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Parasite assemblages of Double-crested Cormorants as indicators of host populations and migration behavior

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ABSTRACT

The Double-crested Cormorant (*Phalacrocorax auritus*) is culled in many states because of the real and presumed damages it inflicts on farmed and recreational fisheries and other ecosystem services. Resident cormorant colonies breeding in the southeastern United States are protected in some areas, so it is important to distinguish these from co-occurring but unprotected migratory cormorants. Migratory *P. auritus* are likely to contain helminthic parasite communities that differ from those of non-migratory, resident birds, because they will encounter a wider variety of habitats and intermediate host communities during migrations. Here, we document five distinct assemblages of helminth parasites collected from 218 *P. auritus* culled from 11 sites in Alabama, Minnesota, Mississippi, and Vermont. The assemblages of *P. auritus* parasites are distinct among many sampling locations and can be used to correctly predict where a host cormorant has been feeding. We provide evidence for mixing of cormorants at a regional scale using discriminant analysis, which suggests there is a single population of migratory cormorants. Furthermore, our models strongly differentiate between migratory and resident *P. auritus* in the southeastern United States. In conjunction with species-by species latitudinal and longitudinal trends, our models could serve as effective tools for managers interested in both the population control of migratory cormorants and the conservation of non-migratory, resident birds. Finally, parasite counts per host are notoriously variable with many zeros and a few large numbers, leading many researchers to use simple prevalence in their analyses. We show that an intermediate level of data resolution, using species occurrence ranks within individual hosts, behaves well statistically and provides the greatest discrimination among distinct host groupings.

1. Introduction

To reduce human-wildlife conflicts in the United States, legislative acts have given authority to state and federal wildlife managers to control mammal and bird populations that pose a threat to human health, safety, and apparent wellbeing (50 CFR 21. 47 eCFR, 2013; FGC 4181, 2014; and 14 CCR 401, 2008). Consequently, programs to limit the colony sizes of the Double-crested Cormorant, *Phalacrocorax auritus*, through culling and egg-oiling programs (Bedard et al., 1995; DeVault et al., 2012; SCDNR News Release, 2013 accessible at http://dnr.sc.gov/news/yr2013/nov21/nov21_cormorant.html) are widespread throughout the United States.

P. auritus is a colonial, pursuit diving waterbird that primarily consumes forage fish (Brugger, 1995; Fenech et al., 2004). Large colonies of *P. auritus* are conspicuous and have been suggested to deplete fish stocks from lakes, rivers, reservoirs, estuaries, and coasts in addition to farmed (aquaculture) aquatic ecosystems (Brugger, 1995; DeVault et al., 2012). Colony numbers and densities of *P. auritus* are higher today than at any time in the last 50 years (Jackson and Jackson, 1995), and colonies are commonly culled to reduce presumed effects to ecosystem services such as decreased sport fisheries, diminished water quality, impacts to co-nesting species, and fouling of nesting islands that could serve as sites for human recreation (Coleman and Richmond, 2007; Wires and Cuthbert, 2010; Boutin et al., 2011). Cormorants are subject to many laws that allow for both protection and management, including lethal control to limit impacts to aquatic resources (Wires and Cuthbert, 2006; Dorr and Somers, 2012). We used these management programs to acquire the carcasses of culled cormorants for parasite assessments.

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Five distinct subspecies of *P. auritus* have been described: *P. a. cincinatus* in Alaska; *P. a. albociliatus* in coastal California; *P. a. heuritas* in the Bahamas, *P. a. floridanus* in the southeastern United States (Audubon, 1840–1844; Bent, 1922; Wires and Cuthbert, 2006); and *P. a. auritus* occurring throughout the interior and east coast of North America south to the Caribbean and Mexico (Palmer, 1962; Dolbeer, 1991; Watson et al., 1991; Hatch, 1995; Wires et al., 2001; Dorr et al., 2014). Based on winter sightings of banded birds, Dolbeer (1991) suggested that *P. a. auritus* consists of two distinct populations, one that breeds in the interior (migrating along the Mississippi flyway) and one on the Atlantic coast. However, molecular studies do not support the existence of multiple populations for any of the cormorant subspecies (Waits et al., 2003). Furthermore, molecular assessments suggest that only three subspecies exist (Alaskan, Pacific coast, and interior/eastern North America; Mercer et al., 2013).

Like many other avian top-predators, *P. auritus* experienced population bottlenecks in the middle of the 20th century, with its geographic distribution shrinking dramatically (Kirsch, 1995; Krohn et al., 1995; Wires and Cuthbert, 2006). Double-crested Cormorants of the interior and Atlantic coast continue to migrate between breeding seasons with notable exceptions in the southeastern United States where resident cormorants are present year-round, including at newly-created freshwater reservoirs and aquaculture facilities. Aquaculture facilities also provide opportunities for wintering birds to reduce migration distances and, in some cases, encourage year-round inhabitance. Some suggest that these 'new' resident colonies are the expanding Florida subspecies rather than *P. a. auritus* (Wires et al., 2001; Wires and Cuthbert, 2006). Although Audubon (1840–1844 available online https://www.audubon.org/birds-of-america/florida-cormorant) considered resident cormorants to be a separate species (*Phalacrocorax floridanus*), they were downgraded to subspecies and molecular assessments have not differentiated migratory *P. a. auritus* from resident birds in Florida and the southeastern U.S. (Green et al., 2006; Waits et al., 2003).

In this study, we examine whether intestinal helminthic parasites differ among foraging groups of *P. auritus* and, if so, whether they can be used to identify the regional breeding locations (interior vs. coastal) and migratory status (northern vs. southern breeding) of individual hosts. Examination for parasites of culled birds from 11 sites in 4 states allowed us to assess the spatial distribution of parasite communities in relation to geographically distinct populations, and resident and migratory status. Using free-living multi-species indices is not uncommon in habitat assessments (Mawdsley and O'Malley, 2009; Ogden et al., 2014) and here we test whether parasite assemblages differ enough among host groups for use as ecological indicators. If parasite assemblages differ for specific sampling sites, management plans for specific foraging groups could be developed. If assemblages differ among breeding regions, this might indicate the existence of distinct populations of coastal and interior *P. a. auritus*. If parasite assemblages differ among resident and migratory birds, then parasites can be used to assign migratory status of cormorants. This would be of basic interest, but could also benefit managers seeking to control one cormorant group while protecting another. For example, a management program for *P. auritus* that includes culling has been developed in South Carolina, where both migratory and breeding resident birds occur (SCDNR News Release, 2013 accessible at http://dnr.sc.gov/news/yr2013/nov21/nov21_cormorant.html) and additional culls are projected for other states where resident and migratory cormorants co-occur. We first describe the sampling methodology and assessment of parasite communities, then define distinct assemblages of parasites, and use predictive models to assign hosts to a site, region, migration status, and parasite assemblage. Finally, we test our models based on predicted (when known) versus actual characteristics of each host.

2. Methods

2.1. Sample collection and processing

The USDA/APHIS Wildlife Service of Minnesota, the Leech Lake Natural Resource Division, and the USDA/APHIS National Wildlife Research Center collected and assisted in preparation of frozen intestines of *P. auritus*, which were obtained from 11 sites from 2010 to 2012 (see Supplemental Interactive Map and Table S.3). Two of the southern sites had previously been reported to support breeding colonies of resident *P. auritus* (Swamp Roost, Mississippi ($n = 20$) and Lake Guntersville, Alabama, U.S.A. ($n = 37$); Hanson et al., 2010; B. S. Dorr, USDA APHIS/WS, personal communication), and four sites were known to support breeding colonies of migratory *P. auritus* (three in Minnesota [$n = 89$] and one in Vermont, U.S.A. [$n = 25$]). The remaining five locations had not been documented as *P. auritus* breeding sites (four in Mississippi [$n = 35$] and one in Alabama, U. S. A. [$n = 22$]).

We based our migratory status assignments of birds from information provided by managers familiar with site-specific breeding and wintering activities (K. Hanson-Dorr USDA APHIS/WS, personal communication). Because some birds were culled during winter months when both resident and migrant birds could be present (Glahn and McCoy, 1995; Farley et al., 2001), all birds from Mississippi ($n = 35$) and Cat Island, AL ($n = 22$) were excluded from migratory model development. Thus, we did not include cormorants where the migration status might be contended (Dorr et al., 2014; Farley et al., 2001; Wires et al., 2001; Wires and Cuthbert, 2006).

Intestines were frozen prior to parasite assessment and defatted before the contents were removed by cutting down the length of the intestine and stripping the contents and lining of the intestine from the tissue by hand (Rae, 2003). We assessed 218 cormorant intestines (from base of proventriculus to cloaca) for presence of helminthic parasites. We washed intestinal contents in a 64 μm sieve and fixed parasites either in 70% ethanol or 10% buffered formalin. Parasites were identified to the lowest possible taxonomic level based on previously reported parasites of the *Phalacrocorax* genus in North America (K.L. Sheehan, unpublished data).

We analyzed parasite data at three levels of resolution: raw counts (abundance) of each of the parasites within individual birds, ranks of relative abundance within individual birds (from 1 – most common, to 7), and presence or absence (prevalence). Raw counts are complete data for analysis, but include many zeros and some very large numbers, making parametric analyses challenging. Prevalence (presence/absence) contains the least information, but can be simplest to analyze. Rank data provide a useful, intermediate alternative that can be analyzed using parametric tests. It was important that we establish the appropriate level of resolution of parasite data in determining whether parasites could be used as biomarkers of host identities and movement.

2.2. Geographic trends of parasite abundance

To assess changes in parasite distribution over the geographic range of *P. auritus* sampled in this study (see Supplemental Interactive Map), we used regression analyses to test for linear and quadratic associations between parasite intensity and prevalence with latitude and longitude. Note that these are the highest and lowest resolution measures that we considered. Positive correlation coefficients for latitudinal data indicated higher parasite numbers in the North and for longitude (using negative values