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Delayed effects of capture-induced barotrauma on physical condition and behavioral competency of recompressed yelloweye rockfish, *Sebastes ruberrimus*

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ABSTRACT

Rebuilding of some U.S. West Coast rockfish (*Sebastes* spp.) stocks relies heavily on mandatory fishery discard, however the long-term condition of discarded fish experiencing capture-related barotrauma is unknown. We conducted two studies designed to evaluate delayed mortality, physical condition, and behavioral competency of yelloweye rockfish, *Sebastes ruberrimus*, experiencing barotrauma during capture followed by recompression (assisted return to depth of capture). First, we used sea-cage and laboratory holding to evaluate fish condition at 2, 15, and 30 days post-capture from 140 to 150 m depth. All external barotrauma signs resolved following 2 days of recompression, but fish that survived (10/12) had compromised buoyancy regulation, swim bladder injuries, and coelomic and visceral hemorrhages at both 15 and 30 days post-capture. For the second study, we used a video-equipped sea-cage to observe fish behavior for one hour following capture and return to the sea floor. Trials were conducted with 24 fish captured from 54 to 199 m water depth. All fish survived, but 50% of fish from the deepest depth ranges showed impairment in their ability to vertically orient ($P < 0.01$). Most (75%) deep-captured fish did not exhibit "vision-dependent" behavior ($P < 0.001$) and appeared unable to visually discern the difference between an opaque barrier and unobstructed or transparent components of the cage. These studies indicate physical injuries and behavioral impairment may compromise yelloweye rockfish in the hours and weeks following discard, even with recompression. Our results reiterate the importance of avoiding fishing contact with species under stock rebuilding plans, especially in deep water, and that spatially-managed rockfish conservation areas remain closed to fishing.

1. Introduction

Pacific rockfish (*Sebastes* spp.) constitute a diverse genus of fishes that are well-represented in many marine habitats in the northeast Pacific Ocean. They are generally long-lived and slow to mature, and exhibit a variety of life history traits and niche partitioning strategies, allowing multiple species to occupy the same habitat. Off the U.S. West Coast, rockfish are captured in various mixed-stock fisheries, and some species are subject to harvest restrictions or have been federally declared overfished (PFMC, 2012). While rockfish fishing is prohibited in some areas with relatively high abundances of overfished species (Rockfish Conservation Areas), bycatch within fisheries is still common. In several fisheries, these species must be discarded at sea and their mortality accounted for, to assure stock rebuilding and inform inseason monitoring and management, as well as future stock assessments. Fish show variable responses to the effects of capture which include wounding, stress, temperature changes and time in air (Davis and Ottmar, 2006; Olla et al., 1998; Parker et al., 2003b). Physoclists like rockfish also experience barotrauma, as the gases within their closed swim bladders greatly expand during ascent to the surface, creating a complex suite of severe pressure-related injuries (Hannah et al., 2008b; Jarvis and Lowe, 2008; Pribyl et al., 2011; Rummer and Bennett, 2005). Retained swim bladder gases can also create buoyancy that can prevent discarded rockfish from returning quickly to depth (Hannah et al., 2008a; Hochhalter, 2012). These

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factors make survival and behavioral competency of discarded rockfishes highly uncertain.

To address the question of discard mortality, a number of studies have been conducted to investigate strategies for increasing survival, with mitigation of barotrauma injuries being of primary interest with rockfish. Encouragingly, assisting rockfish with barotrauma back to the bottom (referred to as recompression), where gas volume is decreased, has shown promise in increasing survival (Hochhalter and Reed, 2011; Jarvis and Lowe, 2008). Recompression studies using fish-friendly drum-type cages have quantified 48–72 h survival for a number of rockfish species by depth of capture and provided mortality curves (Hannah et al., 2014, 2012). To facilitate the use of recompression techniques for recreational anglers, fishery managers and private groups have collaborated to provide angler education materials and training, as well as providing free recompression devices (L. Mattes, ODFW, pers. comm., Theberge and Parker, 2005). Broader acceptance of these methods and strategies has influenced stock assessments resulting in estimates which reflect lower rates of discard mortality (L. Mattes, ODFW, pers. comm.).

Despite this progress, longer-term issues for discarded rockfish remain, as studies show a suite of serious injuries result from the gas expansion; these include: prolapse of the gastrointestinal track, plus cardiac, vascular, swim bladder and optic nerve damage (Hannah et al., 2008b; Pribyl et al., 2011; Rogers et al., 2011; Rogers et al., 2008). Although recompression studies show many fish survive these injuries in the short-term, common sense indicates that fish are not in optimal condition upon release and likely for some time after. For yelloweye rockfish, *Sebastes ruberrimus*, discard studies show some intriguing complexities. Yelloweye rockfish are extremely long-lived (147 yrs max recorded age), have very specific and geographically limited habitat requirements, exhibit high site-fidelity, territorial behavior and appear to have some complexity of multi-age social structure (O'Connell and Carlile, 1993; Hannah and Rankin, 2011; ODFW, unpublished data; Taylor and Wetzel, 2011; Yamanaka et al., 2006; Yoklavich et al., 1999). Deeper-dwelling yelloweye rockfish with barotrauma retain expanded swim bladder gas at the surface, and as capture depth increases, they become less able to descend on their own (Hannah et al., 2008a; Hochhalter, 2012). But with assistance to the bottom, short-term (24–48 h) survival is excellent at >80% (as tested to 174 m water depth in holding cages), and the probability of survival to 17 days at shallower depths was 99% (as tested to 72 m water depth using weighted hook release) (Hannah et al., 2014; Hochhalter and Reed, 2011). Despite this high survival, behavioral observation studies using video to evaluate very short-term (<5 min) behavior for fish departing from a suspended cage reported increasing behavioral compromise with increasing capture depth (Hannah and Matteson, 2007).

Mark and recapture studies have also provided in-situ evidence of longer-term survival and condition for some fish, but recovery rates of tagged fish were generally low. Studies in Oregon (Coombs, 1979) and Alaska (Hochhalter and Reed, 2011) reported about 20% of tagged yelloweye rockfish were recaptured in the weeks or years following release using recompression at capture depths <72 m. Moreover, recaptured fish in the Alaska study were in good condition; 15 recaptured female yelloweye rockfish were determined to be reproductively viable and 7 sampled for larvae had larval quality equal to females that had not been previously captured (Blaine, 2014).

The use of acoustic tagging and tracking can provide evidence of longer-term survival, fish condition and behavior if fish stay within the range of acoustic reception. In research off Oregon, studies have reported on the movements and high survival rates for a variety of acoustically tagged rockfish species in long-term (4–24 mo) studies (Hannah and Rankin, 2011; Parker et al., 2007; Rankin and Hannah Blume, 2013). Nevertheless, attempts at using acoustic telemetry to investigate movements of tagged yelloweye rockfish have yielded mixed results, a puzzling finding in light of their excellent short-term post-recompression survival (Hannah et al., 2014, 2012; ODFW, unpublished data). Further work indicated the use of multi-day sea-cage holding at depth appeared to increase survival of tagged yelloweye rockfish, and indicated some latent effects of barotrauma were being mitigated (ODFW, unpublished data). We used a baited video lander to observe in-situ (wild) behavior of one of these (48 h cage-held) tagged fish, 7 months post-tagging within a group of yelloweye rockfish and other fish species. This video provided evidence of full recovery, complex intra- and inter-specific social behavior, and natural movements including off- bottom hovering and neutral buoyancy (ODFW, unpublished data). We feel these results, the fish's natural history, and the overfished status of the stock justify investigation of the short-term behavioral competency and the longer-term effects of capture and barotrauma injury in yelloweye rockfish.

To investigate longer-term mortality and behavioral competency in yelloweye rockfish, we conducted two experiments. The first was a sea cage and laboratory holding experiment designed to establish 15- and 30-day mortality estimates for recompressed yelloweye rockfish captured from 140 to 150 m water depth, a depth zone where yelloweye rockfish are frequently caught as bycatch in the recreational fishery for Pacific halibut (*Hippoglossus stenolepis*). This experiment also sought to establish the extent and specifics of longer-term barotrauma injuries and to document fish behavior and fish condition over time. The second experiment was designed to investigate the behavior of recompressed yelloweye rockfish after hook and line capture, during a critical time period—the first hour post-recompression. This experiment was designed to be conducted across a variety of depth zones in an attempt to establish the effect of capture depth on post-recompression behavioral competency.

2. Methods

2.1. Delayed mortality and physical condition

We studied the 30-day survival and health of yelloweye rockfish experiencing capture-related barotrauma utilizing a combination of sea-cage and laboratory holding. Condition of surviving fish was evaluated at four time intervals throughout a 30-day period following initial capture. Different groups of five or six fish each were euthanized and evaluated at day 0 (Trial A, to provide baseline data), day 2 (Trial B), day 15 (Trial C) and day 30 (Trial D) post-capture. Fish were examined by either a veterinary pathologist with extensive experience in fish pathology or a Certified Aquatic Veterinarian with extensive training in fish pathology and medicine. Fish were examined at HMSC (Hatfield Marine Science Center) in Newport, OR, or at VDL (Veterinary Diagnostic Laboratory at the College of Veterinary Medicine, Oregon State University in Corvallis, OR). We used predetermined and standardized examination and sampling protocols to minimize the risk of variation between sampler or location. Procedures for evaluating health included complete blood count and blood chemistry panel, necropsy, histopathology and bacterial culture (liver/kidney pool) for each fish.

Yelloweye rockfish were collected on two days, April 13, 2014 for Trial A and B and April 29, 2014 for trials C and D. Fish were captured with hook and line gear, from a depth range of 140–150 m offshore of Newport, OR. For each of four trials, captured fish were evaluated for external signs of barotrauma, measured (cm TL), photographed and PIT-tagged for identification (as per methods in Parker et al., 2003a). To provide baseline data, Trial A fish were sedated with buffered MS222 (tricaine methanesulfonate), sampled for blood, euthanized with buffered MS222, and stored on