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Decadal-scale decline of scamp (*Mycteroperca phenax*) abundance along the southeast United States Atlantic coast

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ABSTRACT

Scamp (*Mycteroperca phenax*) are a long-lived, economically important grouper species for which population trends are unknown along the southeast United States Atlantic coast (SEUS). We analyzed fishery-independent chevron trap (1990–2016) and underwater video (2011–2015) data using two-stage generalized additive models to elucidate changes in scamp relative abundance and mean size across the SEUS. A total of 1813 scamp were caught in 15609 trap samples across 27 years of sampling, and the proportion of traps catching scamp declined from a peak of 18.0% in 1994 to 2.5% in 2016. Likewise, mean scamp relative abundance declined 92% from its peak in 1995 to its lowest point (2016) in the time series. We observed a 29% decline of scamp relative abundance on videos between 2011 and 2015 (N = 6061 video samples), which closely matched the declining trend of trap relative abundance for the same years. Mean annual coefficients of variation were higher for traps (0.41) than video (0.20), but traps were essential given the much longer time series of trap data. Trap and video spatial predictions for scamp were consistently highest on the middle and outer continental shelf (40–100 m deep) between southern North Carolina and Georgia. Mean scamp total length increased approximately 130 mm over the course of the study due to the disproportionate declining catch of small scamp from traps since the early 2000s. Two hypotheses for potential recruitment failure of scamp in the SEUS are recruitment overfishing (increased F) and increased mortality on egg, larval, or juvenile stages (increased M).

1. Introduction

Reef-associated fish species occur in tropical, subtropical, and temperate regions of the world and are often heavily targeted by fishermen (Bellwood et al., 2004). Reef fishes face numerous threats including climate change, ocean acidification, habitat loss, introduced species, and overfishing (Parker and Dixon, 1998; Coleman et al., 1999; Ballew et al., 2016). Moreover, life-history traits of many reef fish species make them particularly vulnerable to overfishing, including long life spans, slow growth, late maturity, the formation of large spawning aggregations, and hermaphroditism (Coleman et al., 1996; Wyanski et al., 2000); all the above complicate effective reef fish conservation and management.

Fishery-independent survey data form the backbone of many reef fish stock assessments (Pennington and Stromme, 1998; Kimura and Somerton, 2006). Trawls are the most commonly used gear in fishery-independent surveys on non-reef habitats because they can be used to estimate fish densities from total trawl catch and area swept by the net (Adams et al., 1995; Kotwicki et al., 2011). Because reef habitats are highly rugose, bottom trawls are not able to sample them efficiently and, therefore, cannot provide reliable fishery independent abundance and distribution data. Instead, the most commonly used methods to sample fish in reef habitats are traps (Munro, 1974; Collins, 1990; Bacheler et al., 2013a), underwater visual census (Whitfield et al., 2014), hook-and-line (Harms et al., 2010), longlines (Ellis and DeMartini, 1995; Mitchell et al., 2014), acoustics (Jones et al., 2012), underwater video (Willis and Babcock, 2000; Bacheler and Shertzer, 2015), and manned or unmanned underwater vehicles (Adams et al., 1995; Karpov et al., 2012). With some exceptions (e.g., Jones et al., 2012; Whitfield et al., 2014), sampling gears in reef habitats provide estimates of relative abundance, not density, because the area sampled by sampling gears is often very difficult to estimate (Kimura and Somerton, 2006).

Scamp (*Mycteroperca phenax*) are a reef-associated grouper species for which fishery-independent data will be useful in determining trends in population abundance along the southeast United States Atlantic coast (hereafter, "SEUS"). Scamp are a moderately long-lived (~25–30 years), slow-growing, hermaphroditic, economically

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important grouper species that associates with hard-bottom temperate reefs from Cape Hatteras, North Carolina, through the Gulf of Mexico (Smith, 1971; Matheson et al., 1986; Harris et al., 2002; Lombardi-Carlson et al., 2012). Scamp typically inhabit rocky pavement, outcropping, and ledge habitats that are often covered in soft corals, sponges, and algae (Gilmore and Jones, 1992; Kendall et al., 2008).

In the SEUS, scamp are typically harvested by recreational and commercial hook-and-line fisheries. Outside of a wintertime spawning closure, recreational fishers can currently harvest up to 3 scamp per person per day over 508-mm total length, while commercial fishers have the same minimum size limit but no trip limit. Recreational or commercial fishing for scamp closes in the SEUS when their respective annual catch limits are reached. There is also a geographic pattern to scamp catches, whereby more scamp are typically harvested in the northern compared to southern SEUS (Manooch et al., 1998). The only stock assessment of scamp in the SEUS occurred in 1998, and it indicated scamp were not overfished and overfishing was not occurring (Manooch et al., 1998). Subsequently, Harris et al. (2002) showed that scamp sex ratios in the SEUS were becoming more skewed towards females over time and egg production was declining due to the loss of older, larger females, suggesting that scamp were becoming vulnerable to exploitation.

Here we examine long-term fishery-independent chevron trap and shorter-term underwater video data to evaluate the temporal and spatial patterns of scamp abundance in the SEUS. There were two primary objectives of our work. First, spatio-temporal variation in scamp abundance was evaluated, and then we assessed whether this variation was influenced by landscape or environmental variables. Second, given the results from the first objective, we evaluated whether recruitment failure may have been partially or completely responsible for declining scamp abundance over time. These results are timely given that a new, comprehensive, statistical catch-at-age model for scamp in the SEUS is scheduled to be developed in 2019 to assess the status of the SEUS scamp stock, and robust fishery-independent indices of abundance like those presented herein will be central to the success of that assessment.

2. Methods

2.1. Study area

Sampling in this study targeted patchily-distributed hard-bottom habitats found across the continental shelf and shelf break in the SEUS. Our sampling stretched across a broad latitudinal range (27–35° N) extending from Cape Hatteras, North Carolina, in the north to St. Lucie Inlet, Florida, in the south. Most of the SEUS continental shelf and shelf break is composed of unconsolidated sand and mud substrates, but patches of hard-bottom temperate reefs naturally occur throughout the region (Fautin et al., 2010). Scamp strongly associate with these hard-bottom habitats (Kendall et al., 2008), which range from flat limestone pavement habitats to high-relief ledges, often covered in sponges, algae, and soft corals (Schobernd and Sedberry, 2009).

2.2. Scamp sampling approach

We used data derived from the Southeast Reef Fish Survey (SERFS) to make inferences about scamp in the SEUS. The SERFS is a collaborative survey and research program comprising three groups funded by the National Marine Fisheries Service (NMFS) that sample the reef-associated fish community identically in the SEUS. The first is the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program, housed at the South Carolina Department of Natural Resources (SCDNR), which NMFS has funded since the 1970s. The MARMAP program has used chevron traps since 1990 to survey reef fishes associated with hard-bottoms in the SEUS. The Southeast Area Monitoring and Assessment Program, South Atlantic Region (SEAMAP-SA) Reef Fish Complement, also funded by NMFS and housed at SCDNR, has sampled in the SEUS since 2009 and has primarily focused on evaluating previously un-sampled hard-bottom habitats in the SEUS. The third program, created in 2010 by the NMFS-Beaufort Laboratory, is the Southeast Fishery-Independent Survey, which added to the MARMAP and SEAMAP-SA Reef Fish Complement by allowing for an additional increase in overall survey effort and the implementation of underwater video.

Based on a sampling frame of known hard-bottom stations in the SEUS, SERFS either used simple random (1990–2014) or stratified random (2015–2016) sampling to select stations. The impetus for the move to stratified random sampling in the most recent years was to make the SERFS robust to future expansions or contractions of the sampling frame of known hard-bottom stations, to prepare the survey for potential changes in resource allocation, and to ensure appropriate spatial coverage annually. The twelve current strata were delineated by four depth (< 30 m, 30–42 m, 43–63 m, > 63 m) and three latitude bins (< 29.71°N, 29.71–32.61°N, > 32.61°N) based on multivariate clustering of long-term SERFS trap data. Sample allocation to strata in the recent years was designed to approximate the spatial distribution of the randomly selected stations selected for sampling in 2013 and 2014, resulting in a very similar spatial and depth distribution of sampled points in 2015–2016 compared to 2013–2014. While most stations were randomly selected in our study, some stations in the sampling frame were sampled opportunistically in a given year despite not being randomly sampled in order to increase sampling efficiency during research cruises (~3% of all stations included in our analyses). Additionally, some new hard-bottom stations were found using the vessel echosounder and sampled, and were included in our analyses in the year they were discovered if these new stations sampled hard-bottom habitat. All sampling occurred during daylight hours on the R/V *Palmetto* (1990–2016), R/V *Savannah* (2010–2016), NOAA Ship *Nancy Foster* (2010), NOAA Ship *Pisces* (2011–2016), and NOAA Ship SRVx *Sand Tiger* (2016) between spring and fall each year.

SERFS has used chevron traps (see Collins (1990) for a complete gear description) since 1990 to sample reef-associated fish species in the SEUS. Previous studies have shown that chevron trap catches are highly related to local (true) abundance for various reef fish species (Bacheler et al., 2013b,c; Shertzer et al., 2016). Each chevron trap was baited with 24 menhaden (*Brevoortia* spp.) and soaked for approximately 90 min. Chevron traps were typically deployed in groups of up to six traps, with no traps being closer than 200 m from any other trap in a given year to provide independence between samples (Bacheler et al., 2013a). Scamp trap catch-per-unit-effort (CPUE) was calculated as the number of individuals caught in a trap sample (CPUE = Catch/Trap). Trap soak time was included as a predictor variable (see below), based on the recommendations of Bacheler et al. (2013a). Chevron trap samples were excluded from the analysis if the validity of the catch was suspect due to trap behavior (e.g., trap moved or was damaged) or if any information was missing from the sample.

Beginning in 2011, the SERFS program attached high-definition video cameras over the mouth and nose of each trap to provide additional data on the abundance and distribution of reef fish. In 2011–2014, the program attached Canon Vixia HF-S200 video cameras in Gates HF-S21 housings over the mouth of each trap deployed, facing away from the trap. In 2015, the survey replaced Canon cameras with GoPro Hero 3+ cameras. Fish were only counted on cameras attached over the mouth of each trap. However, an additional camera (GoPro Hero or Nikon Coolpix S210/S220) was placed over the nose of the trap in order to quantify habitat information in the opposite direction (see below; Bacheler et al., 2014). Videos were excluded from our analyses if they were too dark to identify fish, out of focus, corrupt, or if evidence existed (e.g., bouncing, moving) that the trap may not have behaved as anticipated.

Scamp relative abundance from video was calculated using a derivation of the MeanCount approach (Fig. 1; Schobernd et al., 2014). The most common video reading metric is *MaxN* (Ellis and DeMartini,