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Biotic and abiotic impacts of Double-crested cormorant breeding colonies on forested islands in the southeastern United States

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ABSTRACT

Double-crested Cormorant (*Phalacrocorax auritus*) numbers have increased in North America, and concomitantly cormorants appear to be expanding their nesting range in the southeastern United States. Because colonial nesting waterbirds can impact water quality, soil chemistry and subsequent vegetation succession patterns, our goal was to assess the extent to which cormorant breeding colonies are influencing the biotic and abiotic attributes of forested islands in the southeastern United States. Our objectives were to (1) compare water quality characteristics in near-shore surface waters around forested islands with and without nesting cormorants during the peak-nesting/fledgling period and post-fledgling period, (2) measure soil chemistry parameters for forested islands with and without nesting cormorants, and (3) compare tree health metrics on forested islands with and without nesting cormorants. Our results indicate that cormorant colonies are not significant contributors to general coliforms or *Escherichia coli* levels in waters surrounding southern breeding colonies. Cormorants also do not appear to have significant direct effects on water chemistry. We did find that cormorant colonies are affecting soil chemistry. Soil from within the nesting colony was more acidic and had greater concentrations of phosphorous than soils on reference islands. In addition, we found evidence that cormorants are negatively affecting tree health within nesting colonies as evidenced by a greater number of trees of lower vigor class within the nesting colonies compared to reference sites. While cormorants do cause abiotic and biotic changes, these are part of the natural ecological processes that occur following waterbird colonization. Management to reduce unwanted impacts that nesting cormorants are having on forested island habitats should be considered within a framework that allows for natural ecological processes, including changes in soil chemistry and subsequent vegetation succession.

1. Introduction

In North America, the Double-crested Cormorant (*Phalacrocorax auritus*; hereafter cormorant) has substantially increased in abundance from relatively low numbers in the early 1970s (Dorr et al., 2012). Cormorants have historically wintered in the southeastern United States, but nesting cormorants in the region were relatively rare compared to their northern breeding regions and occurred primarily along the gulf coast and major rivers (Wires and Cuthbert, 2006; Hanson et al., 2010). More recently cormorants appear to have expanded their southeastern nesting range to include man-made sloughs, lakes, and reservoirs not historically available or reported (Reinhold et al., 1998; Wires and Cuthbert, 2006; Hanson et al., 2010; Dorr et al., 2014). The increased numbers of cormorants throughout their range, while a conservation success story, has also come with increased human–cormorant conflicts (Taylor and Dorr, 2003; Dorr et al., 2012). Conflicts associated with nesting cormorants differ from those associated with wintering cormorants. Issues with wintering cormorants typically are associated with direct predation on aquaculture or recreational fisheries (Taylor and Dorr, 2003), whereas cormorant breeding colonies may have broader impacts due to increased competition with co-nesting species, vegetation damage, and changes in soil and water quality associated with the release of nutrient-rich waste due to guano deposition, regurgitated food,

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carcasses and feathers (Jarvie et al., 1999; Shieldcastle and Martin, 1999; Taylor and Dorr, 2003; Ayers et al., 2015; Stewart et al., 2015). Jarvie et al. (1999) found that Black-crowned Night Herons (*Nycticorax nycticorax*) nesting pairs declined with increasing cormorant nesting. Hebert et al. (2005) documented significant damage to trees on forested islands associated with cormorant nesting and that vegetation damage can negatively impact co-nesting avian species that are obligate tree nesters. Fish-eating avian species, such as cormorants, also can affect soil quality (Ishida, 1996; Ligeza and Smal, 2003; Breuning-Madsen et al., 2010; Ayers et al., 2015). Ishida (1996) found that changes in soil nutrients caused by nesting Great Cormorants (*Phalacrocorax carbo*) simplified forest structure and reduced tree species diversity. Breuning-Madsen et al. (2010) found that great cormorant colonies significantly impacted soil nutrient profiles that affected plant community composition by limiting plant diversity to salt-tolerant plants that can grow in extremely nutrient-rich soils.

In addition to the potential terrestrial ecological impacts of nesting cormorant colonies, waterfowl feces may be an important source of fecal contamination in water bodies (Standridge et al., 1979; Makino et al., 2000; Lu et al., 2008). High levels of coliform and *Escherichia coli* bacteria are a concern for many recreational water environments because of the known association between fecal matter and human health risks, and are commonly used as indicator species to measure the quality of recreational and drinking waters (USEPA, 1986, 1999; WHO, 2006). For example, McLellan (2004) found that waterbird feces was an important source of bacterial pollution in some beach areas and contributed to beach closures in efforts to limit potential human health risks. Although research has been conducted on impacts of cormorants on co-nesting species, vegetation, and soil and water quality on their northern breeding grounds (Bédard et al., 1995; Jarvie et al., 1999; Shieldcastle and Martin, 1999; Hebert et al., 2005; Ayers et al., 2015), no research has been conducted on the impact of cormorant breeding colonies in southeastern United States in this regard.

Within the last 10–15 years cormorants began nesting on islands in Guntersville Lake, AL, resulting in concerns regarding impacts to fisheries, vegetation, and soil and water quality (Barras, 2004). Impacts to several islands in Guntersville Lake have been observed including loss of vegetation and possibly increased shoreline erosion (Barras, 2004), presumably due to nesting cormorants. Given the diversity of soil and vegetation types, longer growing season, and generally more eutrophic water-bodies, the ecological impacts of cormorants at southern breeding colony sites may differ substantially from impacts documented at northern colonies. Thus, our goal for this study is to understand if and how cormorant breeding colonies influence biotic and abiotic attributes of forested islands in the southeastern United States. Our objectives were to (1) compare water quality characteristics in near-shore surface waters around forested islands with and without nesting cormorants during the peak-nesting/fledgling period and post-fledgling period, (2) measure soil chemistry parameters for forested islands with and without nesting cormorants, and (3) compare tree health metrics on forested islands with and without nesting cormorants.

2. Methods

2.1. Study site – Guntersville Lake, Alabama, USA

Guntersville Lake (34°32′19.82N, 86°07′05.14W) is the largest lake (27,964 ha) in Alabama, U.S.A. (Fig. 1) and spans 121 km from Nickajack Dam, Tennessee, to Guntersville Dam, Alabama. The reservoir is managed by the Tennessee Valley Authority (TVA) on the Tennessee River in northeastern Alabama and southeastern Tennessee. Cormorants currently nest at three primary locations in Guntersville Lake: Conner's Island (CON), South Sauty Island (SSS), and North Sauty Island (NS); hereafter, these islands will be referred to as colony islands. Reference islands that lacked nesting cormorant colonies were selected based on similar size and proximity (adjacency) to colony islands: southeast of Connor's Island (SEC), north of South Sauty (NSS), west of South Sauty (WSS). When more than one reference island was available, the reference island was selected at random.

2.2. Study design

2.2.1. Water sampling

Water samples for microbial and chemical analyses were collected at each of the colony islands and the reference islands during the period of peak nesting/fledging of chicks (mid-May) and during the post fledging period when cormorant numbers are at a minimum (mid-August), 2010. Island shorelines were mapped using digital orthoquad imagery ArcGIS ArcMap (ESRI® 9.1, Esri Inc., Redlands, CA, U.S.A.).

For microbial analysis, the largest islands shoreline was divided into 10 equal length sample sections. The beginning of each section represents a shoreline starting point for obtaining water samples. Shoreline sections of smaller islands were sampled in proportion to their length relative to the shoreline of the largest island. If section lengths were less than 100 m, a minimum of four sample points were selected, one in each cardinal direction. Water samples were collected at each shoreline section starting point at intervals of 5 m, 15 m and 25 m from the shoreline. Water samples were placed in sterile Whirl-Pak® bags and placed on ice until all water samples were collected. Samples were plated within 4 h of collection (Vail et al., 2003) on 3M PetrifilmTM *E. coli*/Coliform plates (PetrifilmTM) for enumerating general coliform and *E. coli* bacteria (colony forming units [CFU]). PetrifilmTM count plates are a simple, safe, reliable and low cost method for monitoring environmental water samples in the field (Vail et al., 2003). Prior to plating, water samples were allowed to increase to ambient temperature. Plates were inoculated with 1 mL of water using sterile, disposable pipets and allowed to incubate at 35 ± 1 °C for 24 ± 2 h prior to enumeration. Used plates were disinfected before disposal by soaking in 1% hypochlorite solution for 1-h.

Due to logistic constraints associated with the amount of time to run water chemistry tests on-site, samples were taken only at 5 m from shore and at 4 sample locations, one in each cardinal direction from each study island during both the peak nesting/fledgling period (mid-May) and post fledgling period (mid-August). Four water quality parameters were tested: pH, nitrate (NO_3 mg/L), ammonia (NH_3 mg/L), and phosphate (PO_4 mg/L). A digital meter was used to measure pH (±0.1 pH at 20 °C). A Hach multi-parameter surface water test kit was used to measure water chemistry parameters.

2.2.2. Soil sampling

Soil samples were collected from each of the colony islands and reference islands. To establish sampling plots, each of the six islands was overlain with a 10 m × 10 m (0.10 ha) grid using the most recent digital orthoquad imagery available for the area via ArcGIS ArcMap (ESRI® 9.1, Esri Inc., Redlands, CA, U.S.A.). Sampling of 0.10 ha plots was conducted in proportion to island area by randomly sampling 20% of the total available plots on each island. Soil core samples were collected with a soil auger (9 cm diameter × 20 cm deep) at the center of each plot, excluding surface debris. All soil samples were assigned a treatment level based on location relative to nesting colonies that ranged from 1 to 3 (1 = colony island within a nesting colony; 2 = colony island