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Relative ghost fishing of portunid traps with and without escape gaps

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ABSTRACT

Owing to concerns about derelict portunid traps perpetually fishing ('ghost fishing') in southeastern Australia, the utility of escape gaps for minimising temporal catching efficiencies, and damage and mortality, among key species was investigated. Replicate baited traps with (i) no escape gaps ('conventional'), (ii) three escape gaps ('escape-gap' traps), or (iii) three holes where escape gaps would have been if they were biodegradable ('open-hole' traps) were deployed and retrieved after short (one and two weeks), medium (four and six weeks) and long soaks (eight and 10 weeks). No trap had bait remaining after any soak. Total catches comprised 17 species, but 70% was blue swimmer crabs, *Portunus armatus*—most (78%) of which were smaller than a proposed new legal size (≥65 mm carapace length). Many (62%) *P. armatus* were injured (typically missing one or two appendages), but had few mortalities (total of 5%). Compared to conventional traps, the escape-gap and open-hole traps retained significantly fewer undersized *P. armatus* across all soaks (by 93 and 96%) and there were less total injuries (by 86 and 97%) and mortalities trap^{-1} (by 80 and 85%). Irrespective of the trap, catches of total and undersized *P. armatus* and injuries trap^{-1} were greater after short (all by up to 3 ×) than medium or long soaks. Several traps had broken mesh bars, which was negatively associated with *P. armatus* catches and injuries. Only three other species had mortalities (n = 7). The data support using escape gaps for minimising ghost fishing among derelict portunid traps.

1. Introduction

Portunidae comprises > 500 species globally, with several targeted in artisanal, recreational and commercial fisheries (WoRMS Editorial Board, 2017). Two important portunids in Australia are mud crabs (mostly the giant mud crab, *Scylla serrata*) and blue swimmer crabs, *Portunus armatus*; originally *P. pelagicus*). These species spatially co-occur, although *P. armatus* prefers saline areas while *S. serrata* is euryhaline (Tangkrock-Olan and Ketpadang, 2010).

Irrespective of their Australian distributions, both species are targeted by recreational and commercial fishers (mostly during the Austral summer) using various legislated gears. Historically, solid wire-mesh baited traps have been used (Leland et al., 2013). But more recently, collapsible netted round designs have been shown to be more efficient and, where permitted, often are preferred (Grubert and Lee, 2013; Leland et al., 2013; Rotherham et al., 2013). This is especially the case in New South Wales (NSW), where such traps account for most of the *S. serrata* and *P. armatus* harvested by recreational (who can each deploy two traps day^{-1} catching up to 60 and 300 t each year, respectively) and commercial fishers (each fishing ~10–40 traps day^{-1} for up to 160 and 250 t each year, respectively) (Henry and Lyle, 2003). Traps are fished throughout various rivers and estuaries, but an important area is Wallis Lake, which supports extensive recreational effort and is responsible for much of the total NSW commercial catch of *P. armatus* (Broadhurst et al., 2017).

Portunid traps used in NSW have small legislated minimum mesh sizes (50 mm stretched mesh opening; SMO) which means none are 100% selective for the targeted sizes (historically ≥85- and 60-mm carapace length–CL for *S. serrata* and *P. armatus*, respectively) and so large numbers of undersized portunids are caught and then released/discarded. Further, there is a proposal to increase the legal size of *P. armatus* to ≥65 mm CL, which will increase discarding. While studies have suggested minimal associated mortality, there are concerns over sublethal impacts to small, undersized portunids (including appendage loss) and a perception that excessive discarding in such highly visual fisheries is socially unacceptable (Leland et al., 2013).

A simple strategy for improving trap selectivity is to retroactively insert so-called 'escape gaps' (e.g. Grubert and Lee, 2013; Rotherham

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et al., 2013). In NSW, Broadhurst et al. (2014, 2018) demonstrated that when targeting *S. serrata*, collapsible netted round traps fitted with one to four rectangular escape gaps (each 46 × 120 mm) near the trap base were effective in reducing the catches of undersized individuals (and in some cases unwanted fish) by up to ~95%, while maintaining legal catches. Similarly, Broadhurst et al. (2017) showed that up to three escape gaps (33 × 120 mm) in the same types of traps reduced catches of *P. armatus* < 60 mm CL (i.e. the historical minimum legal size) by 51–100%.

The research done-to-date supports using the assessed escape gaps among collapsible netted round traps targeting *S. serrata* and *P. armatus* as a means for minimising bycatch and reducing fishery impacts. But there remain some unresolved issues. In particular, at times traps are lost and could keep fishing as animals enter, die and attract other animals as bait, perpetuating what is known as 'ghost fishing' (for reviews see Matsuoka et al., 2005; Uhlmann and Broadhurst, 2015). No data are available on the number of portunid traps lost in NSW, but derelict traps commonly are observed throughout estuaries, and in the adjacent state of Queensland (QLD), Campbell and Sumpton (2009) estimated up to 3000 commercial traps are lost and not recovered each year.

Quantifying the ghost fishing of traps typically has involved repeated-measures experiments and often via: (i) assessing and sometimes tagging catches in situ by divers (e.g. Parrish and Kazama, 1992; Bullimore et al., 2001; Erzini et al., 2008); or where this is not possible (e.g. owing to poor visibility in estuaries or deep water) (ii) retrieving traps to the surface and then tagging and/or measuring and replacing animals before redeployment (e.g. Hébert et al., 2001; Godøy et al., 2003; Campbell and Sumpton, 2009). Campbell and Sumpton (2009) employed the latter approach in Morton Bay, QLD, and used tags to estimate that one lost conventional netted round trap could catch up to 223 *P. armatus* year^{-1}.

While repeated-measures experiments to quantify ghost fishing and mortality have widespread utility, there is at least some possibility for confounding effects on the behaviour or fate of trapped animals owing to repeated handling and/or barotrauma (Parker et al., 2006) in those traps that are retrieved from water > ~10 m. Further, regularly sampling the same experimental traps increases the risk of poaching. An alternative experimental design is to randomly deploy traps undisturbed and then destructively sample replicates after predetermined soaks (e.g. Newman et al., 2011). Such an approach does not allow absolute catches and mortality to be quantified (because the entry and exit of individual animals cannot be determined), but it does facilitate comparative assessments of conventional and modified gears in terms of their relative efficiencies and injury and mortality rates, and with few confounding effects.

Here, we hypothesised that the potential for ghost fishing by collapsible round netted traps in NSW estuaries might be alleviated via either escape gaps (configured to match the increase in legal size of *P. armatus*) or, if these degraded, a larger opening created in the trap (e.g. Winger et al., 2015). Our primary aims were to quantify the relative efficiencies for key species (and associated mortality and damage) by traps (i) without escape gaps against those (ii) with escape gaps secured, and (iii) with the netting holes cut for escape gaps, but nothing inserted (to simulate loss/degradation of the escape gap) over undisturbed soaks between one and ten weeks.

2. Methods

2.1. Treatment traps

The work was done in Wallis Lake (32.27°S and 152.49°E) between February and June 2017, using 36 collapsible netted round traps (hereafter 'traps' Fig. 1). All traps comprised knotted polyethylene (PE) mesh (stretched mesh opening–SMO of 50 mm and made from 1.2-mm diameter–Ø twisted twine) suspended between two parallel steel rings (10-mm Ø rod) measuring 1020 mm across and separated by four polyvinyl chloride pipes 330 mm apart, with four 300 × 200 mm slitted (20 mm openings) funnel entrances in the middle of the sides of the traps (Fig. 1a). The 36 traps were configured as three treatments.

Twenty-four of the 36 traps each had three holes (each made by removing out three full meshes and measuring ~50 × 120 mm) cut into their bases around the perimeter. In 12 of these traps, three escape gaps were installed, each made from polypropylene frames (90 × 150 mm) with internal openings measuring 36 × 120 mm (termed 'escape-gap traps'; Fig. 1b) which, based on the carapace depth (CD) to CL relationship of *P. armatus*, were designed to allow individuals < 65 mm CL (i.e. the proposed increase in minimum legal size) to pass through (hereafter 'undersized'). In the other 12 traps, the holes were left open ('open-hole traps'; Fig. 1c). The remaining 12 traps had neither escape gaps nor holes ('conventional traps'; Fig. 1a).

The traps were separated into six clusters; each cluster comprising two randomly allocated replicates of conventional, escape-gap, and open-hole traps (Fig. 1d). Each trap in each cluster was separated by 60 m of 6-mm Ø weighted polypropylene rope, and with the last trap of each end attached to a separated 15-kg anchor (Fig. 1d). To reduce the possibility of poaching, there were no surface lines or markers attached to the trap clusters (i.e. they remained hidden while deployed). Replicate temperate and salinity data loggers (Hobo and Greenspan) were attached to some of the traps and configured to collect data every 6 h.

On the first day of fishing, all traps were baited with ~600 g of chopped sea mullet, *Mugil cephalus* placed into a 250 × 200-mm wire-mesh bait bag (10- × 10-mm mesh), and had their access openings (for removing catches) sealed with unique, identifiable plastic cable ties (so that any broken seals would imply poaching). The six clusters (each comprising six baited traps) were deployed on the bottom in 2.5–3.5 m at random marked locations across ~15 ha of conventional fishing grounds in Wallis Lake and left undisturbed to fish for randomly designated soaks (of either one, two, four, six, eight or ten weeks; Fig. 2).

After each designated soak, two clusters were located, retrieved using a grapple hook and sampled (see below). Each trap was cleaned, repaired or replaced as required, before being rebaited and sealed and reordered among clusters. The two clusters were then redeployed at random locations within the Lake. This process was repeated three times to achieve replicates of designated soaks (Fig. 2).

2.2. Data collected and analyses

Immediately after retrieval, the traps were emptied and all organisms counted. Identifiable fragments of crustacean cephalothoraxes and abdomens were separated and used to determine the number of original animals. Complete crustaceans of interest were sexed, measured with vernier callipers for CL (to the nearest 1 mm) and assessed for status (alive or dead) and moult stage following Hay et al. (2005).

For all *P. armatus*, the locations and numbers of old or new exoskeleton injuries (following Uhlmann et al., 2009), defined as missing and/or damaged appendages (chelipeds, pereopods or swimmerets), and/or any carapace trauma were quantified. Ovigerous females were assessed for missing portions of egg clusters (to the nearest 5%). All other organisms were identified to species, counted and assessed as alive or dead. Fish were measured for their total length (TL to the nearest 1 mm) and noted for damaged skin or fins. The amount of bait remaining was quantified, and each trap was inspected for any broken mesh bars which, if present, were counted (and repaired).

Separate generalized log-linear mixed models (GLMM) were fitted to the numbers of total, legal (≥65 mm CL) and undersized (< 65 mm CL) *P. armatus* trap^{-1}, and the numbers of injured (old and new combined) and dead individuals trap^{-1}. Binomial GLMMs were also fitted to the proportions of injured and dead *P. armatus* trap^{-1}. Prior to analyses, soak times were aggregated into three groups: short (one and two weeks); medium (four and six weeks); and long (eight and ten weeks). In all models, the fixed effects considered for inclusion were 'soak time' along with 'treatment trap' (and their interaction), and the number of