Science Foundation Chapter 3 Appendix 3.1 – Case Study Salmon

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DESCRIPTION OF THE SPECIES

This case study covers Chinook salmon (*Oncorhynchus tschawytsha*) and sea-run steelhead (*Oncorhynchus mykiss*). Under natural conditions these salmon spawn in gravel-bedded rivers in the watershed and migrate through the estuary on their way to sea, where they rear for one to several years before returning to their natal streams to spawn. Most Chinook and many steelhead are hatchery-reared fish, which are released in the rivers or in the estuary to begin their migration. A small proportion of these fish spawn in some years in local tributaries to the Bay, such as the Napa River.

CRITERIA FOR SELECTION OF THE SPECIES

Salmon are strongly affected by several aspects of climate. Their spawning and rearing habitats are affected by changes in freshwater flow and temperature. Survival and growth in the ocean depends on ocean conditions, and the warm water and low productivity of El Niños can cause poor survival. Survival of young salmon through the Delta can be very low, and may be affected by various threats including predators, contaminants, and high temperature. High export flows to the south Delta pumping facilities, and unfavorable circulation patterns, can reduce survival of migrating salmon (Newman 2003, Kimmerer 2008). Salmon that spawn in the smaller tributaries are more vulnerable to variability in local flow and temperature, but may provide a source of recolonization and genetic variability to the riverine populations.

OTHER INFORMATION ABOUT THE SPECIES

A monograph by Williams (2006) provides most of the information summarized here. Most of the available information is on Chinook salmon; less is available for steelhead because of their lower abundance and diffuse and variable migratory patterns.

Life cycles of salmon are complex, adaptable, and variable. Chinook salmon spawn in gravel-bedded rivers of the Central Valley, either tributaries in the Sierra foothills or in the mainstem Sacramento River below Keswick Dam. Eggs deposited in gravel hatch and the fry remain within the gravel before emerging when they begin to feed. Fry may remain in their natal reach or drift downstream and rear in other habitats. Most fry go through the process of smolting during their first 6 months – 1 year, by which they become ready to encounter salt water, and begin a rather leisurely movement toward the sea. The fish rear in the ocean for 1-5 years before returning to the rivers where they spawn and die. Life cycles of steelhead are somewhat more complex, in that they migrate to sea at a variety of ages or not at all, and can return to sea after spawning. Steelhead generally oversummer at least once, and are therefore vulnerable to low flow and high temperature during summers. Steelhead are also genetically linked to resident rainbow trout

populations that spawn in the same rivers, indicating some plasticity between the migratory and resident life histories.

Four runs or races of Chinook salmon have been identified based on the timing of adult migration upstream: winter-run, spring-run, fall-run and late-fall run. These runs are genetically distinct and have distinct patterns of timing of upstream and downstream migration, and spawning and rearing habitat. Winter-run Chinook are listed as endangered and spring Chinook as threatened under both state and federal legislation, and Central Valley steelhead are listed as threatened under federal legislation.

Hatcheries, built mainly to replace natural production lost to damming of rivers, produce a large number of fish particularly in the fall-run stock, which is the mainstay of the ocean fishery. The fall-run Chinook population is largely a hatchery stock, although many of these fish spawn naturally (Barnett-Johnson 2007, Johnson et al. 2012). Molecular or isotopic methods are necessary to identify individual fish to run once they have migrated out of the river, so results of studies before 2000 are generally ambiguous as to run.

Young Chinook salmon are present in the estuary throughout the year, but are most abundant in the Delta during April-June. Although estuarine rearing is common in other stocks of Chinook salmon (Healey 1991), estuarine rearing seems less important in Central Valley Chinook. Chinook smolts entering brackish water take about 3 weeks to traverse the estuary, and generally grow less in weight than expected for their length, indicating a shortage of food within the estuary (MacFarlane 2010). Salmon generally consume insects and various crustaceans such as copepods and amphipods, switching to fish as they grow. The low weight of the fish upon entering the ocean is consistent with low productivity in the estuary.

Chinook salmon use marshes extensively in other Pacific estuaries, but in the San Francisco Estuary they appear to be most abundant in shallow waters of the Delta (Grimaldo et al. 2009). A sampling program in the China Camp marsh turned up no salmon in over 13,000 fish (Visintainer et al.2006), while six Chinook salmon were collected out of 9452 fish caught in marshes of the Napa and Petaluma Rivers and the western Delta (Gewant and Bollens 2012). Chinook salmon are abundant during spring in samples collected by the San Francisco Bay Study and comprise on average about 4% of the catch throughout the year. They are about equally abundant in shoal and channel stations, with no trend in catch with depth of the sampling station.

REVIEW OF LONG-TERM EFFECTS

Chinook salmon in the Central Valley are at the southern end of their range and vulnerable to high temperatures exacerbated by loss of habitat due to dams. Winter Chinook once spawned in the high-elevation reaches of the Sacramento River and tributaries, where eggs and fry could develop during summer in dependably cool water. Their spawning is now confined to an artificial cold-water reach below Keswick Dam. This makes them highly vulnerable to a few years of low flow resulting in high temperature because of low reservoir level and high air temperature. A conservation hatchery program has been implemented to hedge against a catastrophic drought. Adult spring Chinook hold over summer in deep, spring-fed pools in streams draining the Lassen watershed, where they are somewhat protected from high-temperature events as long as the spring-water remains cool.

Estuarine conditions will likely continue to impair growth of Chinook salmon. However, high-flow conditions appear less favorable than low-flow conditions of strong salinity penetration into the estuary (MacFarlane 2010). This suggests that the anticipated change toward lower spring-summer outflow and greater salinity penetration may benefit salmon once they get past the Delta, but low-flow conditions within the Delta are probably deleterious to salmon, particularly with the current water export system (Newman 2003, Kimmerer 2008). The proposed change in the point of diversion of freshwater from the southern

Delta to the Sacramento River may benefit salmon by reducing entrainment in the southern Delta, but that depends on details of the design, construction, and operation of the new facilities, which have not been fully developed.

Ocean conditions have a strong influence on early growth and survival of Chinook salmon (MacFarlane 2010, Wells et al. 2012). Upwelling is associated with high abundance of krill, good survival and condition of the fish, and strong subsequent recruitment to the fishery.

Salmon populations in local streams are likely to be vulnerable to high temperature and reduced flow during the protracted dry season, possibly exacerbated by water withdrawal in the local watershed. This is particularly so for steelhead because they over-summer in the streams.

OTHER STRESSORS

Although hatchery production was instigated to mitigate for loss of habitat, hatcheries have had a devastating impact on the integrity of naturally-spawning stocks (Williams 2006, Johnson et al. 2012). Ocean harvest of the hatchery-supported fall Chinook has probably reduced the two listed stocks because the fish cannot be distinguished, although they are somewhat separated and the catches of listed stocks are probably a small fraction of their total abundance.

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

Fall Chinook is maintained by hatchery production and cannot be considered resilient, although the hatcheries should be able to continue maintaining this stock. The two listed runs are highly vulnerable and have few alternatives if spawning areas become unavailable because of drought, heat, or catastrophe. Steelhead by themselves are vulnerable to the same problems; however, if their genetic link with resident rainbow trout indicates strong mixing between these life histories, the resident trout may enhance resilience of the steelhead.

LIKELY CLIMATE CHANGE IMPACTS AND RISKS

High temperature, coupled with changing water project operations and seasonal patterns of runoff, may devastate the listed Chinook runs.

UNCERTAINTY AND KNOWLEDGE GAPS

- Importance of shoals and marsh channels for salmon.
- Contribution of populations in local streams to overall populations.

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