Science Foundation Chapter 5 Appendix 5.1 – Case Study Diving Ducks

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DESCRIPTION OF THE SPECIES

Diving ducks are the most abundant group of waterfowl that overwinter in the open bays and ponds of San Francisco Bay (SFB). Species within this group are primarily benthivores that dive to obtain their macroinvertebrate prey in bottom sediments, although at times they may eat plant matter or forage in the water column. These migratory species include bay ducks (lesser scaup *Aythya affinis*, greater scaup *A. marila*, canvasback *A. valisineria*), sea ducks (surf scoter *Melanitta perspicillata* and bufflehead *Bucephala albeola*), and a stiff-tailed duck (ruddy duck *Oxyura jamaicensis*). These species vary from largest to smallest body mass: canvasback, greater scaup, surf scoter, lesser scaup, ruddy duck, and bufflehead.

Their breeding grounds range from Central Valley grasslands, intermountain wetlands, prairie potholes, boreal forest, and Arctic tundra. Their wintering populations in SFB are most abundant between October and April, and SFB comprises up to 50% of the number counted during midwinter surveys on the lower Pacific coast. Species are found in all SFB regions, but greater scaup and surf scoter are most often seen in subtidal to intertidal waters and are not commonly found in baylands. In contrast, ruddy duck and bufflehead populations are most abundant in baylands, particularly in managed ponds. Canvasbacks are commonly found at estuaries or creek mouths.

CRITEREA FOR SELECTION OF THE GUILD

SFB is particularly important for diving ducks, because this estuary supports a majority of the diving ducks counted in the lower flyway during the winter. Migratory waterfowl are species of special management interest. Most of the waterfowl are hunted, and the annual regulations are derived to maintain healthy populations. In particular, the San Pablo Bay National Wildlife Refuge was established partially in recognition of the area's importance for canvasbacks. Waterfowl may be adversely affected by human disturbance (e.g., boat traffic) in highly urbanized estuaries such as SFB. In addition, multiple stressors including, but not limited to, climate change, sea-level rise, and extreme storm events are likely to affect the key intertidal and subtidal habitats, such as saline ponds, mud flats, and eelgrass (*Zostera marina*) beds, that are used by this guild.

OTHER INFORMATION ABOUT THE GUILD

Diving ducks account for up to 75% of the waterfowl in SFB open bays and saltponds, and peak wintering numbers are typically counted in mid-January (Accurso 1992, Takekawa et al. in review). Scaup and surf scoters are the most abundant species wintering in SFB, comprising between 45-47% and 19-20% respectively, of all waterfowl counted. Ruddy duck, canvasback, and bufflehead average 7-8%, 7%, and <2% respectively, of waterfowl counted in SFB (Accurso 1992). More recent counts (2012) indicate that 31% of ducks in SFB are scaup, 10% are ruddy duck, 9% are canvasback, 5% are scoter, and 4% are bufflehead (Richmond et al. 2014).

Continentally, scaup and scoter populations have been declining at an alarming rate for the past several decades. These trends are reflected in SFB midwinter waterfowl counts, particularly for scoters. Long-term wintering and breeding area surveys for scoters suggest they have declined more than 50% continentally in the past 50 years (Hodges et al. 1996, Savard et al. 1998, Sea Duck Joint Venture SDJV 2001, Dickson and Glichrist 2002, Evenson et al. 2005, USFWS 2009). While scaup numbers have climbed in recent years, North American scaup populations are currently > 1 million birds below the North American Waterfowl Management Plan (NAWMP) goal of 6.3 million scaup (USFWS 2012). Canvasback populations are stable continentally, but have declined in SFB from peak numbers of 60,000 in the 1960s to less than 20,000 in the 2000s, possibly reflecting winter habitat change, redistribution to the Central Valley (Kruse et al. 2003), or both. Ruddy duck and bufflehead populations are both thought to be stable or increasing continentally (Gauthier 1993, SDJV 2001, Brua 2002).

Diets of scoter and scaup in SFB are dominated by bivalves, particularly *Corbula amurensis* (De La Cruz 2010, Takekawa et al. unpubl. data), and depletion of this clam (Poulton et al. 2002) may influence movements of scoters and scaup out of San Pablo Bay by mid-winter (Lovvorn et al. 2013). Pacific herring (*Clupea pallasii*) roe is an important prey item for scoters in the Central Bay, comprising as much as 54% of their mid-winter diets based on stable isotope analyses (De La Cruz 2010). Canvasbacks in SFB also consume mainly bivalves, but typically forage on larger clams buried deeper in the sediment than those chosen by scaup and scoters (Takekawa et al. unpubl. data). Ruddy ducks foraging in North Bay ponds displayed dietary flexibility based on pond salinity; consuming amphipods and bivalves in low salinity ponds, and brine flies and seeds in high salinity ponds (Takekawa et al. 2009). Bufflehead diets have not been studied in SFB, but at other coastal wintering areas crustacean, bivalve, and occasional fish prey, including herring roe, are taken (Erskine 1972, Stott and Olson 1973, Bayer 1980).

REVIEW OF CLIMATE CHANGE EFFECTS ON THE SPECIES

Recent studies in SFB have indicated that net deposition of sediment may not keep pace with sea-level rise (Ganju and Schoellhamer 2010). Sea-level rise increases water levels and reduces wave-induced sediment redistribution of bottom sediments, especially in the shallowest areas (<2m) that are commonly used by diving ducks. Thus, intertidal flats and baylands may not retain current elevations and become deeper.

Changes in salinity, grain size, and possibly water depth may change the invertebrate community composition and their availability to diving ducks. The effect of these changes on primary productivity and associated abundance and distribution of macroinvertebrate prey is not known, but any changes to these main prey items for diving ducks would certainly have some influence.

Sea-level rise (SLR) can decrease light irradiance, but with decreased suspended sediment, optical depth may not greatly differ as a consequence of sea level rise. Increasing frequency of extreme storm events (Graham and Diaz 2001) may result in less favorable foraging conditions for diving ducks. Although diving ducks may forage at night and sediments are typically stirred up by their bottom-foraging activities, they may use their vision to find prey resources. In addition, the timing and extent of phytoplankton blooms may change with changes in light levels on the shoals, influencing bivalve filter feeders upon which diving ducks feed. Increasing water clarity may be beneficial to eelgrass, which is a herring spawning substrate and provides habitat for some invertebrate species consumed by diving ducks (Anderson et al. 2008)

Changes in oceanic conditions may drive distributions of sea ducks, potentially causing shifts in wintering ranges and changes in overall numbers wintering in the estuary. For example, distributions of scoters and other sea ducks on the Atlantic coast have been shown to be related to ocean conditions such as the North Atlantic Oscillation and sea surface temperature, with scoters distributed closer to shore and in estuaries during colder, more severe winters (Zipkin et al. 2010). Additionally, trophic dynamics in SFB are coupled with the California Current System (CCS) such that changes in cold-water upwelling along the Pacific coast can lead to large increases in cold water fishes in SFB (Cloern et al. 2007) that are strong competitors with diving ducks for their bivalve prey.

OTHER STRESSORS

- While wintering in the estuary, diving ducks face a number of potential threats, many of which are associated with urbanization. Potential threats include habitat alteration, disturbance, invasive prey species, declining Pacific herring populations and bioaccumulation of trace element contaminants (Carlton et al. 1990, Ohlendorf et al. 1991, Cohen and Carlton 1995, Linville et al. 2002, Merkel et al. 2009).

- Availability of food is hypothesized as a main limiting factor for waterfowl during winter (Lovvorn et al. 2013). Results of carrying capacity models for the San Pablo Bay show that declining profitability as prey becomes patchy and difficult to find may cause scaup and scoters to leave San Pablo before their absolute threshold prey density is reached (Lovvorn et al. 2013).

- Invasive species as food resources may be limiting to diving ducks if they represent lower foraging profitability or an increased risk of contaminant accumulation (e.g., Linville et al. 2002, Wallace, Lee & Luoma 2003), a continual threat given the rate of invasions in the SFB.

- Contaminants are elevated in SFB diving ducks (Takekawa et al. 2002, Eagles-Smith et al. 2009) and may also be limiting as there is evidence that selenium, mercury, and cadmium may influence body condition in scaup and canvasbacks (Takekawa et al 2002). Contaminants did not appear to influence proximate measures of body condition in scoters (De La Cruz 2010), but other studies have tied mercury and selenium to oxidative stress in SFB scoters (Hoffman et al 1998). These subtle effects on condition may later influence survival, migratory timing, and ultimately productivity.

- Disturbance from human recreational and commercial activities is another potential threat that may become exacerbated if available foraging areas for diving waterfowl shrink or move due to climate

related changes. Disturbance can cause waterbirds to expend more energy flying and spend less time feeding, reducing body condition and the ability to migrate and reproduce (Belanger and Bedard 1990, Haramis *et al.* 1986, Bell and Austin 1985). Repeated disturbance may cause waterbirds to shift distribution patterns, forage in less preferred habitats, or emigrate (Schwemmer *et al.* 2011, Havera *et al.* 1992). Responses to human presence can greatly depend on species, bird densities, individual body condition, foraging conditions in the impact area, type of disturbance, and other parameters (Borgmann 2011, Gill 2007, Yasue 2005), and much remains to be learned about how these factors can interact to influence diving duck responses.

- Oil spills are particularly detrimental to diving ducks because these species are most abundant in open waters impacted by spills. For example, scoters and scaup had the highest mortality rates of all birds during the 2007 *Cosco Busan* spill on SFB (Hampton et al. 2008, De La Cruz et al. 2012). Additionally, many diving ducks species show high winter site fidelity (De La Cruz et al. 2009, Zipkin et al. 2010) and some species pair on wintering areas; thus, catastrophic events that affect survival rates in SFB could have disproportionate effects on local subpopulations (Esler et al. 2000).

- Pacific herring declines may influence body condition and survival of surf scoters and potentially scaup and bufflehead, that rely on roe to build lipid stores during late winter and spring migration (Bayer 1980, Kessel et al. 2002, Anderson et al. 2009, De La Cruz 2010, Lok et al. 2008, 2011, 2012)

ENTIRE LIFE CYCLE AND INFLUENCES FROM OUTSIDE THE ESTUARY

Some diving ducks in SFB are boreal nesting species, with greater scaup and surf scoters among the northern-most nesting waterfowl species (Gauthier 1993, Austin et al. 1998, Savard et al. 1998, Brua 2002, Kessel et al. 2002, Mowbray 2002, Takekawa et al. 2011), and thus, may be especially susceptible to the effects of climate change. Over the past three decades, the North American Northern Boreal Forest (NBF) has warmed more rapidly than any other region on earth (Serreze et al. 2001) and climate-induced changes are predicted to be the greatest in northern ecosystems (Soja et al. 2007). Boreal nesting diving ducks have a limited opportunity to reproduce during the ice free period in the Northern Boreal Forest, and changes in invertebrate prey availability (e.g., Visser et al. 1998) or in wetland nesting habitats (Smol and Douglas 2007) may be particularly detrimental to the timing of their reproduction (Drever et al. 2011). Other threats on the boreal breeding areas are imminent oil, gas, and diamond mining development planned in the NBF (Government of the Northwest Territories; Industry, Tourism, and Investment, http://www.iti.gov.nt.ca/index.html). The parkland and prarie pothole regions are also important breeding habitat for lesser scaup, canvasback, ruddy duck, and bufflehead. Clearing and draining of nesting habitat for conversion to agriculture in these regions are of critical concern for diving ducks (Gauthier 1993, Austin 1998, Mowbray 2002).

In addition to wintering in coastal habitats, many diving duck species molt and migrate along coastlines and in estuaries. During these periods they are aggregated in large groups, often in urbanized areas, and may be more vulnerable to threats than when they are dispersed over large, less populated breeding areas. Along coastal migration corridors and molting areas diving ducks contend with factors related to dense human populations including disturbance, contaminant exposure, oil spills, aquaculture, energy development, non-native species invasions, declining Pacific herring stocks (a key prey item for scoters), or shoreline development (Carlton et al. 1990, Savard et al. 1998, Linville et al. 2002, Stick 2005, Bartling 2006, Merkel et al. 2009).

Poor winter and spring habitat quality has been hypothesized as one explanation for the observed patterns of continental decline in lesser scaup and other diving ducks. This hypothesis suggests that declines in the quantity and quality of winter and spring habitats have resulted in carry-over effects, such that females are arriving on breeding areas in poorer body condition than historically, resulting in reduced reproductive success and survival (Marra et al. 1998, Anteau and Afton 2004).

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

Poor winter body condition can affect resilience of diving ducks by making them more susceptible to disease, lowering survival, or exerting cross-seasonal effects on reproduction. Diving ducks typically have high winter site fidelity to particular areas of in SFB (Accurso 1992, De La Cruz 2010, De La Cruz et al. in review). Ensuring important roosting and foraging areas in open bays and baylands are free from disturbance will help diving ducks maintain winter body condition, and thereby improve resilience to other stressors. Subtidal restorations may increase prey abundance for some species, which would lead to improved body condition and increased resilience.

LIKELY CLIMATE CHANGE IMPACTS AND RISKS

Depending on a given potential climate change effect, impacts and risks will be different for each species. Smaller diving duck species that are more limited by foraging depth may be most influenced by SLR. Prey availability may change for all diving duck species with changes in salinity, fresh water flow, sedimentation, and water clarity. Diving ducks may be forced to disperse to habitat that is not as well suited and prone to more competition, exposure and human disturbance. Changing conditions in the coastal ocean may change distributions of more marine species (surf scoters and greater scaup), as well as the distributions of prey and competitor species in SFB.

MANAGEMENT ACTIONS TO BE CONSIDERED

- Minimize disturbance to existing roosting and foraging sites, and design recreational trails, boating routes, and restorations to minimize disturbance by people, pets, and predators. Diving duck distributions in SFB may change in relation to SLR and altered prey populations, and changing proximity of important habitat to populated or recreational areas.

- Evaluate the feasibility of using subtidal habitat restorations (e.g., eelgrass, oyster [*Ostrea conchaphila*], other natural substrates) to increase foraging opportunities for diving ducks.

- Manage remaining former salt ponds to maximize their value as roosting and foraging habitat for diving ducks.

- Include large channels and muted tidal areas in restored tidal marsh designs to encourage use by diving duck species.

- Develop habitat models using scenarios of sea level rise, salinity, and sediment supply to help determine areas of SFB that may support diving ducks in the future. This is necessary to direct future management actions for these species.

- Continue long-term survey programs (FWS Midwinter Survey, South Bay Salt Pond Restoration Project Surveys) to evaluate long term trends of diving duck use and numbers in SFB. This type of monitoring is key to an adaptive management approach.

- Participate in the creation of Flyway-wide plans to conserve and protect key winter and migratory stop-over habitat for diving ducks.

UNCERTAINTY AND KNOWLEDGE GAPS

- More information is needed to understand the role of climatic and oceanic conditions on the variability in use of SFB by different diving duck species and by their fish and invertebrate competitors.

- The effects of disturbance on foraging and habitat use may be variable by species and time of year. Certain species may be more sensitive and certain conditions (low prey availability late in winter) may make disturbance effects more pronounced (Gill 2007).

- More information is needed about connectivity of breeding, migratory, and wintering habitats for diving ducks, in order to understand how each species will respond to changes in the estuary (i.e., some species may redistribute, while others may experience declines in a particular sub-population that winters in SFB).

- Little is known about ruddy duck and bufflehead habitat use in SFB, making their potential responses to climate change more difficult to assess.

- It is uncertain how quickly local sea level rise will occur and thus difficult to determine when habitat changes may occur for diving ducks.

- It is uncertain how sediment deficits in combination with changing climatic conditions will shape the bathymetry of SFB, thus it is unclear which diving duck species will be most influenced by sea level rise.

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