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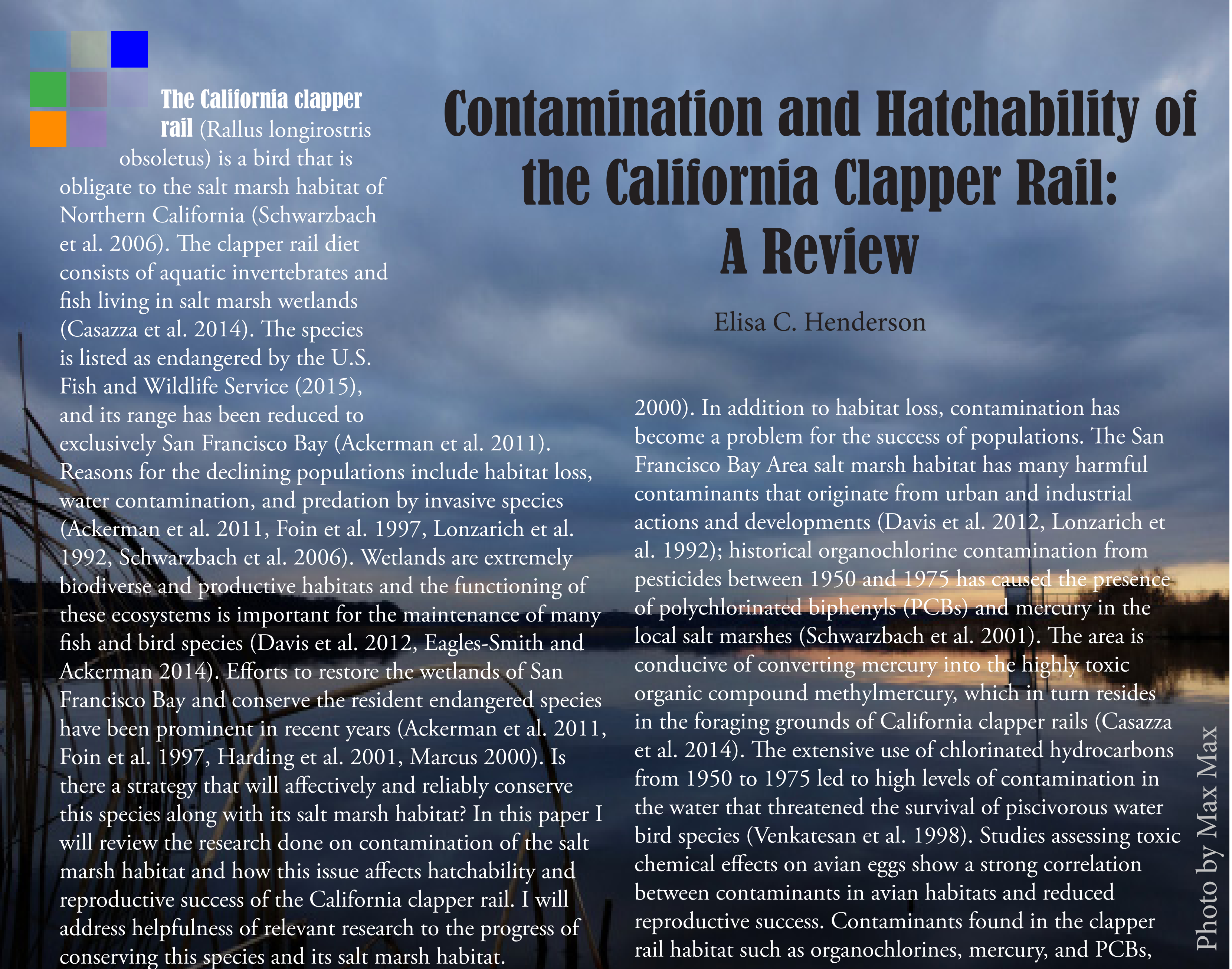


Photo by Max Max

The California clapper rail (Rallus longirostris obsoletus) is a bird that is obligate to the salt marsh habitat of Northern California (Schwarzbach et al. 2006). The clapper rail diet consists of aquatic invertebrates and fish living in salt marsh wetlands (Casazza et al. 2014). The species is listed as endangered by the U.S. Fish and Wildlife Service (2015), and its range has been reduced to exclusively San Francisco Bay (Ackerman et al. 2011). Reasons for the declining populations include habitat loss, water contamination, and predation by invasive species (Ackerman et al. 2011, Foin et al. 1997, Lonzarich et al. 1992, Schwarzbach et al. 2006). Wetlands are extremely biodiverse and productive habitats and the functioning of these ecosystems is important for the maintenance of many fish and bird species (Davis et al. 2012, Eagles-Smith and Ackerman 2014). Efforts to restore the wetlands of San Francisco Bay and conserve the resident endangered species have been prominent in recent years (Ackerman et al. 2011, Foin et al. 1997, Harding et al. 2001, Marcus 2000). Is there a strategy that will affectively and reliably conserve this species along with its salt marsh habitat? In this paper I will review the research done on contamination of the salt marsh habitat and how this issue affects hatchability and reproductive success of the California clapper rail. I will address helpfulness of relevant research to the progress of conserving this species and its salt marsh habitat.

California clapper rail population size has decreased dramatically over the past century. Clapper rails are known to have existed historically throughout the California coast with numbers ranging in the tens of thousands, but by 1997, population size was estimated to be as low as 1,200 individuals restricted to the San Francisco Bay Area (Foin et al. 1995). A recent study has estimated population size at 1,040 to 1,264 (Schwarzbach 2006), similar to those estimated in 1997. Estimated hatchability (percentage of eggs incubated to term that hatch) of California clapper rails was 18.7% and 37.6% in 1980 and 1989 respectively. This contrasts dramatically with the proposed potential hatchability of California clapper rails, based on other closely related species, ranging from 87.3% to 92.3% (Schwarzbach et al. 2006). Research suggests that a major reduction in habitat has greatly contributed to the endangerment of the California clapper rail (Ackerman et al. 2011, Foin et al. 1997, Marcus 2000). In addition to habitat loss, contamination has become a problem for the success of populations. The San Francisco Bay Area salt marsh habitat has many harmful contaminants that originate from urban and industrial actions and developments (Davis et al. 2012, Lonzarich et al. 1992); historical organochlorine contamination from pesticides between 1950 and 1975 has caused the presence of polychlorinated biphenyls (PCBs) and mercury in the local salt marshes (Schwarzbach et al. 2001). The area is conducive of converting mercury into the highly toxic organic compound methylmercury, which in turn resides in the foraging grounds of California clapper rails (Casazza et al. 2014). The extensive use of chlorinated hydrocarbons from 1950 to 1975 led to high levels of contamination in the water that threatened the survival of piscivorous water bird species (Venkatesan et al. 1998). Studies assessing toxic chemical effects on avian eggs show a strong correlation between contaminants in avian habitats and reduced reproductive success. Contaminants found in the clapper rail habitat such as organochlorines, mercury, and PCBs, can decrease hatchability, and thus reproductive success, of the species (Casazza et al. 2014, Schwarzbach et al. 2006).

Source of Contamination

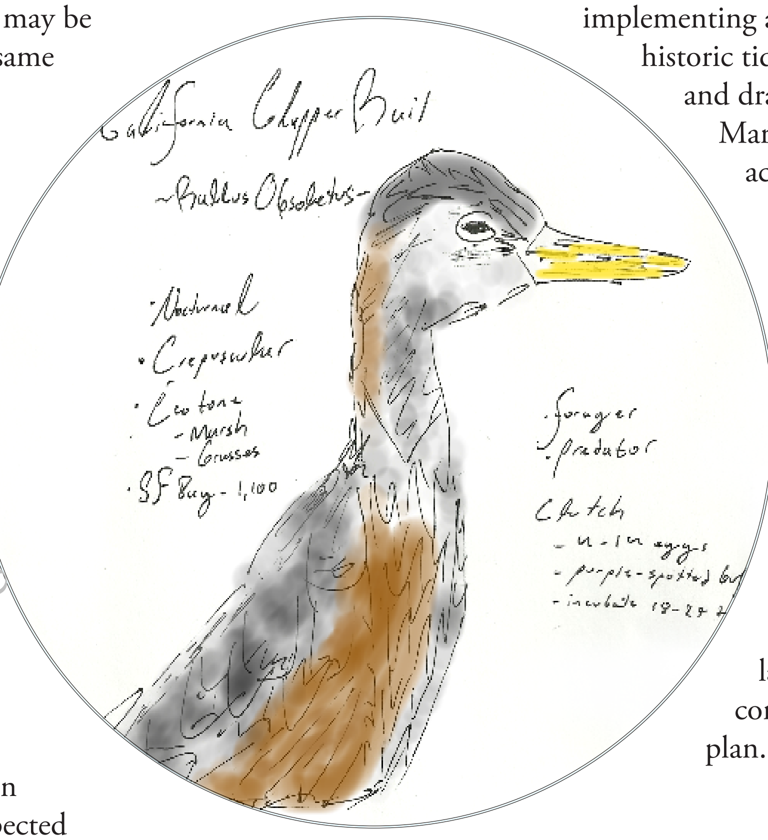
There is strong evidence that industrialization has negatively affected the habitat quality of the San Francisco Bay Area salt marshes. According to Pyle et al. (1999), contamination by organochlorines is a result of agricultural runoff, dredge spills, and pollutants from a radioactive waste site near the Farallon Islands, causing high levels of PCBs and dichlorodiphenyltrichloroethane (DDT) in local fish. Sediments in the San Francisco Bay area may also be polluted with mercury as a result of historic gold mining (Casazza et al. 2014, Ackerman et al. 2011). In an attempt to assess the potential toxicity of contaminants to California clapper rail populations, Lonzarich et al. (1992) collected clapper rail eggs from four sites north of San Francisco and measured selenium, mercury, and organochlorine egg concentrations. They found the highest

PCB concentrations in the Bay Area at Arrowhead Marsh, where high PBC concentrations have been found in the sediment. They also found high selenium concentrations close to the Chevron Richmond Oil Refinery and they suggest that oil refineries have a big impact on selenium pollution in the San Francisco Bay. Lonzarich et al. (1992) concluded that clapper rail populations are extremely vulnerable to pollutants in San Francisco Bay, specifically mercury and selenium. They suggest more research should be done regarding how harmful these pollutants are to the hatchability of clapper rails. This study provides early insight to the affects that water contamination has on clapper rails.

Risk of Contamination

Recent studies have provided evidence that high concentrations of contaminants in water and prey result in high concentrations in blood, eggs, and eggshells. Between 1989 and 1991, Hothem et al. (1995) collected night-heron and great egret eggs from five major sites in the San Francisco Bay and measured organochlorine, PCB, mercury, and selenium concentrations in eggs. They found that PCB levels were much higher in San Francisco Bay than in other California coastal regions and proposed that this is due to the highly urbanized environment. Schwarzbach et al. (2001) measured organochlorine and PCB levels in clapper rail eggs from four sites in South San Francisco Bay and compared these levels to those found by Goodbred et al. (1996) from light-footed clapper rails in Southern California. They found that PCB levels in eggs were much higher in California clapper rails of San Francisco Bay than those found in light-footed clapper rails of Southern California, suggesting that higher levels of water contamination cause higher levels of toxins in eggs of clapper rails. Mora et al (2011) collected eggshells from 20 avian species from various locations in California, Texas, Idaho, Kansas, and Michigan between 1985 and 2007. They measured chemical concentrations in the egg shells and found a strong correlation between concentration in egg shells and concentration in water for species that feed primarily on aquatic invertebrates. Prior to breeding seasons of 2009 and 2010, Casazza et al. (2014) collected aquatic invertebrate and fish taxa from four tidal marshes in South San Francisco Bay. They analyzed each of the 233 prey samples for mercury content and found that spatial patterns in mercury content matched the patterns of mercury content in blood samples of clapper rails observed by Ackerman et al. (2012). These studies provide important evidence that high water contamination is likely to cause high levels of contamination prey and in eggs of clapper rails.

With information that water contamination likely causes high contaminant concentrations in clapper rails, studies sought out to determine how this correlation affects body condition and reproductive success. Evidence that contaminants cause threats to other species of water birds has been found. Hothem et al. (1995) compared findings with those from Fox et al. (1993) and concluded that PCB concentrations in night-heron and great egret eggs were at levels that are thought to cause slow development and deformities in the embryonic stage. Because fish-eating birds that overlap ranges share similar diets, studies such as these may help us estimate harmful levels of contamination for the California clapper rail. This information can help us conclude that levels of mercury and other contaminants in fish in the San Francisco Bay Area may be the cause reproductive impairments in piscivorous bird species (Casazza et al. 2014, Eagles-Smith and Ackerman 2014, Lonzarich et al. 1992). After recognizing very low fecundity in California clapper rails in North and South San Francisco Bay, Schwarzbach et al. (2006) assessed embryo development of clapper rail eggs in nests at six intertidal salt marsh sites throughout the San Francisco Bay. They measured mercury and organochlorine content of assessed eggs that failed to hatch and found contamination to be negatively correlated with reproductive success of rails as exhibited by deformities, hatchability, clutch size, and embryo malposition. Schwarzbach et al. (2006) concluded that the proportion of young to fledge a nest is likely much less than 2.4 on average, primarily due to mercury contamination. They recognized that they may have obtained biased data by only collecting fail-to-hatch eggs, but they nevertheless suggest that water quality be of great importance when considering ways to increase reproductive success of clapper rails. Though they only collected eggs from abandoned nests, their findings of correlations between contaminant levels and body condition are important to recognize and useful for determining causes of reduced fitness. Between 2006 and 2010, Ackerman et al. (2012) collected adult clapper rails from four tidal marsh sites in the San Francisco Bay. They measured morphological characteristics of each individual and took blood samples from a subset of the birds. They also collected eggs from abandoned nests and measured mercury levels in blood, feathers, and eggs. They found that body mass of the California clapper rail is negatively correlated with high levels of feather and blood mercury and that levels of mercury in eggs found in 2007-2010 were similar to those found by Lonzarich et al (1992) in 1986-1987. This study is useful for determining a correlation with body condition and contamination and comparing egg concentrations, but collecting eggs from abandoned nests may again cause slightly biased data. Reduced shell thickness may be another result of water contamination and may also contribute to population decline. In 1993, Pyle et al. (1999) collected eggs from several seabird species in two sites in central California. They measured shell thickness and organochlorine concentration. They found a correlation between concentration of organochlorines and shell thickness in eggs of seabirds and they noted that reproductive success has been found to be affected by eggshell thickness. This information can help us predict further problems for reproductive success in California clapper rails, as they may be affected in similar ways by the same contaminants.



Gabriel Hitchcock

Many studies have concluded that contamination in clapper rail habitat causes negative effects on hatching success, body condition, and overall fitness of individuals. However, little information has been concluded concerning the effect that contamination has on population size. Predicting future population decline that will result from water contamination is important for gaining support for conservation efforts. If we can model the expected rate of population decline of the California clapper rail, we may be able to explicitly show the outcome of contamination, in the theoretical case of no intervention. To determine how to increase population growth and decrease risk to eggs of California clapper rails, it is important to enhance our understanding of the population dynamics of California clapper rails and the role that contamination plays. I suggest more research should be done to predict the rate of population decline as a result of water contamination. There is likely already enough evidence to create a model that will allow us to predict not only how contamination affects individual fitness and nest success, but population outcome as a whole.

Based on the findings of studies reviewed in this article, efforts have been made to conserve the salt marsh habitat of San Francisco Bay Area, focused on increasing reproductive success of California clapper rails. Foin et al. (1997) summarize the effects of human actions on clapper rail populations and habitats and conclude that intense marsh restoration should be initiated. They outline strategies for clapper rail conservation involving expansion, restoration, and preservation of available habitat for clapper rails. However, they do not consider a resolution to water contamination. Marcus (2000) describes how human industrialization has reduced marsh habitat and outlines a concept plan for the restoration of marshlands in San Francisco Bay, California. The project was implemented in March, 2000 and consisted of designing and implementing a tidal marsh in the site of a historic tidal wetland that was diked and drained in 1900. However, Marcus (2000) did not take into account water contamination and did not implement a preventative strategy for contamination in the restored tidal wetland habitat. The fact that clapper rail hatching success remains very low may show that there has been less positive response in the environment than was hoped, possibly due the lack of consideration of water contamination in the recovery plan.

A New Approach

We have encountered and explored a problem that we desire to solve, but perhaps we are taking the wrong approach. Though more research should be done to determine the outcome of population decline, evidence strongly suggests that reproductive success of clapper rails is impaired as a result of water contamination in the San Francisco Bay. Efforts have been made to improve the quality of the salt marsh habitat, but water contamination remains a problem. Evidence shows that there is little use in trying to reduce mercury and contamination levels in the water in SF bay; regulations have been implemented, but with limited success (Davis et al. 2012). Overall, more research should be done to determine the best approach to improve clapper rail hatchability and minimize effects of water contamination.