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Assessment of relative performance of a square-mesh codend design across multiple vessels in a demersal trawl fishery

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ABSTRACT

Implementing gear-based solutions to reduce bycatch in trawl fisheries can be difficult owing to fishers' concerns over the fleet-wide applicability of results from discrete, highly controlled experiments associated with the development of such innovations. In New South Wales, Australia, a codend comprising a posterior section made from 35-mm square-shaped mesh (i.e. hung on the bar) was developed and subsequently recommended for partial implementation in a multi-species demersal trawl fishery (i.e. for use when eastern king prawn – *Melicertus plebejus* – is the primary target species). However, industry concerns over this design have to date prevented its implementation. Here, using direct twin-tow comparisons onboard a subset of the fleet, we quantitatively assessed the performance of the square-mesh codend, relative to the range of diamond-mesh codend designs currently being used, in terms of reductions in bycatch rates and shortfalls in catch rates of retained animals. Generalised linear mixed-effects modelling across all vessels showed that when eastern king prawn was the target species, the square-mesh codend significantly reduced bycatch rates (by ~48%), but with an accompanying significant shortfall in catch rates of eastern king prawn (~7%) and a substantial (though not statistically significant) shortfall in catch rates of an important component of the retained byproduct (whiting, *Sillago* spp., ~36%). Partitioning of data by vessel revealed that such shortfalls in retained catch were evident for only some vessels, while the square-mesh codend performed as intended for the others. When school prawn (*Metapenaeus macleayi*) was the target species, substantial shortfalls in catches of school prawn (~54%) in the 35-mm square-mesh codend confirmed that a codend of a smaller square mesh might be a more appropriate design under those circumstances. Potential strategies to address intra-vessel inconsistencies in performance of the square-mesh codend and thereby facilitate implementation of square-mesh codends in the fishery are discussed.

1. Introduction

The systematic discarding of unwanted organisms – collectively termed 'bycatch' (sensu Saila, 1983) – has long been a problem common to many prawn- (or shrimp-) trawl fisheries around the world (Andrew and Pepperell, 1992; Kennelly, 1995). In response, a suite of strategies to reduce the incidence and overall quantity of bycatches has been employed. These include restrictions on the spatial extent of and temporal access to fishing grounds and the development of modifications to fishing gears that improve their size and species selectivity (Graham et al., 2007; Kennelly, 2007). This latter, gear-based approach has been applied in many prawn-trawl fisheries and a wide range of gear modifications, including bycatch reduction devices (BRDs) and changes to the size and/or orientation of codend meshes, have been developed and some subsequently implemented with varying success (e.g. see reviews by Broadhurst, 2000; Cox et al., 2007; Graham et al., 2007; Catchpole and Revill, 2008).

In many cases where gear-based solutions to bycatch issues in prawn-trawl fisheries have been developed it has been via a succession of discrete, highly controlled field experiments (e.g. Brewer et al., 1998; Robins et al., 1999; García-Caudillo et al., 2000; Broadhurst et al., 2002; Steele et al., 2002) – an initial approach that is both logical and necessary (Kennelly, 2007). Other studies have involved assessing modified gears under as close to 'normal commercial' conditions as deemed practical, with at least one aspect of the sampling design substantially limited or controlled.

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Examples include the type and/or number of vessels used (e.g. non-industry research vessel – Polet, 2000; only one industry vessel – Catchpole et al., 2006; Bullough et al., 2007), limited spatial and temporal extent of industry trials (e.g. limited temporal scope – Brewer et al., 1998; limited depth range – Guijarro and Massutí, 2006), controlled operational procedures (e.g. standardised tow duration – Campos et al., 2002; Broadhurst et al., 2006a), any modifications to gears for sampling purposes (e.g. codend cover – Tokai and Kitahara, 1991; Macbeth et al., 2007), and/or the range of fishing conditions encountered during sampling (e.g. unrepresentative catch sizes and/or composition).

Any of those issues could be perceived to compromise any conclusions in terms of applicability to the true scope of commercial conditions and practices associated with the fishery, despite the general validity and usefulness of the research. Hence, commercial fishers are often reluctant to support and/or adopt the gear modifications ultimately recommended owing to concerns over the fleet-wide representativeness of the research done to develop those gears (Catchpole et al., 2005). Such perceptions, driven by an underlying fear that any alternative to incumbent gear regulations might reduce the economic efficacy of their operations, commonly hinder attempts to legislate gear-based bycatch-mitigating technologies for compulsory use, despite the scientific validity of research on which the recommendations were based (Catchpole et al., 2005).

In continental shelf waters off New South Wales (NSW), south-eastern Australia, demersal otter trawls are used to catch penaeid prawns in the 'ocean prawn-trawl fishery' (Kennelly et al., 1998; Broadhurst et al., 2006a,b). The main target penaeid species, eastern king prawn (*Melicertus plebejus*), is caught at night in waters approximately 40–200 m in depth. School prawn (*Metapenaeus macleayi*) is also targeted at times in waters shallower than ~40 m at specific times, usually when large congregations of school prawn occur in coastal waters adjacent to river mouths following significant freshwater discharge events (Ruello, 1973; Glaister, 1978). Two species of whiting, *Sillago flindersi* and *Sillago robusta*, commonly caught and usually combined for sale, are also targeted when and where it is deemed profitable (Broadhurst et al., 2005). A range of other organisms is also commonly retained as marketable 'byproduct', such as various species of: finfish – flathead (*Platycephalus* spp. and *Ratabulus diversidens*), yellowtail scad (*Trachurus novaezelandiae*) and bluestriped goatfish (*Upeneichthys lineatus*); cephalopods – octopus (*Octopus* spp.), squid (Loliginids and Ommastrephids) and cuttlefish (*Sepia* spp.); and crustaceans – bugs (*Ibacus* spp.) (Kennelly et al., 1998). This byproduct is sometimes considered to be as economically important as the targeted prawns, comprising up to 70% by weight and 30% by value of retained catch (Kennelly et al., 1998). Many demersal species of no commercial interest, along with individuals of the retained species considered too small for sale, are also caught and then discarded – mostly dead.

Concerns over the capture of small fish in the fishery in the 1990s led to the development of a range of behavioural-type 'square-mesh panel' BRD designs via discrete, controlled experiments and other less-formal trials (Broadhurst and Kennelly, 1996, 1997; Broadhurst et al., 1996). Among the range of designs tested, the most effective at reducing discarding of small fish without reducing marketable catches was the 'composite square-mesh panel' (Broadhurst and Kennelly, 1996, 1997). Following industry consultation it was legislated for use, although a number of other behavioural-type BRD designs were also negotiated by industry as permissible alternatives. Since that time anecdotal evidence has indicated that the alternative designs are being used in preference to the composite square-mesh panel by the majority of the fleet.

More recently, the incidental and unwanted capture of small, juvenile eastern king prawns and whiting in the fishery has become a concern for the fishery managers. To address this, a range of alternatives to the conventionally used size and orientation of codend meshes was assessed; again via controlled experiments (Broadhurst et al., 2006a,b) and other less-formal trials. A codend made from nominal 35-mm square-shaped mesh (Robertson and Stewart, 1988) was found to be the most successful alternative to a conventional 41-mm diamond-mesh codend design with respect to reducing bycatch of small prawns and whiting without, in most cases, significant shortfalls in catches of target-size prawns, whiting and other byproduct (Broadhurst et al., 2006a,b). The square-mesh codend was, with minor alterations, subsequently recommended for mandatory use when eastern king prawn is the primary target species. It should be noted that during that research a composite square-mesh panel was installed as the BRD for all codend tests. All mesh sizes quoted above and hereafter refer to stretched mesh opening (Ferro and Xu, 1996).

Many NSW ocean prawn-trawl operators remain unfamiliar with and/or suspicious of the applicability of the square-mesh codend in their fishery – a situation that has, to date, stalled its implementation. So, as an industry extension exercise to address this issue, identical 35-mm square-mesh codends (with a composite square-mesh codend design installed) were provided at no monetary cost to a subset of the fleet comprising 17 of the estimated 63 ocean prawn trawlers operational in northern NSW. This provided a valuable opportunity for the collection of detailed, observer-type catch data onboard some of these vessels to assess the performance of the 35-mm square-mesh codend relative to conventional diamond-mesh codends: (1) across a larger subset of the fleet than was used during previous experiments; (2) over a relatively longer time-frame; (3) under full commercial fishing protocols; and as a consequence, (4) under a relatively wide range of fishing and catch conditions (Cox et al., 2007). Our objective here, therefore, was to quantitatively assess the relative performance of the prescribed 35-mm square-mesh codend/composite square-mesh panel configuration against diamond-mesh codend/industry-designed panel BRD configurations simply in terms of two criteria: (1) reduction of bycatch and (2) shortfalls in targeted catch or byproduct; opportunistically across a subset of ocean prawn-trawl vessels.

2. Methods

The nominal 35-mm square-mesh codend/composite square-mesh panel configuration ('35S codend') distributed to fishers was based on designs previously developed by Broadhurst et al. (2006a,b). Each codend had a posterior square-mesh section 100 bars (~2.05 m) in circumference and 51 bars (~1.14 m) long, with the mesh made from knotless, braided twine of 3-mm diameter (Ø) (Fig. 1A). This square-mesh section was attached to an extension section made from 40-mm diamond mesh (knotted, twisted twine of 2-mm Ø). The extension was 100 transverse (T) meshes in circumference and 33 normal (N) meshes (~1.48 m) long and incorporated a composite square-mesh panel similar in design to that specified by Broadhurst et al. (2006b), positioned 1.2 m from the drawstring of the codend as per local regulations (Fig. 1A).

A total of seven vessels, based at ports between Ballina and South West Rocks (Fig. 1B), hosted observers during this study, with at least one sampling trip (i.e. one night or day) comprising multiple tows done for each vessel. Among the range of diamond-mesh codend designs being used, there were variations in: mesh size (40–45 mm); codend length; type of netting (i.e. knotted/knotless mesh; twisted/braided twine; twine diameter); circumference (i.e. 150T or 200T meshes); and BRD design and position. All BRDs were variants of square-mesh panel made from at least 55-mm mesh and measuring around 450 cm^2 in area (minimum 18 cm width) – the minimum dimensions required according to the regulations. This