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Evaluation of Florida stone crab life history and management scenarios using spawning potential ratios

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ABSTRACT

The stone crab, *Menippe mercenaria*, supported the third most valuable fishery in Florida in 2016. Declining catch per unit effort (CPUE) and a negative trend in landings since 2000 have raised concerns among fishermen, researchers, and fishery managers as to the fishery's sustainability. The Fish and Wildlife Research Institute of the Florida Fish and Wildlife Conservation Commission estimates that the state's stone crab fishery has been overexploited since 1997. This stock status determination, however, is based largely on trends in total landings and CPUE and does not account for the life-history parameters that describe stock productivity, such as size at maturity, fecundity, and survivorship. In this study, an age-structured per-recruit model was developed to evaluate how alternative biological parameters and management scenarios might affect reproductive output, calculated as the spawning potential ratio (SPR), of a theoretical stone crab population. The model incorporated new estimates of size at maturity, fecundity, and temperature-dependent release mortalities. Spawning potential ratios increased with decreasing size at sexual maturity and were sensitive to increasing natural mortality. The largest contributor to changes in SPR was mortality associated with the declawing and release of stone crabs. We also assessed various management scenarios including regulations governing minimum claw length, requiring the use of juvenile trap excluder devices, and institution of temperature-dependent season openings. Increasing the minimum claw length and excluding small juveniles from traps provided moderate protection to the spawning stock. The model suggests that adaptive management strategies that allow fishing only when water temperatures are below 24 °C (the temperature at which modeled survival is improved) could greatly reduce mortality and increase SPR. We examined a suite of management scenarios on the effect of SPR, but additional research should be conducted to determine the socioeconomic impact of changes in regulations in this valuable fishery.

1. Introduction

The United States stone crab fishery operates primarily in the Gulf of Mexico along Florida's coast (Gandy et al., 2016). This fishery is unique in that fishermen remove the claws and release the crabs back into the water, where they have long been presumed to survive because regenerated claws are observed in the catch (Savage et al., 1975). In theory, a legal crab that has been declawed by the fishery can regenerate a lost limb and contribute to the fishery again 2–3 years later. Three decades (1986–2016) of comprehensive commercial harvest data describe a fishery with a rapid expansion in effort, market value, and landings, followed by a peak in 2000 and subsequent decline (Muller et al., 2011). Claw landings have demonstrated two distinct patterns. From 1986 through 2001 landings per season fluctuated, but increased overall, averaging 998 metric tons with a maximum of 1633 metric tons, in 2000 (Fig. 1). From 2001 through 2016 landings declined and were highly variable, ranging from 861 to 1588 metric tons (Fig. 1). Despite a diminishing supply of crabs, revenues have remained high, reaching a maximum of $31.5 million in 2015. High market value has allowed the industry to remain profitable, increasing fishing pressure and causing declines in catch per unit effort (CPUE). The combination of fishing pressure, market value, and demand has resulted in the stone crab being overexploited since 1997 (Muller et al., 2011).

The ability of the stone crab population to continue to persist and sustain high demand is of great concern. At present, stock assessments are limited to effort-based methods, using surplus production and DeLury depletion models that use claws as landings rather than dead crabs. Attempts at more sophisticated models for assessing the stone

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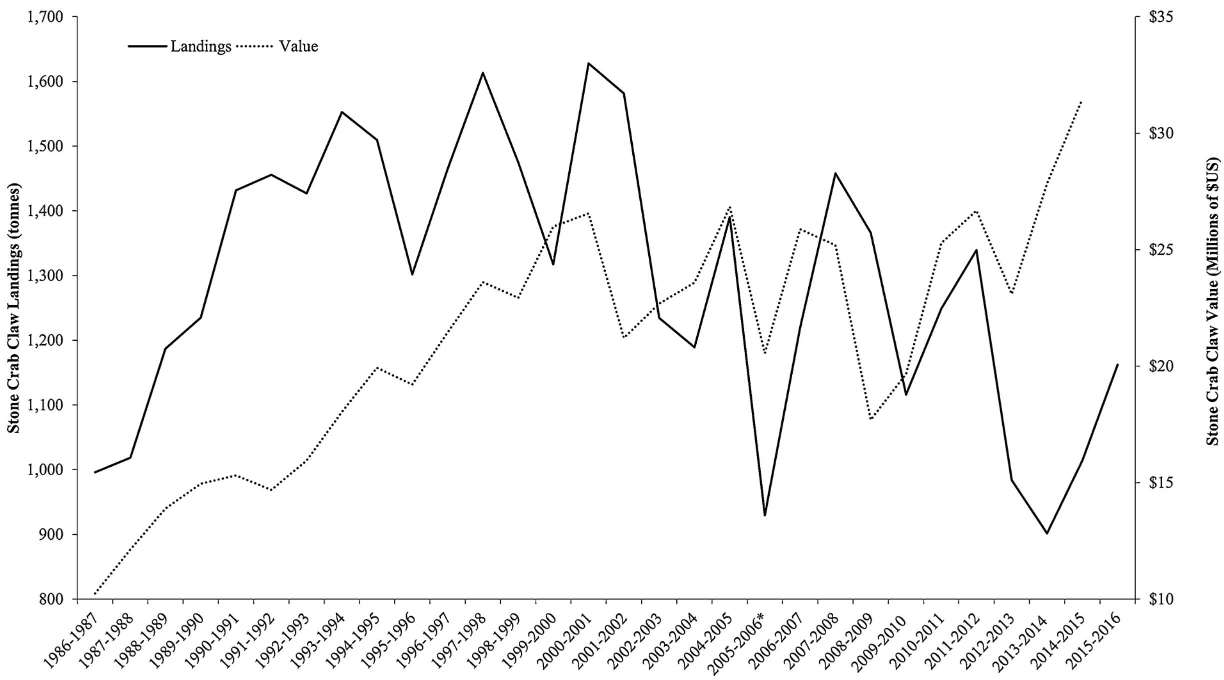

Fig. 1. Stone crab claw landings (tonnes) and value (US$) by season (October 15–May 15). Data provided by the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute Marine Resources Information System, Marine Fisheries Trip Ticket Program. *Designates hurricane year with heavy trap loss.

crab stock have failed because of the fishery's unique practice of declawing and returning the crabs to the water. This prevents accurate determination of catch and mortality rates from fishery landings. One or two claws may be legally harvested from a crab provided it is of legal size (i.e., at present, claws > 70 mm long), which further complicates efforts to translate landings to the number of crabs declawed.

The only attempt to incorporate biological information in assessing the stone crab stock was done by Restrepo (1989). Restrepo developed an equilibrium yield per recruit model to investigate trends in yield, value, and eggs per recruit. These analyses showed the potential for minimal increases in per recruit gains, however, in the yield per recruit model, significant uncertainty surrounded estimates of natural mortality and survival after declawing. In resorting to models that rely on simplified DeLury depletion and surplus production methods, management protocols ignore the critical biological and life-history attributes of stone crabs that affect the sustainability of the population and the fishery.

Declining landings since 2000, and their significant variability, have led the Florida Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute (FWRI) to examine key biological processes and fishery practices that influence stock dynamics with the ultimate goal of developing studies that will support biology-based population assessments. Ongoing research by the FWRI's Stone Crab Fishery Independent Monitoring (SCFIM) program has improved the estimates of size at maturation (Crowley et al., 2018), reproductive output (Crowley, 2017), and release mortality after declawing (Gandy et al., 2016). Histological investigations showed that both females and males reached sexual maturity at carapace widths 20–30 mm less than had been estimated, at 47 mm and 35 mm, respectively (Crowley et al., 2018). The fishery-wide assessment of reproductive output found that fecundity varied with location and that a fecundity estimate for one area may not reflect that for the entire stock (Crowley, 2017). In addition to improving these reproductive indices, Gandy et al. (2016) estimated mortality in crabs that had been declawed and released as a function of water temperature, number of claws removed, and the type of wound caused by removal. The authors found that mortality incurred by the harvest of claws (harvest mortality) was mediated by temperature and could be as high as 82%, resulting in few declawed crabs surviving to again contribute to the fishery (Gandy et al., 2016).

These advances motivated the development of a model that could incorporate this new information to produce biological reference points for stone crabs. The most common biological reference points are based on fishing mortality targets and minimum stock biomass levels (Collie and Gislason, 2001). Fishing mortality reference points are based on production, yield per recruit, and spawning stock biomass per recruit (Collie and Gislason, 2001), all of which can be used to evaluate the effectiveness of fishery practices and guide fishery management decisions (Sissenwine and Shepherd, 1987). A widely used reference point is the spawning stock biomass per recruit or spawning potential ratio (SPR; Mace, 1994). The SPR, developed by Goodyear et al. (1993), assesses the extent to which fishing mortality has reduced the potential reproductive output of a population compared with the output of an unfished population. Among invertebrate fisheries, the recommended reference point varies and ranges from an SPR of 10% for American lobsters, *Homarus americanus* (Anonymous, 1993) to 20% for Chesapeake Bay blue crabs, *Callinectes sapidus* (Bunnell and Miller, 2005), and 30% for California spiny lobsters, *Panulirus interruptus* (Coates et al., 2016). Mace (1994) suggests a target SPR of 40% for data-poor fisheries, especially when the stock–recruitment relationship is unknown.

The present study incorporates the new information on size at sexual maturity, fecundity, and harvest mortality into an equilibrium per recruit model and evaluates the potential reproductive output of the Florida stone crab fishery stock for a suite of management scenarios. This new model has the potential to shift Florida's stock assessments using this species from one that is economic and effort-based to one that produces biological reference points that can be used to more effectively evaluate potential management options, such as size limits and season closures. Our objective was to evaluate how size at sexual maturity, minimum legal claw size, vulnerability to capture, and estimates of natural mortality influence the spawning potential of a theoretical stone crab stock. Several management scenarios were tested to determine the influence of minimum length at declaw, size at capture, and seasonal duration.