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Using fisheries modeling to assess candidate species for marine fisheries enhancement

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ABSTRACT

Selecting target species or stocks in which releases of hatchery fish can contribute effectively to fisheries management goals is a key challenge in many fisheries enhancement programs. Here we show how fisheries modeling informed by stock assessments can be used to evaluate contributions of stocked fish to fisheries and how these contributions are influenced by life history and fishery attributes including regulatory policies and angler effort. We built an age-structured population model to quantitatively assess enhancement contributions to multiple fisheries management objectives: predicted catch, predicted harvest, abundance of catchable fish, abundance of harvestable fish and total spawning biomass. We used this model to evaluate candidate species for marine fisheries enhancement in Florida, where hatchery production capacity is scheduled to expand over the next decade yet it is unclear how fisheries managers can best use this capacity to achieve management objectives. We evaluated five candidate marine fishes in Florida: red drum *Sciaenops ocellatus*, spotted seatrout *Cynoscion nebulosus*, common snook *Centropomus undecimalis*, southern flounder *Paralichthys lethostigma* and red snapper *Lutjanus campechanus*. Comparative analysis shows that contribution of released fish to fisheries outcomes tend to decline with increasing time between release and capture or harvest. Enhancement of red drum, a species targeted by anglers during sub-adult life stages, is predicted to yield lower numbers of stocked fish entering the recruited population compared to alternative species but to contribute more to catch and harvest objectives. Our results demonstrate how commonly available biological information can be integrated with quantitative modeling approaches to provide useful information to managers tasked with identifying best uses of increasing enhancement capacity.

1. Introduction

Interest in marine hatchery production and releases for the purpose of restoration and enhancement is expanding globally. Increased fishing pressure, habitat degradation and human-induced environmental disasters are key drivers of the recent interest in enhancement and restoration for sustaining subsistence and marine recreational fisheries (Welcomme and Bartley, 1998; Cooke and Cowx, 2004; Merino et al., 2012; Worm and Branch, 2012; Lorenzen et al., 2013). In recreational fisheries, releases of hatchery-reared fish can augment naturally recruiting populations (Bell et al., 2006), improve angler catch rates and provide a range of socioeconomic benefits in theory (Camp et al., 2014). Freshwater fisheries enhancements have been well established in fisheries management and often comprise a substantial fraction of management budgets (Johnson et al., 1995; Ross and Loomis, 1999; Loomis and Ng, 2012; Patterson and Sullivan, 2013; US DOI, 2016), perhaps due to its popularity among stakeholders (Halverson, 2008). Past enhancement attempts in freshwater and marine systems, however, have largely failed to meet fisheries objectives and often have unintended ecological or genetic impacts on wild populations (Hilborn and Eggers, 2000; Leber, 2002; Tringali et al., 2008; Lorenzen, 2014). Fisheries managers, who are responsible for allocating resources in ways that meet conservation and stakeholder interests (Ross and Loomis, 1999), are increasingly confronted with challenging decisions regarding enhancement practices.

Concurrent with the increasing interest in marine fisheries enhancement is the development of quantitative methodology to evaluate proposed fisheries enhancement. Past failures of enhancements to meet intended objectives have resulted in questions regarding the efficacy of enhancement practices and motivated the development of quantitative methodology to evaluate enhancement systems (Lorenzen et al., 2010) and provide

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fisheries managers with realistic expectations for proposed fisheries enhancement. The potential to evaluate enhancement actions prior to their implementation is critical for informing management decisions that both avoid unintended negative effects of enhancement on wild populations and also direct resources towards enhancement actions most likely to achieve management objectives (Lorenzen 2005; Camp et al., 2014). Since enhancement is often considered for multiple species, one of the most fundamental decision tasks is to separate good candidate species from poorer alternatives (Munro and Bell, 1997; Taylor et al., 2005). Stakeholder demand and the availability of aquaculture technology, including characteristics of rearing potential, production capacity and cost-effectiveness, can oftentimes play a large role in driving decisions regarding species selection (Blankenship and Leber, 1995). A systematic evaluation process should be performed prior to large investments in aquaculture technology and should score enhancement and/or candidate species on a suite of criteria, such as fisheries management needs, aquaculture potential and the species' life history (Leber, 1994; Taylor et al., 2005; Lorenzen et al., 2010).

In Florida, U.S.A., marine stock enhancement has long been explored as a means to supplement or rebuild coastal fisheries and avoid the need for more restrictive management in response to projected increases in fishing pressure (Tringali et al., 2008). In Florida, recreational fishing effort is high and increasing, supporting a multi-billion dollar industry. Further increases in fishing pressure will likely require more restrictive management regulations that often have associated socioeconomic costs such as decreased angler satisfaction or angling activity. Marine enhancement efforts in Florida have been primarily small-scale and research-driven (Tringali et al., 2008; Camp et al., 2013). However, expansion of marine hatchery capacity is currently being pursued with financial support from Deepwater Horizon oil spill restoration funds. The purpose of this hatchery expansion is the enhancement of recreational fishing opportunities that were negatively impacted by the oil spill, rather than fish population or ecosystem restoration (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). However, it is unclear how fisheries managers can best use this additional hatchery capacity to achieve biological and socioeconomic objectives including sustaining fish abundance, improving angler satisfaction and the economic benefits associated with fishing. This creates a need for quantitative assessments that measure the biological potential of enhancement to meet fisheries management goals and identify species with enhancement potential. Camp et al. (2014) has assessed the biological potential of red drum releases in Florida and found large-scale releases of hatchery fish could potentially increase red drum abundance but likely with negative impacts on wild populations. These results are comparable to others that have found enhancement is capable of achieving some fisheries management objectives while negatively impacting others (Rogers et al., 2010). Assessments evaluating a number of alternative species concurrently are lacking and are urgently needed to help prioritize candidate species for enhancement in Florida.

The overall goal of our work was to identify marine species that can be expected to best achieve fisheries management objectives of sustaining fish abundance and improving angler satisfaction, where anger satisfaction is in part driven by catch and harvest-related attributes of fishing. Specifically, our first objective was to comparatively assess how hatchery releases of each candidate species would be expected to affect multiple fisheries metrics that represent important management objectives: abundance of catchable fish, abundance of harvestable fish, total catch, total harvest and total spawning biomass. We anticipate this information will be immediately useful to managers considering enhancement of the species considered. Our second specific objective was to identify underlying biological factors (e.g. growth rates and size-specific vulnerability to angling) that influence the potential of enhancement to achieve management objectives. Since these biological factors are often known for recreationally valuable fisheries considered for enhancement, this information should facilitate enhancement decisions regarding species beyond those considered in this study.

2. Material and methods

We used quantitative population models, to comparatively assess enhancement of five species that have been identified by the state as potential candidates for the enhancement program due to their popularity and economic importance: red drum *Sciaenops ocellatus*, spotted seatrout *Cynoscion nebulosus*, common snook *Centropomus undecimalis*, southern flounder *Paralichthys lethostigma*, and red snapper *Lutjanus campechanus*. We evaluated how releases of these five species affected metrics that represent important management objectives and identified factors that influence enhancement potential.

2.1. Candidate species and stocks

2.1.1. Basic life history

The candidate species being evaluated in this work are estuarine and nearshore species with the exception of red snapper, a species that generally aggregates around reefs and other offshore structured habitat. A summary of life history and fisheries characteristics for the candidate species are presented in Table 1. Red snapper are a long-lived fish (40+ years) that can mature as early as age-2 but do not reach peak fecundity until at least 10 years of age (Gallaway et al., 2009). Red drum are also a long-lived fish, attaining maximum ages around 40 years in Florida (Murphy and Taylor, 1990). Red drum and spotted seatrout have relatively rapid growth rates, indicated by their high von Bertalanffy growth parameters. Red drum grow rapidly through the subadult stage (age-1 to age-4) and then move out of estuaries to nearshore waters to join the

Table 1
Life history parameters and fisheries characteristics for the five candidate enhancement species.

Symbol	Description	Common snook	Southern flounder[a]	Spotted seatrout[a]	Red drum	Red snapper
L_∞	Asymptotic length (mm)	947	759	698	934	839
K	Von Bertalanffy growth parameter	0.175	0.235	0.363	0.460	0.270
t_0	Age at length = 0	−1.352	−0.570	0.390	0.029	0.000
A	Weight-length coefficient	4.40e-6	8.46e-6	8.46e-6	6.17e-6	1.67e-5
B	Weight-length exponent	3.11	3.30	2.99	3.10	2.95
W_m	Weight at maturity (kg)	2.024[b]	0.448	0.352	6.706	0.544
A_m	Maximum age (years)	20	7	12	40	48
L_l	Lower fish length for vulnerability to harvest (mm)	711	304.8	381	457	406
L_u	Upper fish length for vulnerability to harvest (mm)	813	–	508	686	–

[a] Indicates female-specific growth parameters.
[b] Indicates weight at transition from male to mature female.