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Changes in forage fish community indicated by the diet of the Brandt's cormorant (*Phalacrocorax penicillatus*) in the central California Current

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ABSTRACT

The population, productivity and diet of two Brandt's cormorant (*Phalacrocorax penicillatus*) colonies located in the central California Current were compared. The offshore colony on Southeast Farallon Island has experienced a declining population over time and anomalously low productivity in recent years. The nearshore colony near Point Arguello has been increasing and its productivity has remained stable. The diets of cormorants at the two colonies elucidated by analysis of regurgitated pellets, while different, have shown similar decreases in the consumption of northern anchovy (*Engraulis mordax*) since 2008, followed by increased consumption of rockfish (*Sebastes* spp.) and flatfish (order Pleuronectiformes). By using the diet results from another seabird nesting in central California, the rhinoceros auklet (*Cerorhinca monocerata*), and one from which whole fish can be obtained, we found that the rockfish species assemblage has changed with offshore rockfish species decreasing while nearshore ones have increased. This change in the rockfish species has negatively impacted Brandt's cormorants at the offshore colony by forcing them to make longer foraging trips to meet energy needs of themselves and their chicks; this has led to low breeding success and a declining population at this site. On the other hand, the nearshore colony has abundant nearby food resources, and it has prospered. These results underscore the value of using seabird data from multiple colonies to better understand changes occurring in the marine environment.

1. Introduction

There is increasing emphasis on managing our marine resources through ecosystem-based fisheries management (EBFM) as opposed to the historical single-species management approach. Though currently subject to much discussion (Link, 2002), in general, the overall goal of EBFM is to sustain healthy marine ecosystems, including its fisheries, with specific objectives to prevent ecosystem degradation, maintain species assemblages and ecosystem processes, preserve long-term benefits to people, and understand the processes of the ecosystem to recognize the impacts of humans (Pikitch et al., 2004).

Forage fish are an important part of the marine food web, being prey to many higher-trophic level organisms. Modeling exercises have been used to explore interactions between forage species and their predators (Cury et al., 2000; Field et al., 2010), and the abundance and composition of forage fishes are known to fluctuate on various time scales based on ocean and climate conditions (Chavez et al., 2003; Schwartzlose et al., 1999). Continued research and monitoring in the California Current and elsewhere are necessary to understand these interactions for effective EBFM.

The Brandt's cormorant (*Phalacrocorax penicillatus*) is a large, colonial nesting seabird that breeds along the west coast of North America (Wallace and Wallace, 1998). This mostly piscivorous species forages mainly on or near the benthos (Ainley et al., 1981), and diet information on this species and other seabirds has been used as an indicator of changes in forage fish populations (Piatt et al., 2007a, 2007b).

For the purposes of this paper, we will be comparing two colonies of Brandt's cormorants in the central portion of the California Current System (CCS): Southeast Farallon Island (SEFI) and Vandenberg Air Force Base (VAN) at Point Conception. SEFI is located in north-central California at the outer edge of the continental shelf; this site hosts the largest Brandt's cormorant colony in the world, and it has been monitored for over 40 years (Ainley and Boekelheide, 1990; Capitolo et al., 2014). VAN, located ~400 km southeast of SEFI, is located on a rock just a few hundred meters off the mainland coast where Brandt's cormorants have been monitored since 2000 (Point Blue, unpublished data).

With population size, reproductive success, and diet data collected from these two colonies, we aim to answer three questions: 1) are Brandt's cormorants from SEFI and VAN consuming the same prey species, 2) are any differences in the diet driven by changes in prey availability, and 3) are contrasting trends in population and productivity related to differences in prey availability and therefore diet?

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2. Materials and methods

2.1. Study sites

SEFI (37°42′ N, 122°60′W) is located 30 miles west of the Golden Gate Bridge, San Francisco, on the outer edge of the continental shelf (Fig. 1). It is the largest seabird colony in the contiguous United States and is included in the Farallon Islands National Wildlife Refuge with the surrounding waters under partial management by the Gulf of the Farallones National Marine Sanctuary. Seabirds have been studied at the Farallones continuously since 1970. Data from 13 species includes population, phenology, reproductive success, and diet (see Ainley and Boekelheide, 1990).

VAN is located just north of Point Conception (34°34′ N, 120°39′W; Fig. 1). VAN hosts six species of seabirds (including the Brandt's cormorant), and Brandt's cormorants were first observed breeding here in 1995; monitoring of this colony began in 2000 (Robinette and Howar, 2013). Brandt's cormorants breed primarily on two mainland points: Point Arguello and North Rocky Point.

2.2. Brandt's Cormorant population size

For the Farallon Islands, all-island censuses for Brandt's cormorants on South Farallon Islands (SFI) have been conducted each year in late May or early June, depending on the timing of peak incubation (Capitolo et al., 2014). Census begins at 0930, and all well-built nests on SFI (which includes SEFI, West End Island, and the Islets) that can be viewed from land are counted, usually in a single day. Nests that are counted are established sites (i.e., well-built nests) occupied by a breeding pair of birds. Poorly-built nests or nests that have been abandoned are not counted. When weather conditions permit, areas not viewable by land but visible from boat are also counted. Multiplying the number of well-built nests by two provides an annual estimate for breeding population size.

For VAN, censuses were conducted of all potential breeding habitat along Point Arguello at least once per week from 1 April through the end of July of each year. All nest sites with evidence of breeding behavior (i.e., birds observed in incubation posture for >2 weeks; presence of eggs, chicks, and/or fledglings) are mapped. The maximum number of nests observed for the year is then multiplied by two to obtain an estimate of breeding population size.

2.3. Brandt's Cormorant productivity

Brandt's cormorants were monitored for chick productivity from a subset of at least 60 nests per year on SEFI from 1971 to 2012. At VAN, all nests viewable from land were monitored from 2000 to 2012. Nest contents were recorded every five days (SEFI) or seven days (VAN) from observation blinds using 10 × 42 binoculars and 20–60× spotting scopes from late March through August/September. During each

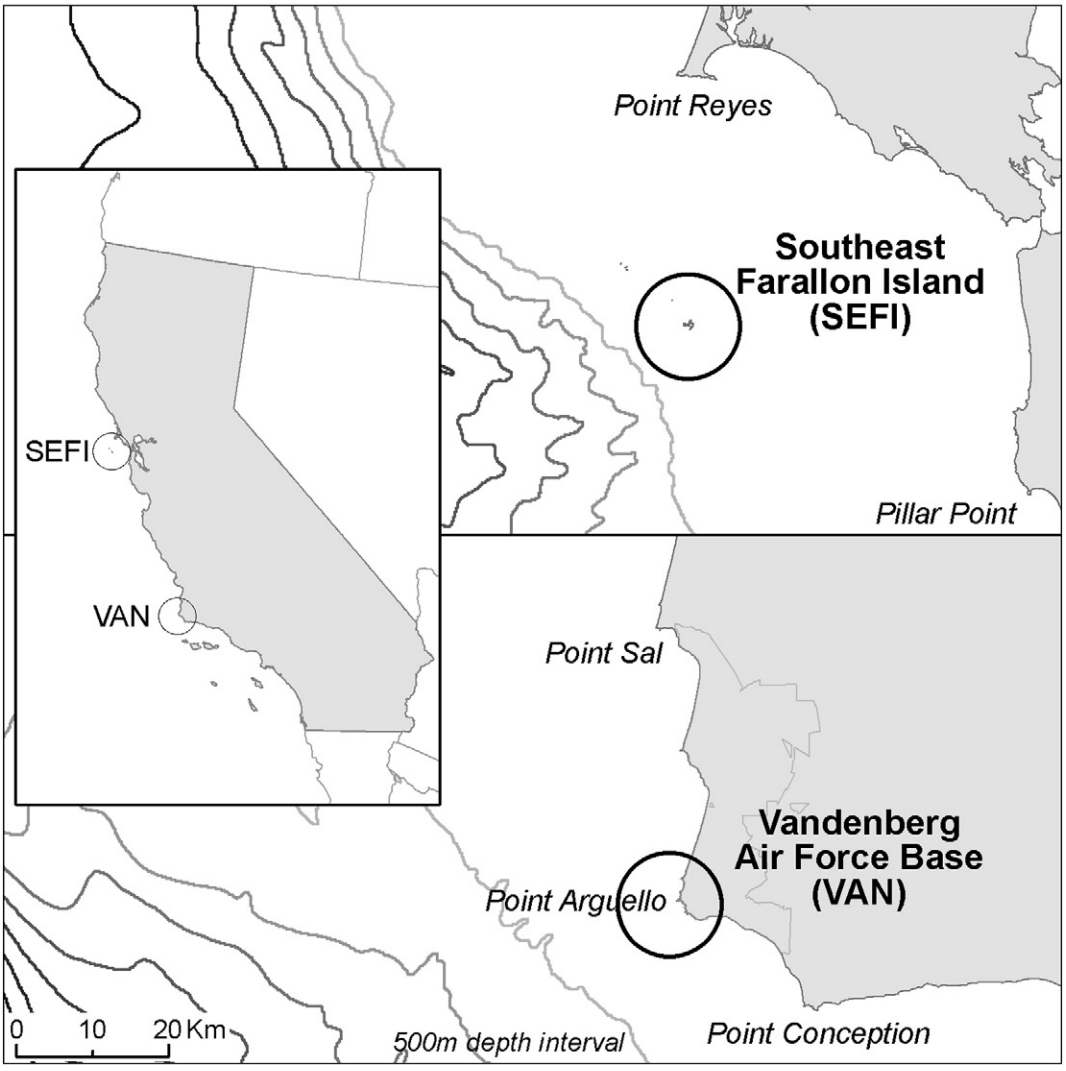

Fig. 1. Locations of the Southeast Farallon Island and Vandenberg Air Force Base Brandt's cormorant colonies.