The Importance of Keeping the Big Ones: Clutch Quality and Reproductive Senescence in Caribbean Spiny Lobster

La Importancia de Preserver las Grandes: La Calidad de Camada y la Senectud en la Langosta Espinosa del Caribe (*Panulirus argus*)

L'importance de Garder les Grandes: Qualité de Couvée et Sénescence Reproductive dans la Langouste Blanche des Caraïbes (*Panulirus argus*)

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EXTENDED ABSTRACT

Introduction: The Need to Conserve Spawner Biomass

Recruitment overfishing, the depletion of adult spawning stocks, is a serious issue for fisheries worldwide and can lead to their irreversible collapse. Harvest restrictions, including legal size limits and spatial restrictions, provide a way to manage fisheries in a manner that conserves spawner biomass. These restrictions protect a fraction of a stock from harvest and provide a buffer from recruitment overfishing and/or growth overfishing (i.e., harvest at a size smaller than what would produce the maximum yield per recruit).

Regulations that restrict catch based on the size of the species are a common management tool (FAO 2012), especially minimum size limits where only individuals above a designated size can be harvested. These are designed primarily to protect juveniles and avoid recruitment overfishing (Allen et al. 2013). Maximum size limits, where only individuals below a given size can be harvested are less common in marine fisheries management; they reduce abundance and competition among smaller size classes and protect the largest, most fecund spawners (FAO 2012).

Combining minimum and maximum size limits results in "slot limits", where individuals of an intermediate size may be harvested or protected (Gwinn et al. 2013). Harvest slot limits are most prevalent in freshwater and coastal recreational fisheries. They are designed to protect both recruits and spawning stock, and are useful when size-dependent maternal effects influence recruitment or when fishing depletes spawning biomass (Arlinghaus et al. 2010, FAO 2012).

Marine protected areas (MPAs), defined here as areas closed to fishing, also serve as biological harvest regulations in addition to their role as effort controls by directly protecting a fraction of a stock. Their effectiveness as a means of guarding against recruitment overfishing depends on the life history of the target species including: growth rate, natural mortality, size at maturity, and home range size (Taylor et al. 2012, Russ and Alcala 1996, Kelly et al. 2000). Marine protected areas increase the density, biomass, size, and species diversity of targeted organisms, though criticisms of their use center around shifting fishing pressure, enforcement, and appropriate scaling (see Halpern 2003).

Protecting the Big Ones: Slot Limits and MPAs for the Caribbean spiny lobster, *Panulirus argus*

The Caribbean spiny lobster, *Panulirus argus* is ubiquitous in the Caribbean and supports one of the largest, most economically valuable fisheries in the region with an estimated annual value exceeding $450 million USD (CRFM 2013). It forms the major fishery of 24 nations and employs an estimated 50,000 fishers and an additional 200,000 in fishery-related jobs (CRFM 2011). Most *P. argus* fisheries are fully-capitalized or overfished and regional landings have decreased by 55% since the early 1990s (Ehrhardt et al. 2010, CRFM 2011).

The advantage of a larger body size for the reproductive success and output of *P. argus* is well established: fecundity increases exponentially with increasing carapace length, larger females usually spawn more clutches per year than smaller females, and large males contribute to more matings and provide more sperm stores than smaller males (MacDiarmid & Butler 1999, Bertelsen and Matthews 2001, Butler et al. 2015). Given the higher fecundity of large females and the mating success of large males, large lobsters contribute disproportionately to a populations' reproductive capacity and the sustainability of the resource (Bertelsen and Matthews 2001, Ehrhardt 2005).

Presently, there are no standardized management measures for *P. argus* in the Caribbean. Instead, most nations have unilaterally developed a range of fisheries regulations that include minimum size limits, closed seasons, and gear restrictions. The only regulation that explicitly conserves spawning biomass (i.e., prohibition of the take of ovigerous females) fails to provide lasting protection for female lobsters and no protection for large males.

However, the implementation of harvest slot limits and MPAs in concert potentially protects the most fecund individuals and increases reproductive output whilst allowing fishing (Steneck et al. 2009). Although no-take MPAs alone can protect some spawning individuals, as demonstrated for a number of lobster species worldwide (Cox and Hunt 2005, Shears et al. 2006, Diaz et al. 2011, Moland et al. 2103), their implementation and enforcement are mired by regional socio-economics. No-take MPAs alone are likely to be too few and too small to substantially increase spawning stock biomass.

No-take MPAs applied in conjunction with harvest slot limits, however, extend protection from harvest to larger spawning individuals that move into or are resident in unprotected areas (Steneck et al. 2009). Few lobster fisheries in the world have instituted slot limits. An exception being state/province-wide and federal slot limits for the clawed lobster, *Homarus americanus.* The recreational fishery for *Panulirus cygnus* in Western Australia once had a maximum harvestable size for female lobsters, but this regulation was recently revoked (GWADF 2016).

Using laboratory experiments and simulation modeling, we are examining the potential efficacy and consequences of combining MPAs and harvest slot-limits as a means of building and conserving spawner biomass for *P. argus* in the Caribbean. In this presentation, we describe a set of laboratory experiments in which we investigated the relationship between lobster size, gamete production, and larval quality over multiple mating events. We found no evidence of reproductive senescence associated with lobster size or with multiple clutches in a season. Instead, second and third clutches appeared to produce higher quality gametes and larvae. These results highlight the importance of maintaining large males and females in populations of *P. argus* to insure reproductive success, and provide support for the conservation of large, spawning lobsters for the sustainability of the species.

KEYWORDS: *Panulirus argus*, reproduction, slot limits, MPAs, spawner biomass

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