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Can optimal trap mesh size be predicted from body depth in a laterally-compressed fish species?

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ABSTRACT

We used fish body depth to predict trap center-to-center mesh sizes that would optimize size selection of black sea bass *Centropristis striata* for both current and proposed minimum size limits for this species. We fished trap types of five different square mesh sizes/configurations: (1) 38.1 mm mesh, (2) 38.1 mm mesh on five sides and 50.8 mm mesh on one side (back panel trap), (3) 50.8 mm mesh, (4) 57.2 mm mesh, and (5) 63.5 mm mesh. The 38.1 mm mesh trap was the control trap type. Back panel traps are the minimally legal mesh configuration in this region while 50.8 mm mesh traps are commonly used in this fishery to further reduce culling of sub-legal black sea bass by fishers. Two previously untested mesh sizes, 57.2 and 63.5 mm, were evaluated because a previously published morphometric relationship between black sea bass body depth and total length (TL) predicted that the diagonal openings of these two respective mesh sizes would retain black sea bass close to the current (279 mm) and proposed minimum TL limits (305 mm). We estimated size selection of each experimental trap type by comparing catches of control and experimental traps. All but the back panel trap displayed relatively steep selection around the fish length at which 50% of individuals were selected (l_{50}). Initial size at retention (l_{10}) by the 57.2 and 63.5 mm trap types were nearly identical to current and proposed minimum fish sizes, respectively. Predictions from the body depth: TL relationship were very similar to estimates of l_{10} and l_{50}, based on uncompressed body depth and compression to 93%. The 57.2 mm mesh and 63.5 mm mesh trap types maintained catches of legal fish but reduced catches of sub-legal fish compared to the back panel and 50.8 mm mesh trap types. Relative to back panel and 50.8 mm mesh traps, use of 57.2 mm mesh traps would reduce rates of discard and discard mortality given current size limits in this fishery.

1. Introduction

Bycatch is an important issue in fisheries worldwide. Globally, bycatch is roughly 40 percent of marine catch (Davies et al., 2009). The effective management of fish stocks necessitates that the magnitude of this bycatch and its contribution to rates of fishing mortality be quantified (Hall et al., 2000). In United States federal waters, the Magnuson–Stevens Fishery Conservation and Management Act requires management councils that oversee ocean fisheries implement measures that minimize bycatch and associated discard mortality. Reduction of bycatch is especially important in reef fisheries in this region, such as those targeting black sea bass *Centropristis striata*, because discarded fishes are subject to mortality from pressure-related traumas (Rudershausen et al., 2007, 2014). Additionally, discarding increases the handling time needed by commercial fishers to process their catch during trap fishing operations. Methods to reduce bycatch of black sea bass in the U.S. South Atlantic include minimum mesh size limits for commercially fished traps.

Passively fished wire mesh traps account for ~80% of commercial harvest of black sea bass in the US South Atlantic (NOAA, 2007). Traps are an attractive gear for commercial fishing because they are more size selective and efficient at catching legal black sea bass than hook and line gear (Bohnsack et al., 1989), which can also be used to commercially harvest black sea bass in this region. Gear types that retain legal black sea bass but allow escape of sub-legal conspecifics help to reduce rates of discard and associated discard mortality because fish that egress from traps before retrieval avoid physical stresses of pressure trauma (Collins et al., 1999; Rudershausen et al., 2014) and air exposure during culling by fishers.

Size selectivity of fish traps has been found to be a function of fish density and behavior, trap mesh size, and fish size

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(Newman and Williams 1995; Gobert 1998). Mesh size influences both the sizes and species composition of fishes retained by traps (Robichaud et al., 1999; Mahon and Hunte 2001; Fisher et al., 2004; Rudershausen et al., 2008). Black sea bass traps exhibit relatively steep selection curves (Rudershausen et al., 2008). Thus, increasing the mesh size of black sea bass traps can have a significant effect on the size selection of fish close to the minimum size limit.

Mesh size rules in the US South Atlantic region from 1999 to 2006 required that each outside wall of a trap be composed of 38.1 mm mesh (square (bar) measure) with a minimum of two 50.8 mm escape vents. The minimum mesh size rule was updated in 2006 to require at least one outside wall of a trap be composed of 50.8 mm square mesh (SAFMC 2006), thus creating a 'back panel' trap type. The back panel trap type reduced the catch of sub-legal black sea bass at that time (<254 mm total length (TL)) relative to traps with full 38.1 mm mesh (Rudershausen et al., 2008). The minimum length limit for commercially caught black sea bass in the U.S. South Atlantic increased to 279 mm TL in 2011 (SAFMC 2011) but without a corresponding increase to minimum trap mesh size regulations. Despite changes to fish size limits, the back panel trap type remains legal in this fishery. Some trap fishers in this region elect to fish traps with full 50.8 mm mesh to reduce culling times (P. Rudershausen, pers. obs); it has been found that this trap type allowed for greater rates of escapement of sub-legal black sea bass at that time (<254 mm TL) relative to the back panel trap type (Rudershausen et al., 2008).

The black sea bass is a demersal serranid that supports valuable commercial and recreational fisheries along the US mid- and South Atlantic states. This laterally compressed species possesses a moderately stout body with body depths ranging from 25 to 33 percent of standard length (Collette and Klein-MacPhee, 2002). Sizes of black sea bass retained by traps in the US South Atlantic commercial fishery range from roughly 160–510 mm TL (Rudershausen et al., 2008).

Simple morphological measurements like body depth might predict trap mesh sizes that will optimize size selectivity (i.e., maximize retention of legal fish while also allowing maximum egress of sub-legal fish) for any one legal fish size limit. This technique has been used to predict openings that will optimize size selectivity around a minimum length threshold in other trap fisheries (Treble et al., 1998; Stewart and Ferrell 2003; Rudershausen and Turano 2009). It is our observation that body depth, more than body width, dictates retention *vs.* escapement through square mesh comprising traps fished for this species (Fig. 1). If body depth is effective at predicting optimal mesh sizes for any given black sea bass size, then this approach provides a more time- and cost-efficient means to modify mesh size requirements than repeating *in situ* experiments each time that fish size regulations change.

In this study we tested whether we could predict an optimal center-to-center trap mesh size that selected for black sea bass of specific lengths; the optimal mesh size would maintain catch of legal fish and reduce catch of sub-legal fish. We fished trap mesh sizes that our predictions indicated would optimize selectivity and simultaneously be of size increments that would have appeal in fisheries and other commercial applications. In measuring selectivity we sought to determine whether a larger mesh size would better match new fish size regulations by retaining legal black sea bass at rates equal to minimally legal trap mesh sizes but permit egress of sub-legal black sea bass at rates greater than minimally legal trap mesh sizes.

Fig. 1. Photograph showing a black sea bass attempting to squeeze through square trap mesh. The fish has oriented itself so that its body depth is parallel to the greatest size opening (diagonal opening) of the mesh (red line). The red circle shows typical free space between the fish's sides and the diagonal measure of the square mesh. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

2. Methods

2.1. Mesh sizes and trap construction

We elected to use four mesh configurations/sizes to test our ability to predict optimal mesh size from morphometry under current (≥279 mm TL) and potential (≥305 mm TL) minimum size limits. We tested the back panel trap type because it is currently the minimally legal trap mesh configuration. We tested a trap with 50.8 mm square mesh throughout because it is commonly used in the fishery and prior work indicated that it is close to, but less than, the optimal size for selecting black sea bass ≥279 mm TL (Rudershausen et al., 2008). Based on the body depth:TL relationship for black sea bass (body depth = 0.942 + 0.272*TL; Rudershausen et al., 2008), we predicted that a fish of the current minimum size limit (279 mm TL) would have a body depth of 76.8 mm. Body depth was measured at maximum depth from the anterior end of the dorsal fin to the pectoral girdle. The practical English measurement that would provide a diagonal opening close to 76.8 mm is 2.25 in square, or 57.2 mm. The diagonal opening of 57.2 mm square mesh is 74.8 mm, which theoretically selects black sea bass ≥272 mm TL. It is important to note that the diagonal opening is different than the center-to-center diagonal of the wire due to wire thickness and the vinyl coating; wire mesh is fabricated based on center-to-center measurements and the opening for this gauge wire is roughly 92.5% of the center-to-center measure. Thus the relationship between the actual diagonal opening (DO) and the center-to-center (CC) square measurement is given by,

$$DO = (2(CC \times 0.925)^2)^{0.5}.$$

A proposed commercial minimum size limit of ≥305 mm TL has been considered but not adopted in this fishery (SAFMC 2011). The predicted body depth of a 305 mm black sea bass is 83.9 mm. The practical English measurement that would provide a diagonal opening close to 83.9 mm is 2.5 in square, or 63.5 mm. The diagonal opening of 63.5 mm square mesh is 83.1 mm, which theoretically selects black sea bass ≥302 mm TL. The predicted body depths at these TLs represent mean values and ~50% of fish at this length should be able to egress from the trap; thus, predicted TLs should be similar to l_{50} estimates from retention probability functions described below (Stewart and Ferrell 2003). The 57.2 and 63.5 mm meshes were custom made by C.E. Shepherd Company, Houston, Texas USA. Unless stated otherwise, all wire mesh measurements