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Short communication

Mortality of sand whiting (*Sillago ciliata*) released by recreational anglers in an Australian estuary

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The mortality of hooked-and-released sand whiting *(Sillago ciliata)* and the key contributing factors were determined during a recreational fishing event in northern New South Wales, Australia. Participating anglers caught 124 sand whiting, of which 60 were tagged with plastic t-bar anchor tags, and then released into replicate sea cages. In all, 109 sand whiting were seined (54 were tagged) and similarly released into replicate sea cages for use as controls. All fish were monitored for mortalities over 7 days. There were no measurable effects of confinement in the sea cages on the stress (measured as concentrations of plasma glucose) of hooked or seined fish. Ten hooked-and-released (four non-tagged, six tagged) and two control (both tagged) sand whiting died during the monitoring period and mostly within 48 h of capture, providing adjusted mortality rates (i.e. accounting for mortalities of control fish) of approximately 6% for total, tagged, and non-tagged fish. Anatomical hook location (oesophagus-ingested hooks) and bait type (beach worms, *Australonuphis teres*) were significant predictors of mortality ($p > 0.05$). The results support current recreational fishing gears and practices for the catch and release of sand whiting.

Keywords: catch-and-release, hooking mortality, recreational anglers, sand whiting, *Sillago ciliata*.

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Introduction

The family Sillaginidae consists of more than 30 species of fish distributed throughout tropical and temperate coastal regions in the Indian and Pacific Oceans, where they form the basis of important fisheries (McKay, 1992; Kailola *et al.*, 1993). In Australia, recreational fishers target several species of sillaginids and catch more than 17 million individuals each year (Henry and Lyle, 2003). Much of this catch consists of King George whiting (*Sillaginodes punctata*; caught from Sydney, New South Wales (NSW) to Jurien Bay, Western Australia) and sand whiting (*Sillago ciliata*; caught along the entire east coast of Australia), but it can include yellowfin (*S. schomburgkii*), trumpeter (*S. maculata*), red spot (*S. flindersi*), western school (*S. bassensis*), and stout whiting (*S. robusta*).

Because of bag limits, minimum legal sizes, and a growing awareness by recreational anglers of the need to conserve stocks, up to some 32% (or 5.5 million individuals) of all angler-caught sillaginids in Australia are released (Henry and Lyle, 2003). The fate of some of these fish is known; one study in South Australia revealing post-release mortality rates of <3% for King George whiting (Kumar *et al.*, 1995). The post-release mortality of other angler-caught sillaginids has not been examined in detail, although Broadhurst *et al.* (2005) compared the fate of 10 sand whiting that were hooked, tagged, and released as part of a recreational fishing tournament with 14 seined-and-tagged "control" fish. During 10 days post-release, only one sand whiting died in each group.

Related survival-type studies have also been done for sand whiting that escaped or were discarded from commercial fishing nets off NSW (Broadhurst *et al.*, 1997; Kennelly and Gray, 2000). This work demonstrated a clear correlation between survival and the severity of particular treatments. Specifically, fish that quickly escaped through the meshes of trawls during fishing sustained minimal physical damage and long-term mortality (<3%; Broadhurst *et al.*, 1997). In contrast, Kennelly and Gray (2000) observed that >40% of sand whiting died after being caught in seines, tangled in meshes, and then released. Such treatment-specific differences are typical, and have been observed for several species after release or escape from various commercial fisheries (Chopin and Arimoto, 1995; Chopin *et al.*, 1996).

Like fish escaping from commercial gears, previous studies have demonstrated that the mortality of fish released by anglers is species-specific and can be influenced by a combination of several environmental and technical factors (for reviews, see Muoneke and Childress, 1994; McLeay *et al.*, 2002; Cooke and Suski, 2004). The potential for cumulative or interactive effects of different factors requires collection of adequate information describing the catch history of individual fish, and then monitoring their mortality. A cost-effective method of obtaining this information involves tagging hooked fish with simple anchor tags, and then releasing individuals into cages (Dunmall *et al.*, 2001; Lukacovic and Uphoff, 2002; Broadhurst *et al.*, 2005). However, the process of angling, tagging, and confinement invokes at least some stress in fish that could contribute towards the mortality of hooked-and-released individuals (Nakashima and Winters, 1984; Stobo *et al.*, 1992; Cooke and Suski, 2005). The potential for such effects therefore needs to be adequately assessed using appropriate controls and experimental designs.

The aims of this study were therefore to assess the post-release mortality of angler-caught sand whiting and, using controlled tagging, to quantify the key contributing factors. The work was done during a tournament involving recreational anglers who fished according to conventional methods and with typical terminal rigs.

Material and methods

The experiment was done in the Wooli Estuary (29°52′S 153°16′E), NSW, between 5 and 13 March 2005 and involved a combination of 35 inexperienced and experienced anglers, 12 researchers, and three marshal boats. Fish were released into nine anchored sea cages made from 16-mm knotless polyamide netting and measuring 2.3 × 2.5 m. Anglers were given 25-l aerated fish-holding tanks, conventional long-shank J-hooks (Figure 1), and yabbies (*Callianassa* spp.) or beach worms (*Australonuphis teres*) for bait; they were asked to target sand whiting from either boats or the river bank between 06:00 and 18:00 local time.

As soon as an angler caught a sand whiting, they placed it in their fish-holding tank and recorded the playing and landing times, duration of exposure to air, anatomical hook location, and the presence or absence of blood and scale loss (to the nearest 25%). Researchers immediately recorded the water temperature and level of dissolved oxygen in the fish-holding tanks, removed each fish, measured their total length (TL, to the nearest 0.1 cm), then randomly tagged approximately half with numbered, 44-mm plastic

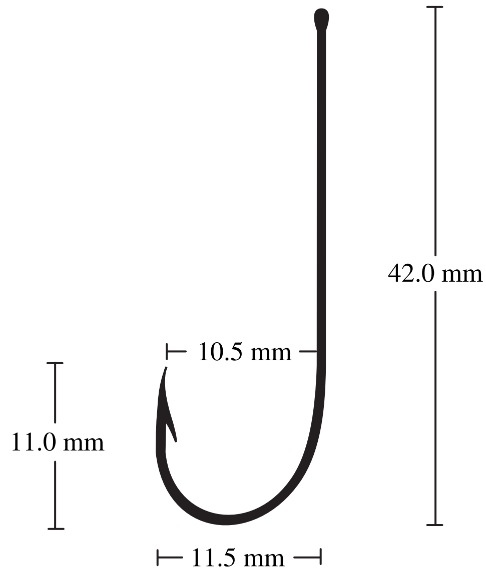

Figure 1. Nominal dimensions of the long-shank J-hooks used by anglers in this study.

t-bar tags, inserted 10 mm below the dorsal fin. All tagged and non-tagged sand whiting (termed "treatment" fish) were transported by the marshal boats and released into four randomly selected sea cages (two replicate cages each for tagged and non-tagged fish).

Once the last angler-caught sand whiting was released into the sea cages, similar numbers were caught by a hand-hauled seine over 2 days. Like the hooked-and-released sand whiting, seined fish were measured (TL), and approximately half were tagged before being transported in fish-holding tanks and released into four of the remaining sea cages (two replicate cages each for tagged and non-tagged fish). These seined, tagged, and non-tagged sand whiting were used as controls. Further, approximately 15 seined sand whiting were placed in the ninth sea cage and used as stock fish to replace mortalities in the treatment and control cages.

All sand whiting were fed a mixture of chopped yabbies and beach worms at a rate of approximately 1% biomass per day, and monitored for mortality over 7 days post-release. All dead fish were measured (TL), identified (if tagged), and replaced by a stock fish of similar size that was either fin-clipped or tagged for identification.

To provide some assessment of the physiological effects on sand whiting associated with the experimental design, six fish were (i) hooked from the Wooli Estuary at the start of the experiment, and then up to three were (ii) scooped from each sea cage 7 days post-release. Blood was sampled from each fish according to the methodology of Broadhurst *et al.* (2005), and plasma glucose was measured by the methods described by Moore (1983).

Size frequency distributions (1-cm TL intervals) of treatment and control fish were compared using two-sample Kolmogorov–Smirnov tests. Two-tailed Fisher's exact tests were used to determine the independence of (i) the treatment of fish, and (ii) replicate cages on mortality. Log-transformed concentrations of glucose (mmol l^{-1}) in wild and captive sand whiting were analysed by one-factor ANOVA. All variables describing the hook and release of tagged, angler-caught sand whiting were separated as either categorical or continuous parameters. The independence of these parameters of mortality was examined using exact logistic regression models (Hirji *et al.*, 1987). Individual models were fitted using SAS (version 8, 2003), as described by Derr (2000), and compared using likelihood ratio tests and examination of deviance residuals.

Results

In all, 124 hooked and 109 seined sand whiting were released into the sea cages, of which 60 and 54 fish, respectively, were tagged (Table 1). Kolmogorov–Smirnov tests detected significant differences between the size frequency distributions of fish that were (i) hooked vs. seined (irrespective of tagging), (ii) hooked and tagged vs. hooked and not tagged, (iii) hooked and tagged vs. seined and tagged, and (iv) hooked and not tagged vs. seined and not tagged ($p < 0.05$). These variations in sizes reflected the different selectivities of the gears used as well as the selection of fish for tagging by researchers.

During angling, more than 95% of sand whiting were landed less than 30 s after being hooked, exposed to air for less than 1 min, and had no visible scale or blood loss (Tables 2 and 3). Most fish were hooked in the roof of the mouth or upper jaw (Table 2). Ten hooked-and-released (four non-tagged, six tagged) and two control (both tagged) sand whiting died 7 days post-release, providing adjusted mortality rates (calculated from treatment and control mortalities) of approximately 6% for the two categories of hooked-and-released fish (tagged and non-tagged; Table 1).

Table 1. Total number, mean total length (TL) ± s.e., longest, % legal, adjusted mortality rates, and mean time until the death of treatment (hooked) and control (seined) sand whiting. –, not applicable.

	Treatment		Control	
	Not tagged	Tagged	Not tagged	Tagged
Total number	64	60	55	54
Mean TL ± s.e. (cm)	19.36 (0.24)	21.8 (0.64)	21.7 (0.98)	24.5 (1.07)
Longest TL (cm)	28.6	36.8	40.4	41.5
% Legal (<27 cm)	1.6	15.0	18.2	33.3
Adjusted mortality rate (%)	6.2	6.3	–	–
Mean time until death (h)	42	33.6	–	24

Table 2. Categorical parameters for non-tagged and tagged hooked-and-released sand whiting at the end of the experiment. Only the data from tagged fish were used in exact logistic regression analyses.

		Tagged	
Parameter	Non-tagged	Alive	Dead
Bait type			
Yabby	54	49	3
Worm	9	5	3
Hook location			
Mouth/Jaw/Gills			
Upper jaw	13	14	1
Roof of mouth	17	12	1
Gill arch	3	2	1
Floor of mouth	5	5	0
Lower jaw	9	4	0
Corner of mouth	11	10	0
Ingested (oesophagus)	1	1	2
Body	5	6	1
Blood at hook wound			
Yes	7	5	0
No	57	49	6
Exposure to air			
<1 min	62	53	5
1–3 min	2	1	1
Scale loss			
Yes	2	0	0
No	62	54	6

Fisher's exact test revealed that mortalities were independent of replicate cages ($p > 0.05$). Similarly, no significant differences were detected between the number of dead tagged and non-tagged treatment and control fish (Fisher's exact test; $p > 0.05$), but the total number of deaths in the treatment group was significantly greater than in the control

Table 3. Mean (±s.e.) continuous parameters for tagged and non-tagged sand whiting at the end of the experiment. Tagged results were used in the exact logistic regression analyses.

		Tagged	
Parameter	Non-tagged	Alive	Dead
Total length (cm)	19.36 (0.24)	21.82 (0.69)	21.43 (1.71)
Line strength (kg)	3.32 (0.15)	3.58 (0.18)	3.48 (0.43)
Play period (s)	22.91 (1.36)	16.96 (1.39)	21.83 (5.29)
Period in holding tank (min)	14.82 (1.55)	16.61 (1.50)	13.67 (3.30)
Temperature in holding tank (°C)	23.01 (0.23)	24.34 (0.36)	22.88 (0.48)
Oxygen in holding tank (mg l^{-1})	6.81 (0.28)	6.68 (0.29)	7.44 (0.82)

group (Fisher's exact test; $p < 0.05$). More than 90% of the mortalities occurred within 48 h of capture. Of the six tagged hooked-and-released fish that died, two had ingested hooks into the oesophagus, while the remaining four were hooked in the mouth, gill arch, or body (Table 2). Exact logistic regression analyses failed to detect any significant interactions between the various categorical (Table 2) and continuous (Table 3) parameters ($p > 0.05$). The main effects of bait type and anatomical hook location were the only predictors of mortality, with three deaths out of eight individuals caught using beach worms as bait ($p < 0.01$), and two deaths out of three fish that had ingested hooks into the oesophagus ($p < 0.05$; Table 2).

No significant differences were detected in the mean ($\pm$ s.e.) concentrations of glucose among six wild (3.42 ± 0.32 mmol l^{-1}) and 22 randomly selected sand whiting from eight cages (4.13 ± 0.23 mmol l^{-1}) at the end of the experiment.

Discussion

The results confirm that common recreational fishing methods used to target sand whiting in NSW result in minimal mortality of released fish (Broadhurst *et al.*, 2005). The low rate of mortality is comparable to that observed for hooked-and-released King George whiting in South Australia (Kumar *et al.*, 1995), but considerably less than that recorded for other key marine recreational species that live in similar habitats. For example, in a related study, Broadhurst *et al.* (2005) observed mortality rates of 28–36% for sparids (yellowfin bream, *Acanthopagrus australis*, and snapper, *Pagrus auratus*) and trevally (*Pseudocaranx dentex*). Such variability is typical for a range of other marine species worldwide, and at least is partially attributable to the key factors associated with the catch-and-handling process (for reviews see Muoneke and Childress, 1994; McLeay *et al.*, 2002).

Although sample sizes were small during this study, the significant causes of the mortalities of hooked-and-released fish were anatomical hook location (oesophagus-ingested hooks) and bait type (beach worms). Previous studies have identified that anatomical hook location is a major predictor of mortality in several species and is often influenced by a range of inter-related factors that include the design and size of hooks, size of fish, behaviour of the target species, angler technique and experience, and the type or size of bait (Muoneke and Childress, 1994; Taylor *et al.*, 2001; Policansky, 2002; Cooke *et al.*, 2003; Broadhurst *et al.*, 2005). While the observed ingestion rates of hooks were low (3.2%) in this study, the utility of alternate hook designs, in particular circle (Cooke and Suski, 2004) or modified J-hooks (Willis and Millar, 2001), may still warrant investigation, especially if such configurations do not result in any reductions in efficiency.

There was no significant interaction between anatomical hook location and bait type, but the significant main effect of bait on mortality might still reflect differences in the intensity of the hooking response, and a greater injury to fish by hooks (irrespective of anatomical location) baited with beach worms. This may have been influenced by a preference towards this type of bait, because Burchmore *et al.* (1988) observed that polychaetes constituted up to 75% of the diet of sand whiting of similar size in another estuary in southeastern Australia. Clearly more work is required to further examine this relationship as well as the potential for any interactions with hook type or the other various components of terminal rigs.

Although not significant, eight of the tagged fish died (six treatments and two controls) compared with only four non-tagged fish (all treatments). The increased mortality of tagged fish may be simply chance, or alternatively, could be isolated examples of cumulative effects associated with the various fishing-and-handling processes, which for the hooked-and-released fish probably included anatomical hook location and bait type, as identified above. It is unlikely that there were any contributory effects attributable to either the size of the fish or their confinement in the cages, because (i) all dead tagged fish were similar in size to those that survived (Table 3), and (ii) levels of plasma glucose were not significantly different between wild-caught and caged individuals at the end of the experiment.

Because our study was restricted to common tackle configurations (i.e. a long-shank J-hook and two bait types) used to target sand whiting in one estuary during a single event, the results may not represent the fate of all sand whiting released in eastern Australia. Further work is required to determine the rates of ingestion of other tackle configurations at different times and places with different environmental conditions. Nevertheless, the results do have implications in terms of promoting some existing angling practices. For example, Henry and Lyle (2003) estimated that, excluding King George whiting, at least 4.2 million unspecified sillaginids were released throughout Australia in 2000/2001, of which almost 1.8 million individuals were primarily sand whiting caught in coastal areas and estuaries throughout NSW. Assuming similar mortality rates to those observed here and in related work (Broadhurst *et al.*, 2005), potentially up to 1.7 million of these sand whiting would have survived hook and release. Such numbers have obvious positive benefits for future stocks and the sustainability of non-consumptive angling for this species. Nonetheless, additional efforts to reduce mortality through angler education and refinements in gear practices should be pursued.

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