Science Foundation Chapter 5
Appendix 5.1 – Case Study
Forster's Tern (*Sterna forsteri*) and California Least Tern (*Sternula antillarum browni*)

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DESCRIPTION OF THE SPECIES

This case study considers two tern species that breed within the San Francisco Bay Estuary, Forster's Terns (*Sterna forsteri*) and California Least Terns (*Sternula antillarum browni*). Forster's Terns are medium-sized (140 g) terns that breed in coastal and interior marshes of North America. Forster's Terns can exploit ephemeral habitats, and colony locations often move among years with change in habitat suitability and resource availability. Least Terns are smaller-sized (45 g) terns that breed along beaches and major interior rivers of North America, and winter along marine coastlines in Central and South America. Forster's Terns and California Least Terns breeding in San Francisco Bay tend to use the same nesting colony locations each years.

CRITERIA FOR SELECTION OF THE SPECIES

Forster's Terns were first documented breeding in the estuary in 1948 (Sibley 1952). Since that time, the breeding population size of Forster's Terns has fluctuated annually from 2,400 (Gill 1977) to 5,000 (Ryan 1997) breeding adults, with the current (2005-2014) breeding population estimated at approximately 1,500-3,500 adults (J. T. Ackerman, unpublished). Because monitoring has been sporadic and not systematic, these population size estimates have a large degree of error and likely have limited usefulness for estimating population trends.

Approximately 30% of the Pacific coast population of Forster's Terns breeds within San Francisco Bay (McNicholl et al. 2001, Strong et al. 2004), where the species' breeding ecology has been well studied (Strong et al. 2004, Ackerman and Herzog 2012). Most Forster's Terns nest within former salt evaporation ponds in South San Francisco Bay, particularly the Moffett (ponds A1, A2W, AB1, AB2) and Alviso (ponds A7, A8, A16) Pond Complexes (Ackerman and Herzog 2012). These managed ponds currently provide nesting habitat for over 80% of the terns breeding within the estuary (Strong et al. 2004, Ackerman and Herzog 2012) and are the primary foraging area of adult and juvenile terns (Ackerman et al. 2008, 2009a). Smaller numbers of Forster's Terns nest in managed ponds, on top of duck blinds, and in marshlands of the Napa-Sonoma marshes around San Pablo Bay. Forster's Terns primarily nest on dredge spoil islands within these managed ponds, but other nesting habitats include former dikes that have been converted into islands (primarily in the Newark Pond Complex), and marshes (such as New Chicago Marsh and Charleston Slough; J. T. Ackerman, unpublished). Forster's Terns are mainly migratory, breeding in the estuary from April through August and over-wintering further south along the Pacific Coast of California and Mexico (Gill and Mewaldt 1979) with small numbers wintering locally. The first young hatch in late-May and fledge in mid-June (J. T. Ackerman, unpublished).

California Least Terns were first documented breeding in the estuary in 1967 (Chandik and Baldridge 1967 in Gill 1977). California Least Terns are federally endangered and breed at only a few sites in San Francisco Bay. In 2011, a systematic survey of 49 known breeding locations of Least Terns in California estimated 4,826-6,108 breeding pairs statewide. In San Francisco Bay, there were about 300 breeding pairs at Alameda Point, 30 breeding pairs in the Napa-Sonoma Marsh, and 70 breeding pairs at the Hayward Regional Shoreline (Marschalek 2012). Least Terns have also nested sporadically in Eden Landing Ecological Reserve (<10 nests; J. T. Ackerman, unpublished), although no nesting has been documented in this area for the past three years (Marschalek 2012). The largest colony at Alameda Point is highly managed, and is extremely important to the overall statewide population. This site produces a substantial percentage of the fledglings produced in the state (e.g. ~15-22% of the statewide total fledglings in 2009; Marschalek 2010). This site has also maintained a stable number of breeding Least Terns, compared with the large fluctuations in other sites in southern California (Burton and Terrill 2012 and references listed therein) and has been growing at a rate of ~9% per year since 1976 (Elliott et al. 2011).

REVIEW OF CLIMATE CHANGE EFFECTS ON THE SPECIES

Forster's Terns and Least Terns both rely on islands for nesting habitat in San Francisco Bay. Nest survival is considerably greater on islands than in marshes where terrestrial predators can access nests (Ackerman et al. 2014b). Flooding of nesting islands from fluctuating water levels in managed ponds and tidal wetlands is also a significant cause of nest failure for Forster's Terns.

Forster's Terns forage predominantly along the bay's margins within managed ponds and marshes, and to a lesser extent within tidal flats and sloughs (Ackerman et al. 2008, 2009a). Foraging locations for Least Terns from the Alameda colony include marine and estuarine habitats within ~3.5 miles of the colony site (Elliot et al. 2004, Steinbeck et al. 2005). With rising water levels in the estuary associated with climate change, maintaining suitable nesting habitats in close proximity to food resources will be critical to preserving tern nesting colonies. Rising water temperatures and changing habitat conditions associated with climate change also may negatively impact key prey fish species exploited by terns. Northern anchovy (*Engraulis mordax*) may be of particular importance to Least Terns as a small increase in the abundance of anchovy in the diet appeared to lead to an increase in fledging success (Elliott et al. 2007), thus maintaining this resource may be important.

OTHER STRESSORS

Studies indicate that Forster's Terns nesting in San Francisco Bay already face considerable stressors from widespread mercury contamination, and a rapidly expanding predator (California Gulls; *Larus californicus*) population. Although Forster's Tern nest survival (61%) and egg hatching success (95%) tend to be fairly high in San Francisco Bay (Ackerman and Herzog 2012), chick survival is low (22%) predominantly due to predation on chicks by California Gulls (Ackerman et al. 2014a). In fact, 54% of all Forster's Tern chick deaths were caused by California Gulls (Ackerman et al. 2014a). Additionally, Forster's Terns and Least Terns both have very high risk to methylmercury contamination. Of 17 species of waterbirds studied in San Francisco Bay, Forster's Terns had, by far, the highest mercury concentrations in eggs, and egg mercury concentrations in Least Terns ranked sixth (J. T. Ackerman, unpublished). Importantly for Forster's Terns in San Francisco Bay, failed-to-hatch eggs and abandoned eggs had higher mercury concentrations than randomly sampled eggs (Ackerman and Eagles-Smith 2008), the likelihood of an embryo being malpositioned increased with egg mercury concentrations (Herring et al. 2010), the probability of an egg successfully hatching decreased with egg mercury concentrations (Eagles-Smith and Ackerman 2010), and the probability of nest survival decreased with egg mercury concentrations (Eagles-Smith and Ackerman 2010). Repeated dredging for the creation of shipping channels adjacent to the Alameda Point Least Tern colony may be exposing the terns to increased risk of contamination by legacy pollutants buried in the sediments (Burton and Terrill 2012 and references listed therein). Warming temperatures, changing water dynamics (precipitation, runoff), and changing habitats associated with climate change have the potential to have a synergistic effect on methylmercury production in San Francisco Bay, thereby possibly increasing the bioavailability of mercury to wildlife, including terns.

LIFE CYCLE CONSIDERATIONS AND POPULATION DYNAMICS

Little is known about population dynamics of Forster's Terns or Least Terns in San Francisco Bay. The best available data suggest that the Forster's Tern population might be declining (Strong et al. 2004, J. Ackerman, unpublished data) and the small population of Least Terns is likely stable (Elliott et al. 2007). It is unclear what impacts varying climate change scenarios might have on these species, and limited population data currently prohibits robust population projections.

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

Population resilience will depend on maintaining or enhancing reproductive success, especially nest survival and chick survival. Reducing egg and chick mortality due to predation and contamination, especially mercury, will enhance resilience.

Maintaining island nesting habitat, particularly within managed ponds, will help maintain resilience. Of immediate concern is the conversion of 50% to 90% of the former salt evaporation ponds into tidal marsh habitat under the South Bay Salt Pond Restoration Project. Forster's Terns rely on the project's managed pond habitat for foraging and nesting, and reducing its availability will likely result in a smaller tern population. This large-scale wetland restoration project will likely have a larger influence on the bay's Forster's Tern population than any changes related to climate change. Maintaining managed ponds and associated nesting islands preferred by Forster's Terns will be important (particularly project ponds A1, A2W, AB1, AB2, A7, A8, and A16), as will the creation of new nesting islands suitable to terns.

LIKELY CLIMATE CHANGE IMPACTS AND RISKS

Forster's Terns and Least Terns rely on wetland habitats along the margins of San Francisco Bay. In particular, managed ponds and their associated dredge spoil islands are critically important for tern foraging and nesting. Management to enhance reproductive success is likely the most critical factor for maintaining or increasing populations in San Francisco Bay, and loss of island nesting habitat and methylmercury contamination both have been shown to impair reproduction. Because most Forster's Terns nest in South San Francisco Bay, reduction in managed pond habitat (former salt evaporation pond) by as much as 90% by the South Bay Salt Pond Restoration Project will likely have a dramatic influence on the viability of tern populations.

MANAGEMENT ACTIONS TO BE CONSIDERED

Management should focus on enhancing reproductive success through improved nest survival and chick growth and survival. Therefore reducing nest predation rates and methylmercury bioaccumulation is recommended. Reducing nest predation rates could be accomplished by increasing the terns' island nesting habitats in close proximity to food resources, but away from colonies of the growing population of California Gulls (Ackerman et al. 2006, 2009b, 2010a, Ackerman et al. 2014a). Reducing methylmercury contamination is more challenging, but enacting management actions in wetlands to reduce methylmercury production and bioaccumulation may be possible (Ackerman et al. 2010b, Ackerman et al. 2012).

UNCERTAINTY AND ITS SOURCES

The demographic response of Forster's Terns and Least Terns to climate change is not known, especially with regard to survival rates. One thing that is more certain, however, is that enhancing or increasing island nesting habitat within wetlands along the bay's margins should benefit breeding terns and allow colonies to move to new nesting locations as resources fluctuate spatially and temporally.

IMPORTANT DATA GAPS/NEEDS

The main data gap is uncertainty regarding what impacts the South Bay Salt Pond Restoration Project may have on the breeding population of Forster's Terns in San Francisco Bay. Of particular importance is understanding where and how to construct nesting islands that will be used by terns and promote sustainable reproductive success rates. Additionally, more information is needed about the benefits of not converting (into tidal marsh habitat) the most productive current tern nesting locations. Demographic responses of Forster's Terns and Least Terns to climate change is not known, especially with regard to nest and chick survival rates, and deserves more detailed study.

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