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Effects of knot orientation on the height and drag of a penaeid trawl

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ABSTRACT

The knots used to make fishing nets are asymmetric which, in most cases for trawls, means they present either a positive or negative angle of attack (AOA) in horizontal panels, producing hydrodynamic side forces and changes in system geometry. The extent of associated displacement and drag were quantified in a flume tank using four, full-scale penaeid (shrimp/prawn) trawls with the same generic design, but with all possible combinations of knot orientation in the top and bottom panels. All four trawls had the same distance between the footrope and flume-tank floor at the wing end during a flow of 1.2 ms^{-1}, but the trawl with both panels at a positive AOA had a significantly greater footrope height at the centre (by up to 13 mm). Further, compared to both trawls with their top panels orientated to have a positive AOA, the two with their top panels producing a negative AOA had up to 27% lower headlines and 10% less total drag. Differences were also observed among vertically partitioned drag at the wing ends—depending on knot orientation in the bottom panel, which led to greater force on the headline or footrope when at negative or positive AOAs, respectively. The magnitudes of observed variations in footrope and headline heights and drag are likely to affect the catching and engineering performances of penaeid trawls, and so knot orientation should be considered during attempts at improving selectivity and reducing drag. The results also reiterate a need for consistency among knot orientations to avoid confounding effects during fishery-dependant/independent surveys.

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1. Introduction

The meshes used in fishing nets have knots (known as 'sheet bends') that are asymmetric to the netting plane; a characteristic that creates small hydrodynamic side forces when the net has a zero angle of attack (AOA) to the relative water movement. During the manufacture of most bundles of netting, the knots are constructed/alternated between rows such that there is a consistent direction of force which, when used in the more-or-less horizontal netting panels of mobile gears like trawls, can create substantial displacement (Broadhurst et al., 2016; Fig. 1).

The broad effects of knot orientation in trawls were first documented in Australian fishing-industry magazines some 25 years ago and based on observations during flume-tank tests at the Australian Maritime College (Paice, 1991). These tests identified that for a penaeid (i.e. shrimp or prawn) trawl in flow, alternating the knots in the top and bottom body panels between a positive AOA (i.e. with the bight of the sheet bend at the anterior top and posterior bottom in alternate rows) and a negative AOA (with the bight at the posterior top and anterior bottom) affected vertical geometry. Based on these characteristics, many Australian penaeid fishers configure horizontal body panels in their trawls to achieve varying perceived benefits. Most fishers orientate the top panel to provide a positive AOA (to create lift), but configure the bottom panel with either a positive or negative AOA—depending on whether they seek to reduce or increase bottom contact, respectively.

There are few formal field-based trials assessing the impacts of knot orientation on the performance of benthic trawls. In one recent study, Broadhurst et al. (2016) showed that orientating knots in both body panels of a penaeid trawl to produce a negative AOA resulted in greater wing-end spread, but fewer school prawns,

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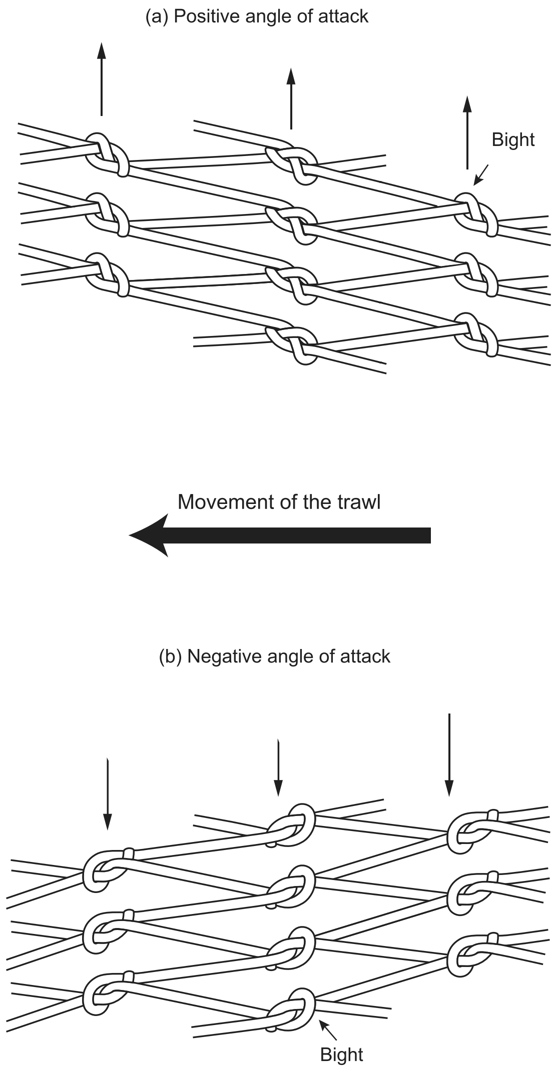

Fig. 1. Diagrammatic and simplified representation of panels of netting orientated so the knots provide (a) positive and (b) negative angles of attack.

Metapenaeus macleayi (means reduced by up to 26%) and three key species of unwanted schooling fish (by up to 67%) and more debris (4×) ha^{-1} trawled than when the knots had a positive AOA. In contrast, catches of two other unwanted benthic teleost species remained unaffected by knot orientation.

The results observed by Broadhurst et al. (2016) were attributed to species-specific differences in vertical distribution and the negative knot-AOA trawl probably having a lower headline height. This hypothesis was supported by the relatively greater wing-end spread and a slight (~2.5%; albeit non-significant) reduction in drag for the negative knot-AOA trawl. Nevertheless, the extent of the variation in vertical geometry of the trawl proposed by Broadhurst et al. (2016) was speculative and remains unquantified.

Quantifying any engineering impacts to trawls associated with various combinations of knot orientation is important for at least two reasons. First, penaeid trawls are among the most poorly selective fishing gears, accounting for >25% of global bycatch (Kelleher, 2005)—much of which is discarded with high mortality (Broadhurst et al., 2006). Understanding the effects of subtle generic changes to trawl configurations is a precursor to developing more efficient designs. Second, penaeid (and other benthic) trawls frequently are used in fishery-dependant/independent surveys. To accurately extrapolate catch rates as indices of relative abundance, the effects of important technical factors (such as knot orientation within netting panels) on trawl selectivity need to be identified, quantified and standardised.

Considering the above, the aim of this experiment was to test the null hypothesis that there were no differences in the anterior vertical profile and drag of a four-seam generic penaeid trawl with the knots orientated in the top and bottom panels according to all four possible combinations. The specific treatments included both panels with knots producing (i) positive and (ii) negative AOAs, (iii) the top panel with a negative- and the bottom with a positive-knot AOA, and (iv) the top panel with a positive- and the bottom with a negative-knot AOA.

2. Materials and methods

2.1. Equipment used

The experiment was done at the Australian Maritime College flume tank. This facility comprises a recirculating-flow tank of fresh water and has three levels: (i) an upper level where trawls are deployed into the tank; (ii) a level with the test section (11.2 m long, 5 m wide, and 2.5 m deep) and observation area (where trawls are positioned for testing) with a continuous viewing window (made from poly(methyl methacrylate)) on one side, a wall on the opposite side and a moving conveyor belt at the floor; and (iii) a water-return channel below the test section. The two lower levels feature a series of delivery bends and screens that aim to maintain constant water velocity throughout the volume of the test section. Four variable-speed electric motors directly coupled to impellor shafts provide a water flow of up to 1.65 $m\,s^{-1}$.

Four full-scale, four-seam penaeid trawls (all 3.7-m headline lengths) made from nominal 42-mm (stretched mesh opening–SMO) mesh (1-mm diameter–Ø polyethylene twine) were used in the experiment (Fig. 2). The basic trawl plan was originally designed for testing in the Clarence River penaeid-trawl fishery in NSW, Australia, and had a total twine area of 2.13 m^2 (Broadhurst et al., 2013). Here, the only difference between the four trawls was the orientations of their top (0.37 m^2) and bottom body panels (0.34 m^2), which were configured to represent all possible combinations of knot orientation (both at positive or negative AOAs, and either panel at a positive AOA with the other at a negative AOA).

All trawls had their side panels orientated so that the knots were 'pushing out' and ground gear comprising 6-mm chain vertical so-called 'drops' (each 139 mm long and used to separate the footrope and ground chain) encased in 20-mm polyvinyl chloride (PVC) tube attached to a ground chain as per conventional local trawls used in the Clarence River (Fig. 2). Each ground chain was 4.8 m long and comprised two lengths of 8-mm chain (each 1.8 m) either side of 10-mm chain (1.2 m) in the centre (Fig. 2). The maximum stretched height of the top of footrope to the bottom of the ground chain was 169 mm at the wing end and 173 mm at the centre of the trawl (Fig. 2). All trawls had a zipper (Buraschi S146R, 1.45 m long) at their posterior-body extension (around the circumference) to facilitate attaching a section (100 T × 30 N) containing a Nordmøre-grid BRD and codend (Broadhurst et al., 2013; Fig. 2).

2.2. Experimental design and data collected and analyses

Prior to starting the experiment, the four trawls (and their rigging) were weighed and 20 randomly selected meshes in the bodies/wings, Nordmøre-grid extension and codend were measured for their SMOs, using a local purpose-built gauge. On each day of testing, the headline and combined footrope and ground chain at the wing ends of the trawl being tested (with the extension and codend zipped on) were secured to four load cells (Futek LSB210) within 1.48 m of 'sweep' (including the load cell and shackles)

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