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Keywords
elongatus, mugilidae, mortality, angled, sand, mullet, post, myxus, release

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Post-release mortality of angled sand mullet (*Myxus elongatus*: Mugilidae)

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Abstract

Grey mullets (Mugilidae) are important to recreational fisheries throughout the developed world. In Australia, several species are angled and then released in large numbers; all with virtually unknown fate. In response to the need for such data to facilitate effective stock management, this study sought to quantify the post-release mortality and key causal factors for sand mullet (*Myxus elongatus*). A total of 125 fish were conventionally angled, and then released along with 50 controls into floating cages in a south eastern Australian estuary, where they were monitored for four days. Five treatment fish died, providing a non-significant mortality of 4%. The few fatalities were mostly explained by a significant positive relationship with the length of trace (between the float and hook) used, and bleeding during release. While sand mullet appear quite tolerant of catch and release, their welfare nevertheless could be improved through simple changes to fishing strategies.

Keywords:

Catch and release

Unaccounted fishing mortality

Mugilidae

Hook and line

Post-release survival

1. **Introduction**

The family Mugilidae comprises 14 genera and more than 60 species that are globally distributed throughout tropical and temperate estuarine and nearshore areas (Thomson, 1997). Their often large abundances, schooling behaviour and accessibility means that mugilids are targeted by commercial and artisanal seiners and gillnetters throughout their range, and by recreational fishers in developed countries (West and Gordon, 1994; Bacheler et al., 2005; Rangel and Erzini, 2007).

In Australia, more than 10 mugilids are caught commercially (e.g. Chubb et al., 1981; West and Gordon, 1994; Gray et al., 2005), while at least five species (including yelloweye mullet, *Aldrichetta forsteri*, bluespot mullet, *Valamugil seheli*, sand mullet, *Myxus elongatu*s, goldspot mullet, *Liza argentea* and sea mullet, *Mugil cephalus*) are also taken by recreational fishers (Henry and Lyle, 2003; Grant, 2008). There are few quantitative data on recreational catches, although a national 12-month survey done late last century estimated a total of nearly four million mugilids; ~50% of which were angled (Henry and Lyle, 2003). Further, owing to a combination of minimum legal sizes (21–25 cm TL) and personal daily quotas (15–60 fish) in most states, more than 25% of these fish were released. While the exact species composition remains unknown, a large proportion of the angled discards probably comprised sand mullet, and especially off south eastern Australia where this species is often incidentally caught by anglers seeking sand whiting (*Sillago ciliata*; Sillaginidae) (Grant, 2008).

Despite their abundance, and unlike other important species angled across the same habitats (e.g. yellowfin bream, *Acanthopagrus australis*: Sparidae – Broadhurst et al., 1999; sand whiting – Butcher et al., 2006; dusky flathead, *Platycephalus fuscus*: Platycephalidae – Butcher et al., 2008 or luderick, *Girella tricuspidata*: Kyphosidae – Butcher et al., 2010), there is no information available on the fate of released sand mullet. Quantifying any associated so called ‘unaccounted fishing mortality’ is a necessary prerequisite for ongoing stock assessments and effective management. Also, irrespective of fatalities, in recent years there has been a growing social impetus to identify and ameliorate any fishing and handling practices that negatively affect the welfare of released fish (Davie and Kopf, 2006).

Given the requirements above, and the paucity of relevant information, our main aim in this study was to estimate the short-term (four days) mortality and key causal factors for sand mullet caught and released by anglers using conventional methods in a south eastern Australian estuary. A secondary aim was to recommend appropriate strategies by which negative impacts to this species might be minimized.

2. Materials and methods

2.1. Catch and release of fish

Sand mullet were angled by 11 mostly boat-based fishers during one afternoon (1400–1800) and two morning (0700–1100) sessions over two days in the Wooli River (29^{o}52'S 153^{o}16'E) during February 2009 (Table 1). Participants were provided with 20-l holding cages made from polyvinyl chloride (PVC) buckets with one top and three lateral windows (each <230 cm^2) covered by 6-mm PVC mesh. Each 20-l cage could hold ~5 l of water when lifted on board. All sand mullet were individually released into the 20-l cages, which were then tethered to the side of the boat. Anglers completed a datasheet for each fish (see below), secured this to the relevant 20-l cage and then cast them adrift. Researchers collected and transported the 20-l cages to five 2600-l floating cylindrical cages (made from 22-mm knotless mesh suspended from a stainless steel ring fitted to a square frame of PVC tubing) moored in the river, where each fish was released without air exposure. To facilitate identification beyond TL, similar-sized fish were caudal-fin clipped (while submerged) or released into separate 2600-l cages.

On the second angling day, 50 sand mullet were transported from the National Marine Science Centre aquaria facilities (Coffs Harbour, 30°16'S 153°05'E), fin-clipped for identification as controls, placed into the water-filled 20-l cages for ~25 min (i.e. similar to angled fish - see below) and then evenly distributed among the five 2600-l cages. These controls were originally caught by cast netting (one month previously) and handled and monitored following Broadhurst et al. (1999). All of the caged control and angled fish were offered live yabbies (*Callianassa* spp: Callianassidae) and monitored for mortalities over four days, after which they were measured (TL) and released.

2.2. Data collected

The following data were collected for angled fish: angler name; angling day; hook type (J or circle) and absolute size (mm^2); length of trace (i.e. distance between the float and hook in cm); bait type; playing time (s); whether or not they were dropped during landing; restraint method; period of air exposure (s); general and specific anatomical hook locations; whether or not the hook was removed; TL (cm); the presence or absence of fin damage, scale loss, or blood; time spent in the 20-l buckets prior to release into the 2600-l cages (and the number of the latter); and whether they survived the experiment. The river temperature (^{o}C), salinity (psu) and dissolved oxygen (DO; mg l^{-1}) were recorded at the monitoring and fishing sites three times daily using an Horiba U10 water quality meter.

2.3. Statistical analyses

The independence of the treatment of fish (angled vs. control) on mortalities at the end of the experiment was investigated using a Fisher's exact test. All of the data describing each angled fish were collated as either fixed 'terminal rig', 'landing' or 'angling response' factors. These terms were then considered along with the random effects of 'anglers' and 'fishing days' (and their interaction) and 'cages' in generalised linear mixed models (GLMM) fitted via penalized quasi-likelihood to the dichotomous status (alive vs. dead) of sand mullet at the end of the experiment.

The baseline model contained only the random terms and the intercept. Two GLMMs were then separately fitted to determine which of the (i) terminal rig and landing or (ii) angling response factors contributed towards fatalities. All modelling was considered descriptive rather than predictive and so, rather than strict criteria, a forward selection from the baseline model with a pseudo F-to-enter strategy was chosen, based on the asymptotic p-value of the Wald statistics from the GLMM. All analyses were done in ASReml-R (Butler et al., 2007).

3. Results

A total of 125 sand mullet (mean TL ± SD of 26.39 ± 5.49 cm) were angled and released into the 2600-l cages (25 fish $cage^{-1}$) with the 50 controls (which had similar sizes; 26.90 ± 5.95 cm TL). Angled fish were caught using one of three sizes of J-hooks (baited with some form of bread constituent) attached to <5.5 kg monofilament line and with a 30–40-mm diameter float located 5–60 cm above the hook (encompassing the trace; Table 1). Most individuals were played for <30 s and during landing, nearly 80% were restrained by bare hands (typically dry; Table 1). Nearly all (~97%) fish were hooked in the mouth (categorized as 'shallow' hooked), and mainly in the maxillary or mandible, or at their junction (~66%; Table 1). All hooks were removed by the anglers. Very few (<25%) sand mullet were dropped during handling (Table 1). Scale loss, bleeding and fin damage were evident among ~2, 13 and 2% of fish, respectively (Table 1). Angled fish spent an average (±SD) of 22.61 ± 12.38 min in the 20-l buckets before being released (all alive) into the 2600-l cages. Water temperature (range and mean ±SD of 22.8–28.5 and 24.6 ± 1.6 ^{o}C), salinity (constant 35.6 ± 0.0 psu) and DO (5.74–6.82; 6.12 ± 0.34 mg l^{-1}) remained similar among the fishing and monitoring days.

None of the controls and only five of the angled fish died (one on the third day and four on the fourth day), providing a non significant mortality of 4% for the latter group (Fisher's exact test, $p >$ 0.05). All of the eventual fatalities were caught by two anglers on the first day (Table 1). These two random effects accounted for almost 40% of the variance in the baseline model, but the remaining proportionally larger residual also indicated the influence of fixed effects. Subsequent exploration of the importance of just the terminal rig and landing factors (first model) revealed a significant impact of trace length ($p < 0.05$; Table 2). More specifically, while both anglers used a range of trace lengths (15–60 cm), all fatalities were restricted to ≥50 cm traces (mean ±SD of 56.0 ± 5.5 cm; Table 1). The second GLMM investigating the effects of the angling responses identified the presence of blood as the only significant predictor of mortality ($p < 0.01$; Table 2), with three of the deaths among a total 16 bleeding fish (caught by several anglers). There was no significant effect of hook location, but two fatalities were hooked in their eyes ($p > 0.05$; Tables 1 and 2).

Discussion

The short-term mortality (4%) among angled-and-released sand mullet was lower than that recorded for many teleosts (range and mean of 0–95 and 18% provided by Bartholomew and Bohnsack, 2005), but close to estimates for several similarly handled species caught across comparable habitats (e.g. Butcher et al., 2006; 2008; 2010). Further, like for these other assessed fish, the few fatalities to sand mullet were attributed to clear technical and biological variables; the impacts of which can be explained by behavioural and physiological mechanisms and possibly cumulative environmental influences.

The importance of the terminal rig in determining the fate of released fish is well established, with several studies demonstrating that those configurations which are more passively fished, either through design (i.e. with long traces after a float) or manipulation (i.e. tension by the angler), often cause more deaths than those with short traces or that are actively fished (i.e. greater resistance between the hook and angler; reviewed by Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2007). While a key mechanism contributing towards such deaths is the concomitant ingestion of hooks, this is not always the case (Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2007). For example, Butcher et al. (2006) isolated bait type (beach worms, *Australonuphis teres*: Onuphidae) as a significant predictor of fatalities among mouth-hooked sand whiting, which was attributed to a greater intensity in hooking response to a preferred diet. The same response could have occurred among sand mullet, with baits attached to longer traces moving freely in the water column and more closely resembling their natural food than those on shorter traces. A more aggressive approach towards such baits might explain the two eye-hooked fish (both of which died).

A stronger response to baits on longer traces was further supported by three of the fatalities haemorrhaging at the hook wound; the only angling response variable identified as a significant predictor of mortality. One possible indirect impact of bleeding is clotting across the gill lamellae during air exposure which could have inhibited respiration; although any such impacts might be expected to cause more rapid deaths than those observed here (Reynolds et al., 2009). An alternative hypothesis is that the dead sand mullet simply succumbed to infection and/or their injuries, with the initial haemorrhaging reflecting the level of damage incurred (Arlinghaus et al., 2007).

Irrespective of the influence of any terminal rig, landing or angling response variables, the angling environment may have had a cumulative impact on the few observed fatalities. Several variables, including salinity, DO and water temperature have been shown to affect the post-release mortality of numerous teleosts (Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2007). In this study, and based on their known distribution, all three variables were within the acceptable range for sand mullet, although the maximum recorded temperature of 28.5 ^{o}C was probably towards the upper limit (Thomson, 1996). Depending on species-specific tolerances, increasing temperatures evoke a range of physiological disturbances in most animals, including a faster metabolic rate and demand for oxygen (Pörtner, 2002). Such effects have been shown to significantly increase the mortality of various angled-and-released teleosts, and could have similarly affected sand mullet (Arlinghaus et al., 2007).

The results from this study suggest that sand mullet are a fairly robust species and apparently well suited to catch and release. Nevertheless, it is important to remember that mortality was assessed using cages and only for four days. The observed delayed mortalities (i.e. most after 96 h) support a protracted negative response to the evoked treatments. In the wild, any impaired fish may be more vulnerable to predators, which could add considerably to their overall unaccounted fishing mortality model. The potential for such impacts should be considered in future research. In the interim, anglers should use short traces (<50 cm) and perhaps actively fish the line to limit aggressive hooking responses by sand mullet. Based on the results here, doing so would minimise injury, virtually eliminate short-term mortality and ultimately improve the welfare of this species post-release.

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Table 1
Summary of categorical and, where applicable, mean (± SD) continuous random and fixed (‘terminal rig’, ‘landing’ and ‘angling response’) factors collected for the live and dead angled-and-released sand mullet (*Myxus elongatus*).

Variables	Alive	Dead
Random factors		
Angling day		
1	95	5
2	25	0
Angler		
1	2	0
2	2	0
3	5	0
4	7	0
5	7	0
6	8	0
7	8	0
8	11	0
9	15	3
10	19	2
11	36	0
Cage (2600 l)		
1	23	2
2	24	1
3	25	0
4	25	0
5	23	2
Terminal rig factors		
Hook size (mm^2)		
122.60	22	0
165.19	64	5
201.70	34	0
Trace length (cm)	35.2 (11.0)	56.0 (5.5)
Bait type		
Bread centre	104	2
Flour and water mixture	15	2
Bread crust	1	1
Landing factors		
Playing time (s)		
<10	18	0
11 to 30	75	3
31 to 60	24	2
Fish dropped		
No	90	3
Yes	28	2
Restraint method		

Bare hand	95	2
Shirt/cloth	12	3
Towel	13	0
Wet restraint method		
No	75	2
Yes	45	3
Air exposure (s)		
<10	36	0
11 to 30	51	2
31 to 60	30	3
Angling response factors		
General hook depth		
Shallow (preorbital)	118	2
Deep (postorbital)	1	1
General hook location		
Ingested	0	1
Mouth	118	2
Body	1	2
Specific hook location		
Junction of mandible and maxillary	30	2
Mandible	27	0
Maxillary	54	0
Palate	3	0
Gill	1	0
Body	1	0
Oesophagus	0	1
Floor of mouth	1	0
Eye	0	2
Scale loss		
No	120	3
Yes	0	2
Bleeding		
No	106	2
Yes	13	3
Fin damage		
No	118	5
Yes	2	0

Table 2

P-values for variables tested in generalized linear mixed models (GLMM) for their independence on the mortality of angled-and-released sand mullet (*Myxus elongatus*) during four days of monitoring in five 2600-l cages. Two groups of models were applied; the first to just the terminal rig and landing variables, and the second to only those data describing the angling responses of fish. *P*-values of the F-to-enter Wald statistic are presented in two columns; those for each variable added to the baseline model, followed by those for each variable added to the baseline + trace length/bleeding model.

Variables	Baseline model *p*	Baseline + trace length/ bleeding model *p*
Termina-rig-and-landing GLMMs		
Trace length	0.015	–
Bait type	0.080	0.386
Restraint method	0.146	0.835
Fish dropped	0.319	0.220
Wet restraint method	0.556	0.798
Playing time	0.702	0.566
Hook size	0.900	0.972
Air exposure	0.914	0.787
Angling-response GLMMs		
Bleeding	0.004	–
General hook location	0.072	0.178
Scale loss	0.887	0.888
Fin damage	0.928	0.952
Specific hook location	1.000	1.000