Part II

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DIET OF A PISCIVOROUS SEABIRD REVEALS SPATIOTEMPORAL VARIATION IN ABUNDANCE OF FORAGE FISHES IN THE MONTEREY BAY REGION

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EXTENDED ABSTRACT ARTICLE

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Seabirds have increasingly been studied as indicators of the marine ecosystem (Piatt et al. 2007). As a piscivorous generalist (Ainley et al. 1981) the Brandt's Cormorant (*Phalacrocorax penicillatus*) is a good indicator species in the California Current System (CCS). Their distribution includes the full latitudinal extent of the CCS (Wallace and Wallace 1998), thereby providing insight into the spatial aspects of prey fluctuations. Northern anchovy (*Engraulis mordax*), rockfishes (*Sebastes* spp.), and market squid (*Doryteuthis opalescens*) that are common in Brandt's Cormorant diet are important to many other predators in the CCS (Morejohn et al. 1978; Ainley et al. 1990).

The Brandt's Cormorant is the most abundant locally nesting seabird in the Monterey Bay region of central California. From 1989 to the mid-2000s many new colonies formed, some with rapid growth, including the first report of nesting within Monterey Bay (Carter et al. 1992; Bechaver et al. 2013; Capitolo et al. 2014). The species occupies a middle-to-upper trophic position in the nearshore marine food web (Ainley et al. 1995), consuming young-of-the-year, juvenile, and small adult fishes and, to a lesser extent, squid (Sydeman et al. 2001; Webb 2013). Given their reliance on the inner continental shelf habitat, year-round occurrence (Briggs et al. 1987; Wallace and Wallace 1998), and consumption of approximately 20% of their body mass per day (Ancel et al. 1997), Brandt's Cormorants can potentially extract large numbers of prey from the Monterey Bay region.

Two previous Brandt's Cormorant diet studies in Monterey Bay were conducted during the 1970s and sampled the nonbreeding season, September to March (Baltz and Morejohn 1977; Talent 1984). Rockfishes and Pacific sanddab (*Citharichthys sordidus*) were the two main prey during the 1970–71 and 1974–75 nonbreeding seasons; however, northern anchovy and market squid also were important in 1974–75. Since then, overfishing and an unfavorable warm water period caused a substantial decrease in abundance of juvenile rockfishes during the 1990s in the central California Current with only partial recovery as of the early 2000s (Mills et al. 2007). Commercial market squid landings in Monterey Bay decreased substantially beginning in 2005 (CDFG 2009) indicating decreased abundance. Our goal was to determine present diet composition of Brandt's Cormorants to further our understanding of how a major avian predator responds to a decrease of multiple important prey resources, thereby providing important information about central California food web dynamics. El Niño and La Niña conditions during the study (CalCOFI 2008) provided a unique opportunity to examine predator response to changes in oceanographic conditions (Webb 2013; Webb and Harvey 2014).

Brandt's Cormorant diet composition in the Monterey Bay region was investigated using regurgitated pellets (n = 285) collected on 19 sampling days at 3 roosting locations: Año Nuevo Island, Moss Landing Harbor, and Monterey Harbor, during the 2006–07 and 2007–08 nonbreeding seasons. Each cormorant casts one regurgitated pellet per day at roosting locations containing prey remains from the prior 24 h. Most fish otoliths, cephalopod beaks, and other prey hard parts contained in cormorant pellets have enough structure to determine species ingested; therefore, pellets are useful for answering broad spatial and temporal questions such as comparing diet among seasons or years (Ainley et al. 1981; Duffy and Laurenson 1983). Pellets can be collected with minimal disturbance, especially during the nonbreeding season, but this source of diet information has been underutilized. Sampling design, sample size, pellet processing method, prey size, and fine-scale spatiotemporal variability in the diet also were assessed (Webb 2013; Webb and Harvey 2014).

Although 29 prey species were consumed during the 2006–07 and 2007–08 nonbreeding seasons, northern anchovy dominated and speckled sanddab (*Citharichthys stigmaeus*) also was important in the diet. Few rock-

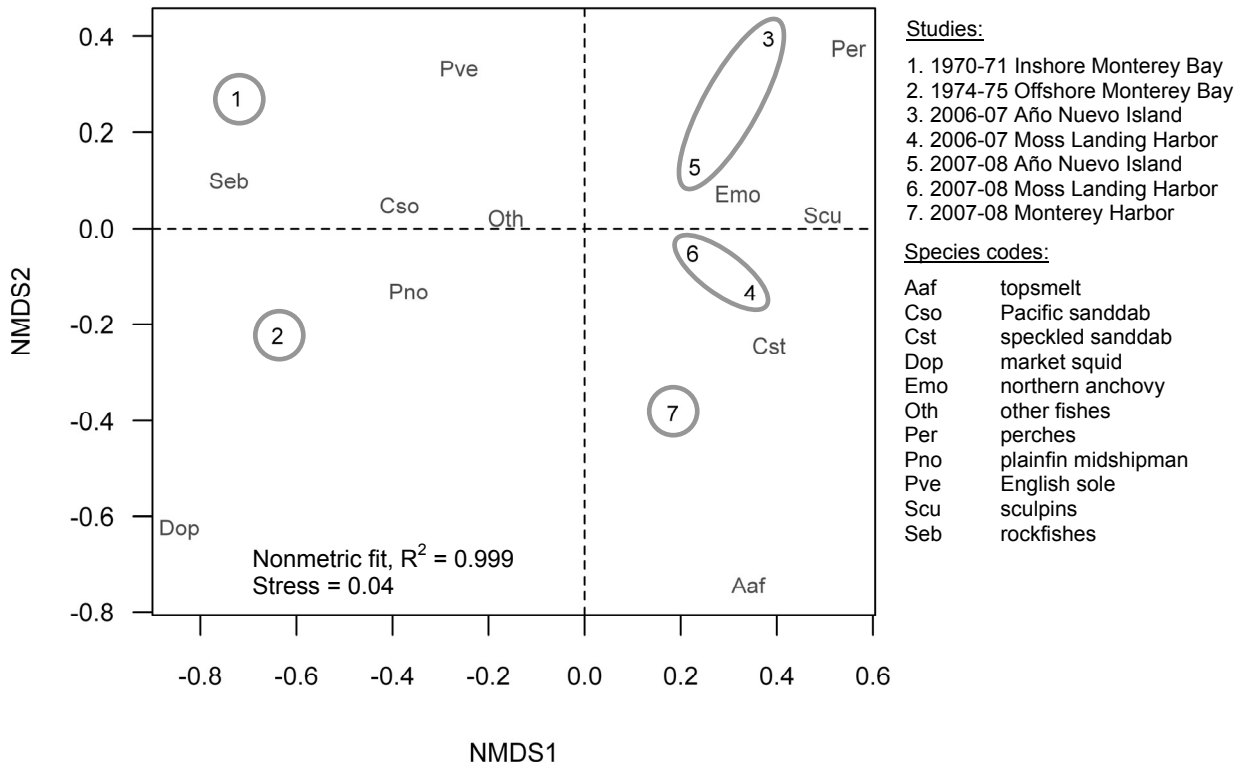

Figure 1. Nonmetric multidimensional scaling ordination comparing overall Brandt's Cormorant diet composition by percent number (%N) among studies in the Monterey Bay region. Each study is represented by a number and studies with the same location are circled. Prey species comprising less than 5% of the diet were combined into category "other fishes". Proximity to three letter prey species codes indicates importance in the diet. Historic data are from 1) Talent 1984 and 2) Baltz and Morejohn 1977 while the remaining data are from this study.

fishes and market squid were consumed compared with great prevalence in previous studies in the Monterey Bay region during the 1970s.

Overall multivariate diet composition data (percent number, %N) for the two historical nonbreeding season diet data sets in Monterey Bay during the early 1970s (Baltz and Morejohn 1977; Talent 1984) and the five location and nonbreeding season combinations sampled in this study were compared using nonmetric multidimensional scaling (NMDS; fig. 1). The first NMDS axis separates the historic data from this study by differences in dominant prey: rockfishes were prevalent in the historical data compared with northern anchovy in this study. The second NMDS axis further separates the diet by prey consumed in particular nonbreeding seasons and locations. Pacific sanddab was consumed during both studies in the 1970s whereas market squid was only in the diet of birds collected offshore in Monterey Bay during the 1974–75 nonbreeding season. During this study, perches (Embiotocidae) occurred in the diet at Año Nuevo Island, speckled sanddab was prevalent in the diet at both locations inside Monterey Bay, whereas topsmelt (*Atherinops affinis*) was mainly observed in the diet at Monterey Harbor.

There was a clear shift in the diet of Brandt's Cormorants from rockfishes in the 1970s to northern anchovy in the mid-2000s in Monterey Bay. There is some evidence that another major fluctuation in the dominant prey of Brandt's Cormorants began at the end of this study. The dominance of northern anchovy waned during the 2007–08 nonbreeding season. Brandt's Cormorant breeding population size in the Monterey Bay region peaked during our study, declined in 2008 and 2009, and then began rebounding in 2010 (Bechaver et al. 2013; Capitolo et al. 2014). Abundance of northern anchovy in central California has been suggested as a contributing factor to the breeding population increase and the subsequent decline of northern anchovy as the potential cause of the 2009 central coast die-off of Brandt's Cormorants (Gibble et al. 2010; Bechaver et al. 2013; Capitolo et al. 2014). This study demonstrated the importance of periodic sampling to detect spatiotemporal variability in the diet of opportunistic generalists.

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