snapper.
[i] Also known as emperor snapper.

null hypothesis that leaving hooks in place, rather than removing them, has no effect on the probability that fish are recaptured.

Methods

The ANSA Suntag database contains more than 500,000 records of fish captured, tagged, and released by anglers and more than 30,000 records of recaptured fish. We matched capture and recapture information for all species in the database and retained for study those data for species for which there were at least 1,000 capture records. We categorized captured fish according to whether the original tagging record indicated (in a comment field) that the hook was not removed from the fish before its release. The species retained in our analysis (Table 1) are among those that are most commonly captured and released by Australian anglers (Higgs 2001; Roy Morgan Research 2003; Broadhurst et al. 2005; Mapleston et al. 2008; Sumpton et al. 2008).

To test the hypothesis that fish from which hooks were not removed and those from which hooks were removed would be recaptured at an equal rate, we used relative risk (Sutton et al. 2000), which is widely used in the medical and epidemiological literature in the analysis of binary data. Relative risk is the probability of an event (recapture) in a treatment group (those with hooks not removed) divided by the probability of an event in a control group (those with the hook removed). We added 0.5 to all cells to accommodate those with zero values, as recommended by Sutton et al. (2000), and calculated relative risk as follows:

$$\text{relative risk} = [R_{\text{nr}}/(R_{\text{nr}} + \text{NR}_{\text{nr}})]/[R_r/(R_r + \text{NR}_r)],$$

where R_{nr} is the number of fish from which hooks were not removed that were recaptured, NR_{nr} is the number of fish from which hooks were not removed that were not recaptured, R_r is the number of fish from which hooks were removed that were recaptured, and NR_r is

TABLE 2.—Relative risk (with 95% confidence intervals [CIs]) for 27 species of Australian fish grouped according to the habitat in which they are typically captured.

Habitat	Number of species	Relative risk	95% CI
Estuarine	13	1.17	0.99–1.39
Freshwater	3	1.19	0.21–6.76
Inshore pelagic	5	1.32	0.37–4.72
Reef	6	1.18	0.71–1.97

the number of fish from which hooks were removed that were not recaptured. A value of 1.0 for the risk ratio implies no effect of removing hooks and values greater than 1.0 imply that leaving hooks in place increases capture rates, which can be considered an indirect measure of survival (e.g., Sumpton et al. 2008; Wilde 2009).

We used MetaWin 2.0 (Rosenberg et al. 2000) to calculate relative risks and their SE values. We assessed whether there was significant heterogeneity among species in relative risk using Cochran's Q (Rosenberg et al. 2000), which is distributed as a χ^2 statistic with $n - 1$ df, where n is the number of groups being compared. We then performed a fixed effects meta-analysis of relative risk among species grouped by habitat type (freshwater, estuarine, inshore pelagic, and reef) and across all species combined.

Results

Records for 248,010 captured and released fish representing 27 species are included in our analysis (Table 1). Numbers of tagged fish ranged from 1,124 for saddletail snapper to 67,596 for barramundi. Overall, 8.8% of tagged and released fish were recaptured, the proportion of recaptures ranging from 2.2% for bluefish to 22.9% for red emperor. Hooks generally were removed from captured fish before release; however, in 1.1% of fish (range, 0.0% in Australian bass to 7.5% in speckled javelin) hooks were not removed.

There was little evidence that hook removal affected recapture probability (Table 1). Relative risk ranged from 0.30 in swallowtail dart to 7.8 in bar-cheeked coral trout and differed from 1.0 in only three species (dusky flathead, orangespotted grouper, and bar-cheeked coral trout). There was no significant heterogeneity among species in relative risk ($\chi^2 = 32.03$, df = 26, $P = 0.1921$) so we performed two meta-analyses. In the first, there was no evidence of any difference in relative risk ($\chi^2 = 0.06$, df = 3, $P = 0.1008$) among fish species based on habitat type. Ninety-five percent confidence intervals (CIs) for species grouped by habitat encompassed 1.0 (Table 2), indicating that hook removal did not affect recapture rates. In the second analysis, results were pooled across all species and habitats yielding an overall relative risk of 1.18 with a 95% CI (1.02–1.36) that did not overlap 1.0. This suggests that the recapture rate of fish in which hooks were not removed before release was 18% greater than that for fish released without hooks.

Discussion

The approach we have taken here, comparison of relative risk rates, allows us to combine results across species (e.g., Wilde 2009) but does not require us to assume a common recapture rate among species (e.g., Sumpton et al. 2008) or among those typical of different environments (freshwater versus saltwater) or that recapture rates are related directly to survival, although there is evidence that they are (Gillanders et al. 2001). The utility and limitations of data collected by cooperative tagging programs are well known (Kearney 1988; Gillanders et al. 2001); however, we have made two assumptions that warrant discussion. First, we assumed that tagging and recapture data were correctly reported and, in particular, that all fish in which hooks were left were so identified. Overall, hooks were reported to have been left in 1.1% of captured fish, which may be low, but it is unlikely that the true incidence is much greater. Further, given the large number of fish in our sample and the differences in sample sizes of fish from which hooks were not removed versus removed, the observed relative risks are robust to under-reporting of the numbers of fish in which hooks were left in place. Second, we assumed there is no difference in reporting rates of captured (and recaptured) fish based on whether hooks were removed or left in the fish. We have no means of testing this assumption, but there is no reason to expect any systematic difference in reporting based on whether hooks were removed.

Based on comparisons of the relative risk of recapture, leaving hooks in fish benefits survival of only three of the species studied herein and there is no evidence that this practice benefits species typical of different habitats; however, our results suggest there is no adverse effect to the practice of leaving hooks in fish. We did find evidence of a benefit to leaving hooks in fish when results were cumulated across all species: leaving hooks in these fish increased recapture rates by 18%. Our results differ from those of previous experimental studies, which suggest that leaving hooks in deeply hooked fish increases survival by an average 87% (random effects meta-analysis: risk ratio = 1.87, 95% CI = 1.41–2.48), ranging from no effect in summer flounder *Paralichthys dentatus* to a 300% increase in survival in Atlantic salmon *Salmo salar* (Table 3). This is significantly different (fixed-effects

TABLE 3.—Relative risk (with 95% confidence intervals [CIs]) of survival in deeply hooked fish in which hooks were left in place, calculated from published studies.

Species	Relative Risk	95% CI	Source
Atlantic salmon	3.99	1.71–9.27	Warner (1979)
Black bream *Acanthopagrus butcheri*	1.37	1.09–1.71	Grixti et al. (2008)
Brown trout *Salmo trutta*	2.71	1.85–3.96	Hulbert and Engstrom-Heg (1980)
Mulloway *Argyrosomus japonicus*[a]	3.23	1.62–6.42	Butcher et al. (2007)
Rainbow trout *Oncorhynchus mykiss*	2.96	1.93–4.52	Mason and Hunt (1967)
Rainbow trout	2.06	1.45–2.94	Schill (1996)
Rainbow trout	1.77	1.55–2.02	Schisler and Bergersen (1996)
Silver perch	2.38	1.33–4.26	Van der Walt et al. (2005)
Summer flounder	1.00	0.79–1.27	Lucy and Holton (1998)
White seabass *Actractoscion nobilis*	1.64	0.84–3.21	Aalbers et al. (2004)
Yellowfin bream	1.09	0.99–1.20	Butcher et al. (2007)

[a] Also known as Japanese meagre; includes only samples in which fish were deeply hooked.

meta-analysis: $\chi^2 = 4.309$, df $= 1$, $P = 0.03791$) than our estimate derived from recaptures of tagged fish. The effect of leaving hooks in deeply hooked fish was studied experimentally in only two of our study species. In both cases, silver perch and yellowfin bream, the tagging results suggest a smaller benefit (relative risk = 0.76 and 0.96, respectively; Table 1) than did the experimental studies (relative risk = 2.38 and 1.09, respectively; Table 2).

There are several possible explanations for the difference between our results and those of the experimental studies summarized in Table 3. First, although anglers release most of the fish they capture (Higgs 2001), including many of legal length (Roy Morgan Research 2003), they do keep some fish. The decision to keep or release any given fish may be influenced by the angler's judgment of the possibility that the fish will survive (e.g., Brown et al. 2008; Sumpton et al. 2008). Among deeply hooked fish, many that eventually die do so quickly (Hysmith et al. 1994; Dedual 1996; Arlinghaus et al. 2008; Grixti et al. 2008). Thus, anglers may be able to assess a fish's survival chances, which might affect their decision to release deeply hooked fish. Second, deeply hooked fish may suffer wounds (e.g., Pelzman 1978) or barotraumas (e.g., Rummer and Bennett 2005; Sumpton et al. 2008) that ultimately result in mortality regardless of whether hooks are removed. Third, compared with fish from which hooks are removed, delayed mortality occurs over a longer period among deeply hooked fish in which hooks are left in place (Van der Walt et al. 2005) and there is some evidence that leaving hooks in has adverse long-term effects on fish health and, potentially, survival (Borucinska and Martin 2001; Borucinska et al. 2002, 2003; Broadhurst et al. 2007; DuBois and Pleski 2007). Finally, in the experimental studies, the decision to remove hooks or leave them in deeply hooked fish was made before any attempt at removing hooks. In contrast, anglers may attempt to remove hooks from deeply hooked fish and only after failing to do so, decide to leave the hooks in place. This would increase handling time and air exposure (e.g., Cooke et al. 2001) and trauma associated with attempted hook removal (Warner 1979). These explanations are not mutually exclusive and each separately, or in combination with others, has the potential to obscure any benefit of leaving hooks in fish.

Based on differences in survival between deeply hooked fish in which hooks were removed and those in which hooks were left in place, Schisler and Bergersen (1996), Van der Walt et al. (2005), and Butcher et al. (2007) recommended that anglers cut the leaders on deeply hooked fish. Similar recommendations were made by Davie and Kopf (2006) and Cooke and Sneddon (2007) based on animal welfare concerns. Although our results suggest a small benefit to leaving the hooks in deeply hooked fish, the number of fish captured and released by anglers is so large that even a modest increase in survival can have a substantial fishery effect. Thus, our results support the recommendation that anglers be encouraged to leave hooks in deeply hooked fish; however, additional study is necessary before a definitive recommendation can be made as to whether anglers should immediately cut their lines and leave the hooks in deeply hooked fish or whether they should first make an attempt at removing hooks before cutting their lines.

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