CONSERVATION BIOLOGY PROGRAM

Summary Report: Green Sturgeon, Longfin Smelt, and Dredging Operations in the San Francisco Estuary

Prepared for U.S. Army Corps of Engineers

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1. **ABSTRACT**

In 2009, California Department of Fish and Game Commission listed longfin smelt (*Spirinchus thaleichthys*) as threatened, and NOAA formally adopted "take" provisions for green sturgeon (*Acipenser medirostris* Ayres). These changes in the management status, and associated permitting issues, have prompted renewed interest among LTMS participants in the management of these native fish. In response, LTMS held symposia on December 2 and 3, 2009, to review and consider the science, management, and policy related to dredging activities and these species. A primary stressor to both species is reduction of appropriate habitat, due to water diversion activities and other basin-scale modifications in water flow. Local studies of dredging have shown little evidence of direct entrainment for either species, and the frequency of encounter with sites of dredging activity is likely to be very low. Nevertheless, spatial and temporal patterns of population movements and reproductive activity vary from year to year, making it difficult to employ an environmental work windows approach. Available information is limited on other direct effects of dredging, including sediment contamination, habitat modification, and underwater noise. Indirect effects due to maintenance of active navigation channels pose potential concerns. In particular, introduction of invasive species, and mortality due to propeller strikes, both warrant attention.

As a follow up step to the symposia, we recommend that LTMS host a workshop targeted towards specific LTMS management needs for green sturgeon and longfin smelt. The workshop should include LTMS participants, the scientists that presented at the symposium, and dredging operators, and could focus on the integration of current research findings into tools that would be useful for managers. Appropriate tools for consideration include predictive or descriptive models of species distribution, and of potential impacts of various dredging activities. There should also be consideration of management approaches that broadly address the primary ecosystem-level stressors for green sturgeon and longfin smelt, rather than employing small scale project-level mitigation. In particular, an integrated regional restoration and monitoring program may be the most effective approach to improve the health of the species.

2. ACKNOWLEDGEMENTS

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3. INTRODUCTION[1]

The Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region (LTMS) provides a cooperative framework for maintaining the navigation channels of the San Francisco Estuary in an economically and environmentally sound manner. LTMS is an ongoing collaboration of multiple participants[2].

In order to gain a better understanding of how dredging impacts two species of concern, North American green sturgeon (*Acipenser medirostris* Ayres) and longfin smelt (*Spirinchus thaleichthys*), the U.S. Army Corps of Engineers (USACE) funded the San Francisco Estuary Institute (SFEI) to hold two symposia to evaluate and disseminate the latest available information on these species. The objectives of the symposia were to:

- Disseminate current knowledge,
- Review guidelines needed to manage these species and comply with relevant regulatory mandates; and
- Develop study plans for further work.

The symposia were held on December 2 and 3, 2009, in Oakland, CA, with one day dedicated to each species. There were over 100 participants, including scientists, regulators, representatives from the dredging community, and other interested parties. The symposia also included discussions of the various management options for these species with respect to dredging operations in the region, such as the dredging window policy. This brief report summarizes the major findings and discussions of the symposia, including the current state of knowledge, management history of the species, potential impacts (both direct and indirect) of dredging, priorities and issues identified by stakeholders, and future research recommendations.

In the past few years, declining populations of green sturgeon have increased awareness of the species, and resulted in local research studies, including both published literature and unpublished studies (Armor et al. 2006, Klimley et al. 2007). This has included tagging studies performed by California experts in the field, funded by LTMS. The southern distinct population segment (DPS) of North American green sturgeon (*Acipenser medirostris* Ayres) was listed as “threatened” by NOAA Fisheries under the Federal Endangered Species Act (ESA) in 2006. Three years later, in May, 2009, NOAA Fisheries proposed a ruling to apply “take” provisions for this population. Green

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[1] This Introduction is partially based on prior project documents, including the project Concept Proposal, drafted by Chris Werme, an independent consultant, and the SFEI response to the project RFP

[2] Agency participants include the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NOAA Fisheries), the California Department of Fish and Game (CDFG), the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (EPA), Bay Conservation and Development Commission (BCDC), State Water Resources Control Board (SWRCB), and other local agencies. Stakeholder participants include dredging contractors, municipalities and private entities that perform dredging activities, and private and public entities that procure dredged sediments for habitat restoration and other beneficial reuses.

sturgeons outside of the Bay-Delta region have also suffered population declines. For example, they are listed as “rare” in Canada (Moyle 2002).

Less research has been conducted on longfin smelt, though CDFG survey data indicate that the longfin smelt has declined substantially since the 1980s (Rosenfield and Baxter 2007, California Department of Fish and Game 2009). In January 2009, the California Department of Fish and Game (CDFG) listed longfin smelt as “threatened” under the California Endangered Species Act (California Department of Fish and Game 2009).

The California ESA (CESA) is very similar to the federal ESA in many ways (e.g. the listing process and the definition of take) although there are some differences. The state ESA protects only species and limits “take” within the boundaries of the state, while the federal ESA also protects distinct populations and can limit take within a defined area of critical habitat for the population. CESA is more stringent than the federal ESA in two key ways: 1) while species are on the candidate list, they are afforded full protection of a listed species and take is prohibited, and 2) full mitigation for take is required for listed species. This means that under the CESA, if an activity would result in the take of 10 fish, an action that would improve conditions to replace those 10 fish (through habitat improvement, for example) is required.

Previous reviews identify multiple probable threats to longfin smelt and green sturgeon populations in California, including reduction in Delta outflows, entrainment via water diversions, elevated water temperatures, climatic variation, exposure to toxic substances, predation, poaching, and both direct and indirect effects due to invasive species interactions (Moyle 2002, Adams et al. 2007). The relative impacts of these multiple factors on survival and recruitment of green sturgeon and longfin smelt, and the relationships of these factors to dredging activities have received little attention.

Green sturgeon are at further risk of population declines due to their long life span, late maturity, reduced habitat size, and loss as bycatch. Their life history and late maturity mean that the loss of even a few spawners could be harmful to the population. Green sturgeon are often caught as bycatch during recreational and commercial harvesting of white sturgeon (Adams et al. 2007). Risk to the Sacramento River green sturgeon population is particularly severe compared to that of the Northern DPS in the Klamath River basin, as spawning areas above water diversion dams are now inaccessible, when historically sturgeon may have been able to access the entire Sacramento River system upstream of dams (including tributaries such as the McCloud, Pit and Feather Rivers; Adams et al. 2007).

The recent changes in listing status of green sturgeon and longfin smelt to “threatened” are important to LTMS participants. This new, more protected status has implications for dredging operations and dredged material placement. Millions of cubic yards are dredged from San Francisco Bay annually to maintain the navigation channels needed to support the shipping industry and recreational boating activities. Potential direct effects of dredging on fishes include interference with egg attachment, fertilization, or respiration; exposure to chemical contaminants in suspended sediments; entrainment; effects to survival and movement through multiple life stages; and behavioral impacts on adult spawning activity (Wilber and Clarke 2001). Dredging can also affect fishes by indirect mechanisms - intermediate pathways resulting from ecosystem changes or human activities. For example, large commercial vessel activity is facilitated by maintenance of navigational channels. These vessels can be vectors for species introduction, and can injure fishes or disturb their movements or behavior.

Given the threatened listing status of these species, and concern about their long-term population viability, there is a need to review and synthesize the latest knowledge on their population biology and management.

4. GREEN STURGEON

4.1. *Management history and current state of knowledge*

In May 2009, NOAA-Fisheries formally adopted "take" provisions for the threatened southern district population of the green sturgeon (Federal Register Volume 74, Number 97, available at http://www.nmfs.noaa.gov/pr/pdfs/fr/fr74-23822.pdf). This population segment includes the San Francisco Estuary. The recent provisions prompt an additional need for information about potential adverse effects that dredging activities may have on the species and possible ways to avoid or minimize those effects.

Critical habitat for this species has been designated by NOAA Fisheries. Critical habitat includes the San Francisco Bay and Delta, the Sacramento River, and waters off the coastline from Monterey Bay to the Strait of Juan de Fuca (Figure 4.1). Brian Ross (EPA) and Ellen Johnck (Bay Planning Commission) opened the symposium with discussions of the need to develop new strategies for the green sturgeon. Protection of green sturgeon presents a new challenge to stakeholders because 'take' of this year-round Bay resident cannot easily be avoided through designated work windows, unlike many other protected species (David Woodbury, NOAA Fisheries). Stakeholders, including Len Cardoza and Jay Ach, agreed that new strategies and more clear directives are needed to help them fulfill their responsibilities to both comply with the Endangered Species Act (ESA) and conduct business, which includes periodic dredging. In particular, stakeholders expressed a desire for clearly defined, predictable regulatory requirements. Such requirements will enable the stakeholders to meet their ESA responsibilities and continue to conduct maintenance dredging to provide uninterrupted commercial navigation.

Cynthia Fowler (USACE) described the types of hydraulic and mechanical dredges that are routinely used in San Francisco Bay. She also provided an overview of the many ongoing dredging projects in the Bay. Dredged sediment is generally disposed of by one of four methods: 1) disposal in one of four in-bay sites; 2) re-nourishment of shorelines; 3) reuse for restoration projects; or 4) disposal in an offshore disposal site in the Pacific Ocean approximately 50 miles offshore of San Francisco. She described dredging as a "moving target" – the exact sites and projects may change each year depending on shoaling patterns, climatic variation, and available funding. Her maps summarized the diverse range of locations of dredging and dredged materials placement activity (Figure 4.2).

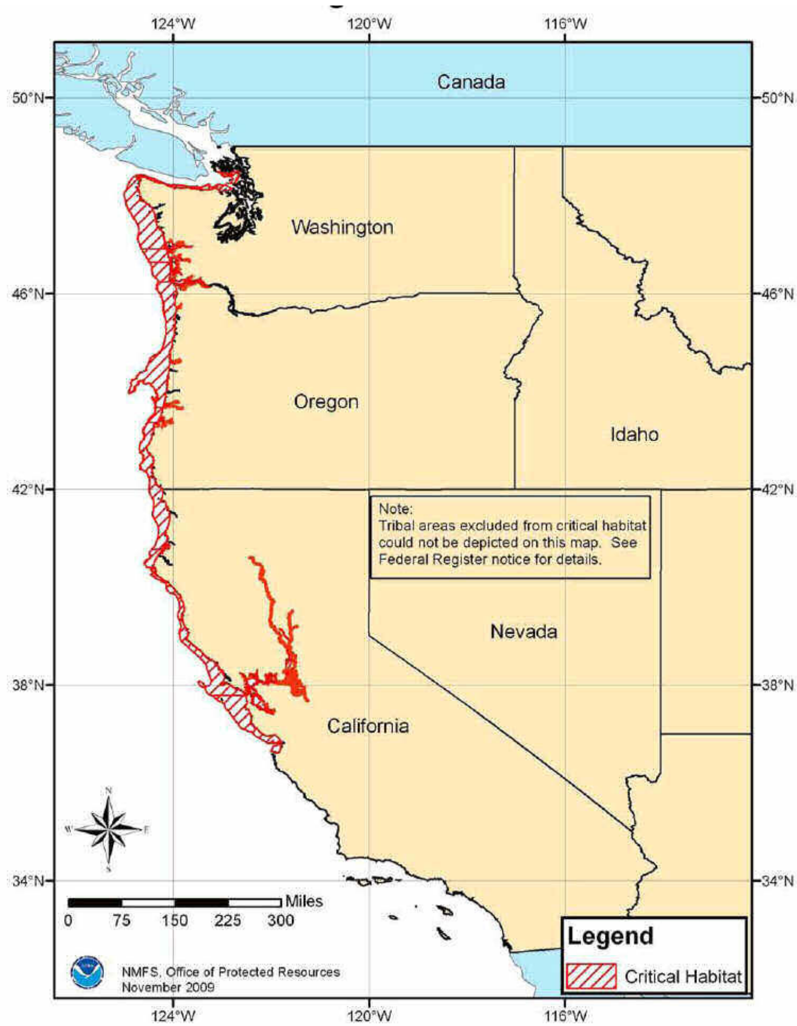

Figure 4.1. Critical habitat for green sturgeon extends from portions of Puget Sound, Washington, southward to Monterey. It includes the San Francisco Bay-Delta region and the Sacramento River and selected tributaries (NOAA Fisheries).

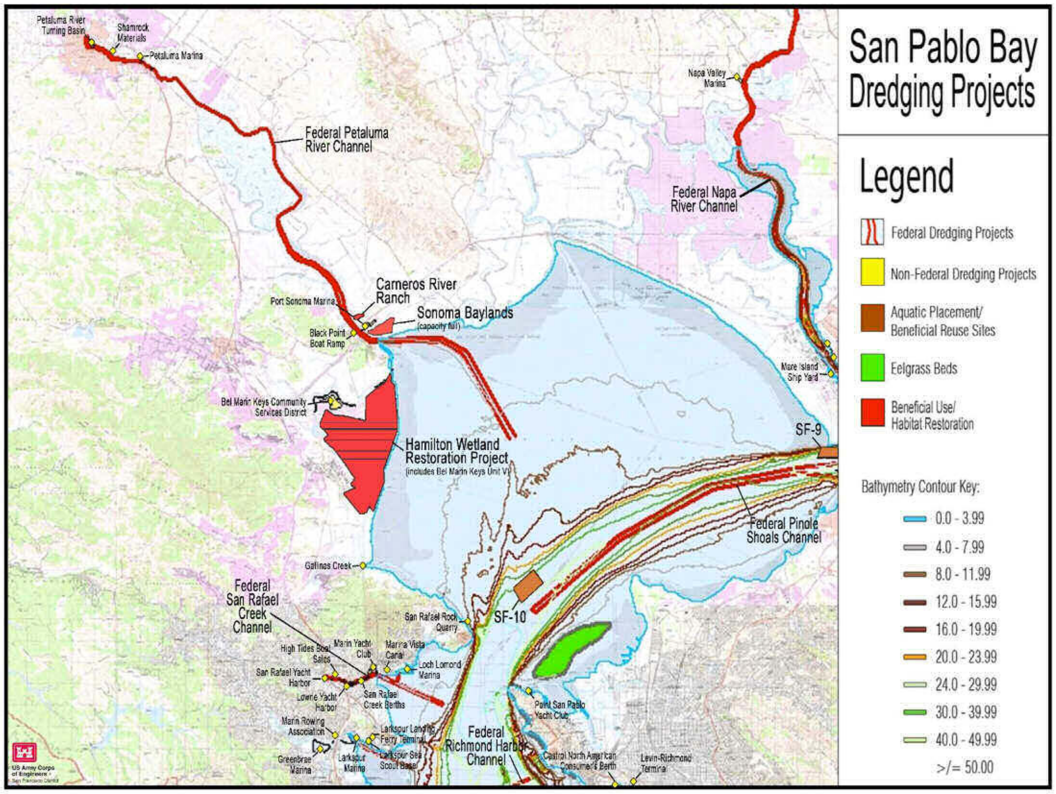

Figure 4.2. Current (2008) dredging activity and dredged material placement in San Pablo Bay (Fowler). This is one of many graphics with detailed information regarding dredging activities and dredged material placement throughout the San Francisco Estuary. The database is based on a Geographic Information System (GIS), and is available through the USACE.

4.1.1. **Green sturgeon biology and ecology**

Dr. Josh Israel (UC-Davis[3]) presented the current state of research on green sturgeon. Green sturgeons spend much of their adult lives in coastal oceans, returning to estuaries beginning in late February to spawn (Figure 4.3). They move rapidly upriver during early spring flows, spending weeks to months in the Sacramento River (below the Shasta Dam) where they broadcast spawn into river benthos. Larvae drift slowly down river, maturing to live in the Bay and Delta for between one and four years before entering the coastal oceans. This period remains poorly understood and individuals vary in their time of residence within the Estuary.

[3] Current affiliation is U.S. Bureau of Reclamation

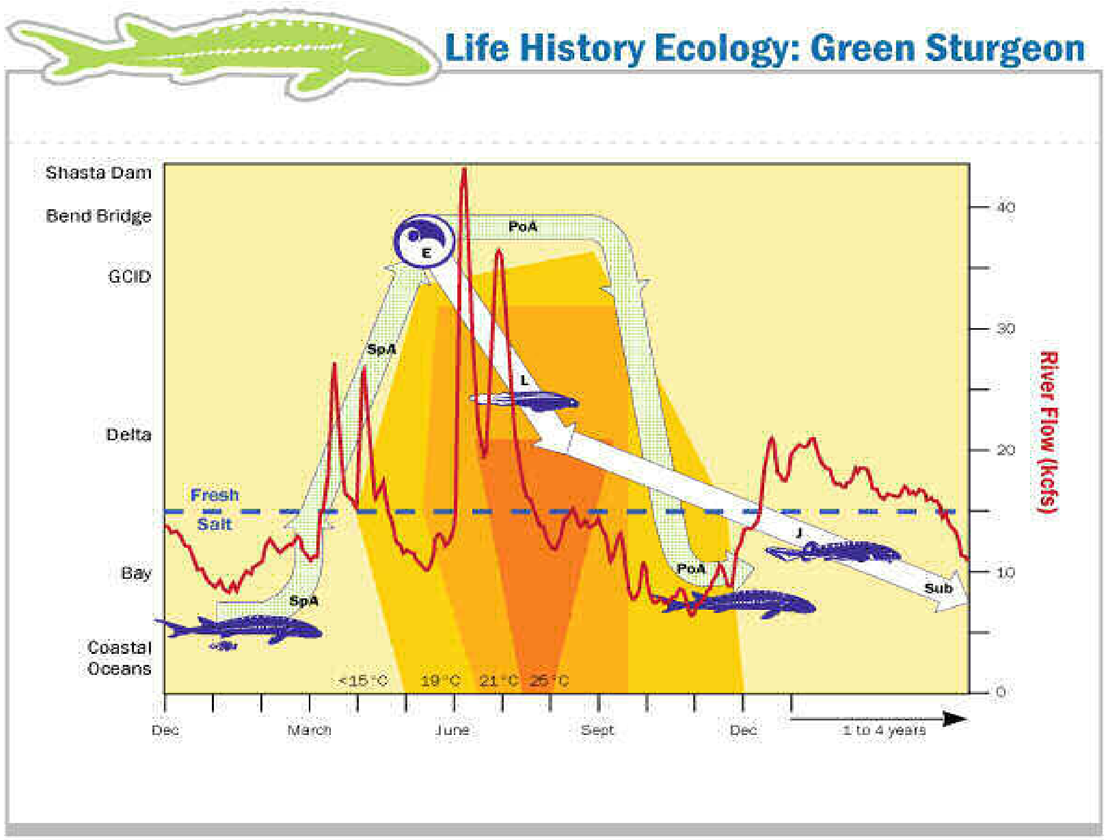

Figure 4.3. Green sturgeon life history corresponds with river flow and salinity. Adult sturgeon move upstream to spawn periodically (every 1 to 4 years) during large spring flow events. Larval sturgeon move downstream, and develop into juveniles in brackish estuarine conditions (Israel).

Dr. Peter Klimley (UC-Davis) tracked movement patterns of sub-adult and adult green sturgeon, finding that there are two different types of movement: highly directional migratory movements, which often occur close to the surface and within channels; and non-directional movement along the bottom, which can occur in both deep water channels and shoals. This non-directional movement is speculated to be foraging activity. Both of these behaviors could put sturgeon at risk from dredging as newly dredged channels may impact within-channel migration, and direct entrainment and sediment disturbances could interfere with feeding near the bottom.

Alex Hearn (UC-Davis) contributed information from his tracking study of 300 adult sturgeon, which revealed a wide variety of behaviors. Sturgeon were detected in both shallow nearshore areas and channels, and returned upstream to spawn at time intervals ranging from one to three years. He indicated that green sturgeon were more concentrated near the Golden Gate in the summer, while in winter they were distributed more widely throughout the Estuary. He also found that while some of the tracked fish did visit four dredged sites, cumulative duration of site visits (per fish) ranged from less than 30 minutes to just over four hours.

Mike Thomas (UC-Davis) contributed additional research from active tracking of three juvenile green sturgeons. He found that all of the fish used the deep water shipping channel, but also spent significant time outside of the channel, and may have shown preference for non-deep water channel habitats.

Mike Parsley (USGS) presented research describing the use of a fine-scale positioning system to monitor movements of white sturgeon in the Columbia River in areas where dredging operations occur. He described a pattern of daily vertical migrations in white sturgeon, as fish moved from deeper waters during the day, typically within the navigation channel, to shallower waters outside of the navigation channel at night. His analysis of the movements revealed that white sturgeon preferred areas with some bedform habitat for feeding, possibly because this rough surface can provide current breaks within a high energy environment. He also divided white sturgeon individuals into two categories, based on dispersal tendencies, which he referred to as the "homebodies" and the "nomads." Homebodies tend to remain within a limited area over time and so could potentially be more disturbed if forced to move by a dredging operation. Nomads spent little time in any one area and thus may be more resilient to localized disturbance.

4.1.2. **Impacts of dredging**

Speakers presented the current state of knowledge on the impact of dredging on green sturgeon, explaining that much is still unknown (Table 4.1). Speakers varied in their rating of the relative importance of potential dredging impacts, and emphasized the need to differentiate between the impacts from dredging for maintenance versus dredging for new projects (such as channel deepening). There are a range of potential direct and indirect impacts, including the following:

<u>Direct effects</u>

- Hydraulic entrainment
- Contaminated sediments
- Sediment resuspension (turbidity) and sedimentation
- Underwater noise
- Change to habitat - bed leveling

<u>Indirect effects</u>

- Impact on prey base
- Ship propeller strikes
- Invasive species introductions from change in shipping patterns (supported by disturbance from dredging)

Doug Clarke (USACE) outlined two major factors to consider in assessing risk of direct entrainment, which were the rate of encounters and the rate of detrimental outcomes from encounters. Encounter rate is a function of the spatial distribution and temporal frequency of dredging activity, and the spatial and temporal movement patterns of sturgeon. Rate of detrimental outcomes upon encounter depends on the avoidance and escape behavior of the fish (Figure 4.4). Josh Israel (UC-Davis) similarly identified three specific fish behaviors that would impact risk from dredging: orientation of fish in current, time to fatigue, and position in the water column. Understanding fish behaviors such as swimming capacity and tendency to swim into or away from the current (for green sturgeon) would help us assess risk.

Tracy Collier (NMFS) discussed the potential for contaminated sediments to cause direct impacts to fish via liver disease, impaired reproduction, loss of immune system function, and reduced growth. He suggested that there are contaminant thresholds above which the proportion of individuals affected greatly increases (e.g., impacts to flatfish increase at 1000 ng/g dry weight PAHs). Developmental effects could be of particular concern for green sturgeon because they produce eggs with unusually large, fatty yolks, which could pass on high concentrations of contaminants from mother to offspring. Additionally, elevated contaminants could indirectly affect green sturgeon by changing prey biomass and abundance. Some fish (e.g., flatfish, Pacific herring, shiner surfperch, staghorn sculpin, and Sacramento splittail) currently exhibit toxicological responses at environmentally relevant concentrations.

Andrew Cohen (Center for Research and Aquatic Bioinvasions [CRAB]) reviewed potential mechanisms by which dredging activities may lead to exotic species impacts on green sturgeon. Navigational maintenance dredging and development of new navigational channels maintains the ability for commercial vessels from distant ports to utilize San Francisco Bay ports, and this shipping activity can result in the introduction of organisms carried in the water in ballast tanks and sea chests[4], or attached to vessel hulls. Dredging activities may also disturb local environments in ways that make it easier for exotic species to become established. Impacts on green sturgeon could arise through predation, competition (such as from exotic sturgeon species introduced as eggs or larvae in ballast tanks or sea chests), alteration of food webs (a recent example of such alteration in the Bay being from the Asian clam *Corbula amurensis*, introduced in ballast water), changes in contaminant pathways (such as selenium accumulated in *C. amurensis* and ingested by sturgeon), introduction of diseases or parasites (including fish viruses that can be carried in ballast water), introduction of harmful, bloom-forming algae, or by fouling of fish passage or salvage facilities (such as by Chinese mitten crabs, zebra or quagga mussels, or the ecological similar golden mussel from Asia, all of which have been introduced across oceans in ballast water).

Propeller strikes are another potential indirect impact to green sturgeon. As with exotic species, dredging to maintain and develop navigational channels enables large commercial vessels to enter the Estuary. As larger, higher powered vessels enter San Francisco Bay, the risk of propeller strikes may increase. Doug Clarke (USACE) found trauma in 2% of fish caught in an entrainment study on the Mississippi River. Like San

[4] Sea chests are ship compartments that are located immediately inside a cargo ship's hull. They receive water passively from the ocean through slotted holes 1-2 cm wide, which is then pumped to the ballast tanks. Small fish and other organisms have the potential to move freely between sea chests and the surrounding water. The transport of organisms in sea chests is not directly regulated, and most mechanisms used or proposed for reducing the transport of live organisms in ballast tanks would have little or only limited effect on organisms traveling in sea chests (Cohen).

Francisco Bay, the Mississippi River is a system where stakeholders must balance the needs of shipping and of protecting native finfish.

Mike Parsley (USGS) discussed research on the response of white sturgeon to dredging operations. In particular, the fish did not disperse during dredging operations, but became more active. This increased activity could have resulted from either stress or increased foraging activity. Parsley and colleagues also found that white sturgeon remained in a disposal site throughout a several hour sediment disposal operation.

Stephania Bolden (NMFS) discussed her work with Atlantic sturgeon in Florida, and identified modification of critical habitat as the most pressing concern. She noted that the type of dredge made a difference in entrainment rates. Hopper dredges generally resulted in the most take, and clamshell the least. Ms. Bolden pointed out that even clamshell dredges resulted in some mortality to sturgeon, though the rates were relatively low.

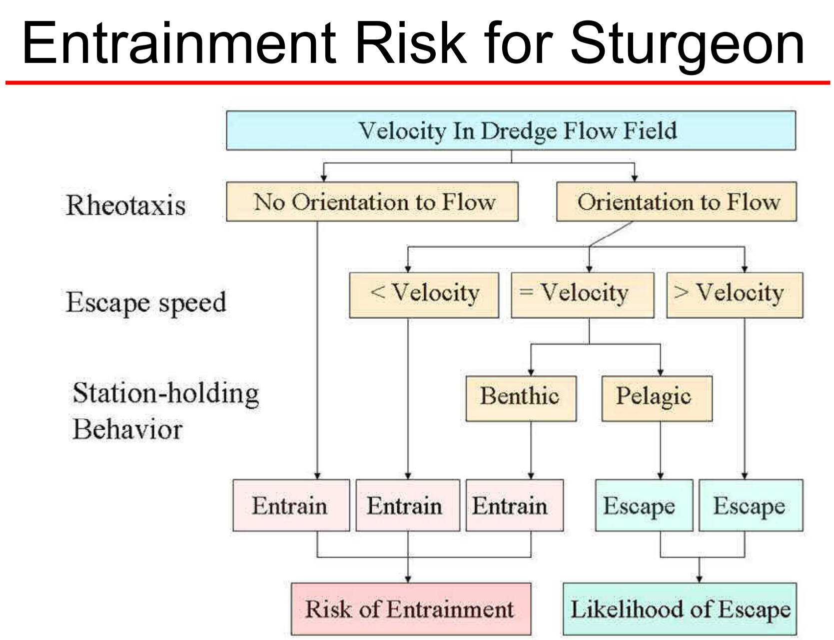

Figure 4.4. Flowchart conceptual model of entrainment risk for sturgeon (Clarke). Entrainment risk will differ and may be modeled depending on rheotaxis (orientation towards current), escape speed, and station-holding behavior.

Table 4.1. **Types of potential dredging effects on green sturgeon, current knowledge regarding effects, and potential future studies that will provide more information about the effects.**

Effect	Current knowledge	Potential future studies
Direct entrainment	Entrainment rates appear to be generally low	Direct assessment of entrainment rates, particularly for different dredging types. Chamber studies on swimming capacity and current orientation patterns, extrapolated with entrainment models to assess risk
Contaminated sediments	Sediment contamination is elevated in some regions of the Bay. Some fish species exhibit toxicological responses at environmentally relevant concentrations. There is the potential for sturgeon to pass on high levels of contaminants to young	Specific vulnerability of sturgeon in different life stages to sediment contamination
Sediment resuspension	Sturgeon appear to be undisturbed by high concentrations of naturally-produced suspended sediment. Therefore, adverse effects of sediment resuspension are unlikely	Assess impact of suspended sediment resulting from dredging (may have high levels of ammonia or hydrogen sulfides). Lower priority for this species
Underwater noise	Little known	Chamber studies on behavioral response to sonic exposure, e.g., using sound exposure as a management tool to disperse sturgeon and reduce direct entrainment
Change to habitat (bed leveling)	Sturgeon may prefer deepwater habitats, or inhabit both deepwater and shoals. Habitat modification could interfere with daily vertical migrations, and result in loss of bedform habitat structural complexity	Habitat preference studies, including synthesis of current tracking data to infer habitat preferences. Habitat assessment studies to identify important areas
Impacts to prey base	Introduction of invasive species or contaminated sediments could harm prey base	Dietary studies on prey base; impact of dredging alteration to prey production areas
Ship strikes	Multiple fish species in other regions encounter ship propellers, sometimes resulting in mortal injury. Risk may increase with higher powered vessels. Substantial commercial boating activity (e.g., cargo shipping) presents a potential hazard of ship strikes	Specific risk to green sturgeon. Methods could include net deployment behind commercial vessel propellers, though these studies are difficult to perform
Increased introduction of invasive species	Possible negative impacts through introduced parasites and competitors	Methods of reducing species invasion, including management of sea chests
Impact on larval and juvenile life stages	Little is known about the behavior of very young sturgeon and susceptibility to dredging impacts	Not known – larval stages not likely present in SF Bay

4.2. ***Concerns of stakeholders***

A stakeholder panel expressed concerns and engaged in discussion with the scientists and regulators regarding the ongoing challenges of managing dredging with green sturgeon. The panel was composed of Anne Whittington (Port of Oakland), Len Cardoza (Weston Solutions), David Woodbury (NOAA Fisheries), and Tom Gandesbery (State Coastal Conservancy). Stakeholders in the dredging community expressed concerns about the impacts of the recent listing of green sturgeon on commerce, recreation, and jobs. They emphasized that to effectively plan and run their businesses, dredgers need to know what they must do to minimize and mitigate impacts on green sturgeon. Stakeholders are interested in exploring other solutions for this species. Adding an additional work window to the already complicated system of overlaid work windows would be challenging. They also expressed interest in a larger programmatic solution that could take both industry needs and the needs of the species into account. Lastly, stakeholders discussed the need for continued and improved communication between resource and federal agencies and permit applicants.

4.3. ***Future research and recommendations***

During presentations and scientist discussion, several suggestions for future research relevant to dredging operations emerged. These recommendations focused on gathering information to enable modeling of the green sturgeon life history and the impacts of dredging on this life history. This would allow managers to identify the most important impacts and effective forms of mitigation for sturgeon. Conceptual models such as those developed by DRERIP (Delta Regional Ecosystem Restoration Implementation Plan) could be helpful for prioritizing research on factors limiting recovery of green sturgeon populations (Figure 4.5). For example, if exposure of fish eggs and larvae to pollutants impacts the population disproportionately, ESA mitigation actions may focus on reducing such exposure.

Panelists recommended studying basic aspects of sturgeon life history and ecology that could affect risk from dredging. They also recommended further evaluation of the relative risk associated with specific dredging impacts. Basic study recommendations included:

1. *Additional study of juvenile life history and migrations.* Little is known about juvenile movement, distribution, and consequent potential exposure to direct hazards from dredging and other human activities. Such studies are technically difficult because of the relatively small size of juveniles, and low abundance in comparison to other species.
2. *Behavioral studies to indicate frequency and hazard of dredging exposure.* Evaluation of fish behavior was identified as a means to better estimate the encounter rate and probability of adverse impacts upon encounter. A better understanding of feeding patterns and habitat preference (e.g., deepwater channels vs. shallow shoals) would aid in determining the likely frequency of dredge encounters. The potential for entrainment or injury could be evaluated based on time to fatigue and on fish orientation and position in the water column

(rheotaxis). These factors could be combined into quantitative models to estimate the expected rate of entrainment and other direct dredging impacts.

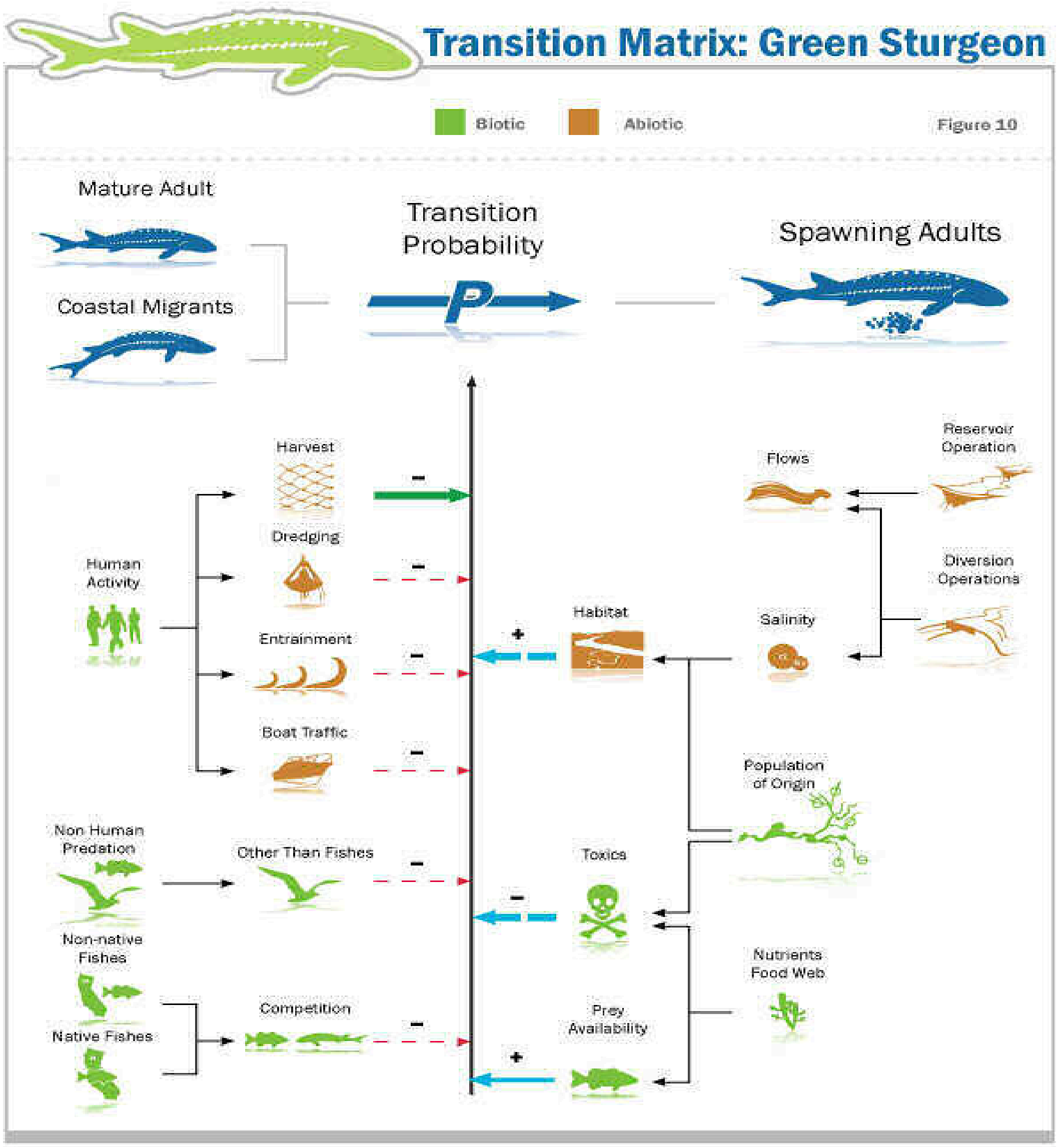

Figure 4.5. Transition matrix showing factors affecting survival for green sturgeon (Israel). Dredging is listed as one of four direct impacts of human activity (upper left) that may impair successful spawning. Understanding of the impact of dredging and other factors is limited, as indicated by red dotted arrows.

The Science Panel indicated that the following potential threats merit study and comparison to determine relative risk:

1. Direct entrainment from dredging, including comparison among dredging types
2. Ship and propeller strikes
3. Impact of invasive species

4. Impact of toxic chemicals and level of chemical contamination
5. Habitat modification
   - Effect of alterations to benthic community on juveniles
   - Impact of altered channels on migration patterns – green sturgeon appear to use deepwater channels for migration
6. Interaction of green sturgeon with dredging sites
   - Research on a few individuals indicates that fish pass through dredging sites quickly (Hearn), though additional data would be useful to determining if this is true of the larger population
   - Fish appear to use shipping channels (Thomas), but it is unclear if they show a preference for shoal habitats

Finally, some suggested action items for LTMS included the following; however, prioritization of these topics was not addressed[5]:

1. Consider developing limited work windows. There is some research showing green sturgeon move further downstream towards the central Bay in winter (Hearn), move to deeper water in daytime (Parsley), and may seek constant water temperatures. All of this information could be used to develop a new type of work window.
2. Consider the importance of using correct dredging techniques to minimize impacts on green sturgeon, e.g. prevent dredge draghead from losing contact from bottom.
3. Reconsider sediment deposition and the many potentially productive uses for dredged sediment.
4. Ensure that deposition is not destroying green sturgeon habitat, e.g., consider spreading thinly, over time, and away from key habitats (Bolden).
5. Regulate sea chests to control invasive species.
6. Investigate methods to move fish out of an area of interest using nets or sounds before dredging (Bolden).

[5] The need for future activities to prioritize among and critically evaluate these suggestions is discussed in Section 6. Next Steps.

5. LONGFIN SMELT

5.1. *Management history and current state of knowledge*

Longfin smelt (*Spirinchus thaleichthys*) is an estuarine, anadromous species. On March 4, 2009, the California Department of Fish and Game (CDFG) listed the longfin smelt as threatened under the California Endangered Species Act (CESA; Fish and Game Code §§ 2050 et seq.). The U.S. Fish and Wildlife Service has thus far declined to list the San Francisco Estuary population of longfin smelt. In November 2009, a suit was filed by the Center for Biological Diversity, The Bay Institute, and the Natural Resources Defense Council to challenge the federal decision not to list longfin smelt. The Fish and Wildlife Service is currently reviewing available information to re-evaluate whether listing is warranted (Rosenfield). As with the green sturgeon, research on this species has been limited up to the present.

Ellen Johnck (Bay Planning Coalition) opened the symposium with her observation on the challenge and importance of developing a new management strategy for a threatened species. Jennifer DeLeon (CDFG) provided background information on the state listing process and legal status of longfin smelt. She emphasized that more clarity will come with time as scientists and regulators develop a better understanding of longfin smelt.

5.1.1. **Longfin smelt biology and ecology**

Jonathan Rosenfield (The Bay Institute) and Randy Baxter (CDFG) presented information on the life history of longfin smelt. The San Francisco Bay is at the southern extremity of the spawning range for longfin smelt, which extends from San Francisco Bay to Prince William Sound, Alaska (Figure 5.1). Historically, this species was found in three estuaries in California: the San Francisco Bay-Delta Estuary, Humboldt Bay, and the Klamath River Estuary. At this time, the largest and southernmost self-sustaining longfin smelt population is in the San Francisco Bay-Delta Estuary. It is likely that the two northern populations are extinct, and other locations, such as the Russian River, do not support a self-sustaining population.

Longfin smelt spawn and die in their second year, creating two reproductively distinct populations within any given region. They spawn at the interface between fresh and brackish water, likely between December and March. Spawning sites distribute around X2 (defined as the distance between the Golden Gate and where the low salinity (2 ppt) zone starts), shifting upstream and downstream with the change in freshwater inputs from the Delta. Young exist as yolk sac larvae for one to two weeks, moving downstream with the current.

As adults, longfin smelt occupy much of the Bay but appear to limit their distribution to between Suisun Bay and Central Bay in the summer, perhaps due to temperature. More research is needed on habitat preferences, but longfin smelt appear to be more abundant in deepwater channels than shoals.

Dr. Jim Hobbs (UC-Davis) presented research showing that smelt larvae appear to use depth in the water column to stay in the moderately saline productive zone associated with X2 (Figure 5.2). Historically, this positioned the larval smelt in areas of high productivity and food availability. Modern-day changes to the Delta appear to have impaired their ability to reside in these conditions.

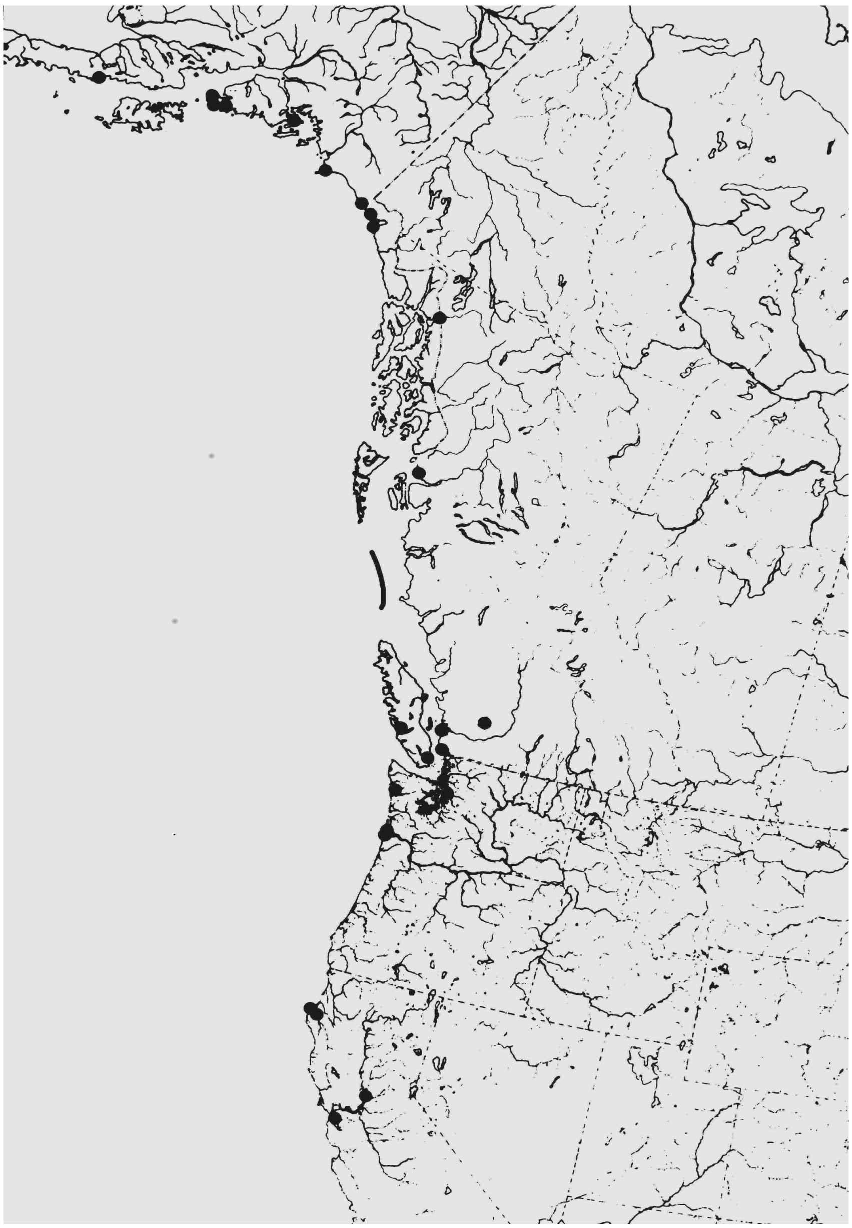

Figure 5.1. The historic spawning range of longfin smelt extends from San Francisco Bay to Prince William Sound, Alaska (Rosenfield)

Due to hydrological modification of the Delta and Central Valley watersheds, decreased freshwater flows have moved the fresh-salt interface upstream to shallow, narrow reaches. This has reduced stratification, consequently reducing the ability of longfin smelt to control position by vertical movement in the water column. In another study using otolith biochemistry, Dr. Hobbs found that between 2000 and 2007, surviving smelt occupied a narrower range of salinities, and were restricted to more saline waters. This indicates that longfin smelt habitat has been dramatically reduced.

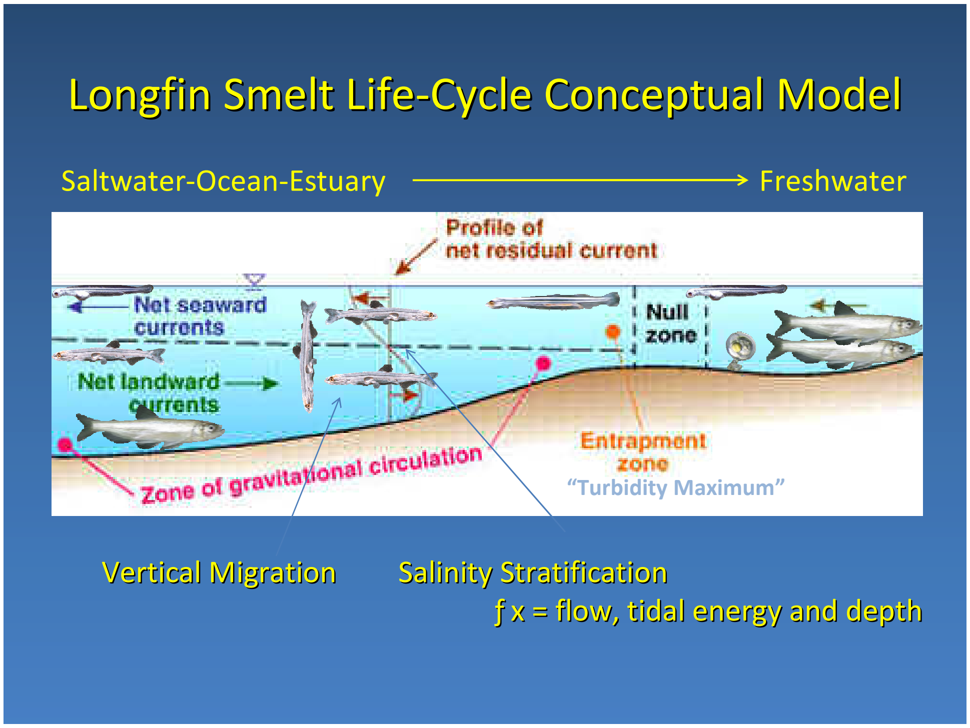

Figure 5.2. Jim Hobbs' longfin smelt life-cycle conceptual model indicates that larval fish perform vertical migration on a tidal current cycle to maintain position near the entrapment zone, an area of high productivity and food availability.

Dr. Josh Israel (UC-Davis) presented preliminary research comparing genetic information for longfin smelt in Lake Washington (Seattle, WA) and the Bay-Delta. He found that although the majority of the variation was within rather than between the populations, it was possible to match an individual to the correct population. These findings suggest that the two populations are genetically distinct. Further confirmation of these findings could help to determine that the San Francisco Bay population is a distinct population, which may result in a Federal decision to list the population.

5.1.2. Impacts of dredging

Although dredging can have both direct and indirect effects on longfin smelt, studies to date have focused on entrainment and other direct effects only. Several participants indicated that indirect effects, such as invasive species and harm by commercial vessels, should also be considered (Table 5.1). Whereas most potential effects were described as negative, increased turbidity may have a positive effect on longfin smelt. Specifically, Dr. Hobbs found a higher density of longfin smelt in more turbid waters. This finding suggests that longfin smelt appear to seek refuge from predators in turbid waters. Dr. Hobbs also discussed the potential for new dredging projects to change hydrodynamics and habitat. Longfin smelt may be particularly sensitive to changes in hydrodynamics, as they appear to use channel depth and the pattern of water flow through a channel to maintain position near the entrapment zone (Figure 5.2). Substantial channel deepening could conceivably increase stratification and consequent ability of longfin smelt to maintain position by vertical migration.

Brian Swedberg and John Zentner (Port Sonoma) and Jordan Gold (Mari-Gold Environmental Consulting) presented two studies that measured the impact of direct entrainment by hydraulic dredging on native fishes. In 2007, Mr. Swedberg and Mr. Zentner filtered 65,000 cubic yards of dredged material from the Port Sonoma project at the mouth of the Petaluma River. While large numbers of longfin smelt were caught in the area when trawling for shrimp (establishing presence), no longfin smelt were found in the dredged sediment in 2007. Ninety-nine percent of fish caught were non-native gobies, with 15 native fish caught in total. Mr. Swedberg and Mr. Zentner emphasized the importance of correct dredging technique - one longfin smelt was entrained in 2006 while the dredge head was running above the sediment surface. Correct technique could have prevented entrainment of that fish.

Mr. Gold described deepwater channel dredge monitoring work performed for Ross Island Sand and Gravel Co. (subcontractor to USACE). For this program, situated in the Delta, he conducted both fish community sampling and dredge entrainment sampling. Between 2006 and 2009, longfin smelt was the most common native species encountered in community sampling. Of 32,067 individual fish from 32 species, 918 longfin smelt were caught. In 2006, 895 of the longfin smelt captures came from a dredge site near Rio Vista. Since then, two longfin smelt were captured in 2007, 21 in 2008, and zero in 2009[6]. Although the program only samples fish at dredge sites, it is likely that the elevated capture in 2006 resulted from a relatively high abundance of young of year fish, resulting from high river outflow (Figure 5.4). Mr. Gold hypothesized that the reduced catch between 2007 and 2009 could also result from decreased dredging in the lower reaches of the rivers and a shortened work window, compared to 2006 (and therefore less overlap between dredge activity and smelt distribution).

Mr. Gold also performed an entrainment study using a custom-built entrainment screen. In this study, 725 fish of 15 species were captured. The majority of the catch was composed of non-native species including shimofuri goby, channel catfish, and white catfish. No longfin smelt were captured. In combination with the Port Sonoma study, these findings suggest very low rates of longfin smelt entrainment due to hydraulic dredging.

[6] By comparison, two green sturgeon were captured, both in 2006.

Table 5.1. Types of potential dredging effects on longfin smelt, current knowledge regarding effects, and potential future studies that will provide more information about the effects.

Effect	Current knowledge	Potential future studies
Increased turbidity	Potential preference for turbid waters; might provide protection from predators, but may impair feeding	Although negative impacts of turbidity are uncertain, smelt preference for turbid waters suggests that turbidity studies may be a relatively low priority
Change in hydrodynamics	May disrupt or improve habitat, particularly for young of year smelt that rely on tidal stratification to maintain position (Figure 5.2)	For large new dredging projects in primary habitat for young of year smelt, hydrodynamic modeling studies could be performed to determine effects of bottom change on stratification and tidal flow
Direct entrainment	Extremely low direct entrainment from hydraulic dredging	Additional studies on entrainment rates, particularly for different dredging types. Evaluating use of clamshell dredging as mitigation activity resulting in reduced entrainment
Effect on larvae	Nothing known due to relative difficulty of studying larvae	Inclusion of larval sampling in entrainment studies. Modeling studies to evaluate potential for larval entrainment
Increased introduction of invasive species	Potential negative impact, as evidenced by step decline in abundance after introduction of *Corbula amurensis* (Figure 5.4)	Evaluation of mitigation activities to reduce species invasion from large vessels
Contaminated sediments	Sediment contamination is elevated in some regions of the Bay. Some fish species (e.g., flatfish, Pacific herring, shiner surfperch, staghorn sculpin, and Sacramento splittail) exhibit toxicological responses at environmentally relevant concentrations. However, longfin smelt spend little time at the sediment surface, likely resulting in limited exposure to sediment contamination	Not a high research priority for this species
Underwater noise	Little known	Chamber studies on behavioral response to sonic exposure. This includes the possibility of using sound exposure as a management tool to disperse smelt and reduce direct entrainment
Impacts to prey base	Introduction of invasive species could harm prey base	Dietary studies on prey base, including evaluation of use of introduced species
Ship strikes	Multiple fish species in other regions encounter ship propellers, sometimes resulting in mortal injury. Risk may increase with higher powered vessels. Substantial commercial boating activity (e.g., cargo shipping) presents a potential hazard of ship strikes	Specific risk to longfin smelt. Study methods could include net deployment behind commercial vessel propellers, though these studies are difficult to perform

5.1.3. **Other potential threats to longfin smelt**

The San Francisco Bay-Delta longfin smelt population size is clearly declining, and in fact is critically low (Rosenfield). There has also been a recent decline in the number of sites where longfin smelt were found during sampling. As population numbers decline, and perhaps because of this decline, the distribution is also becoming restricted in range. The panelists described three potential threats to the longfin smelt population, other than dredging: Delta outflow, invasive species, and changes in temperature.

Longfin smelt survival is highly correlated over time with winter river flows coming out of the Delta (Figure 5.3). Flow during the incubation and larval period is the most important predictor of the longfin smelt population size in any given year (Baxter).

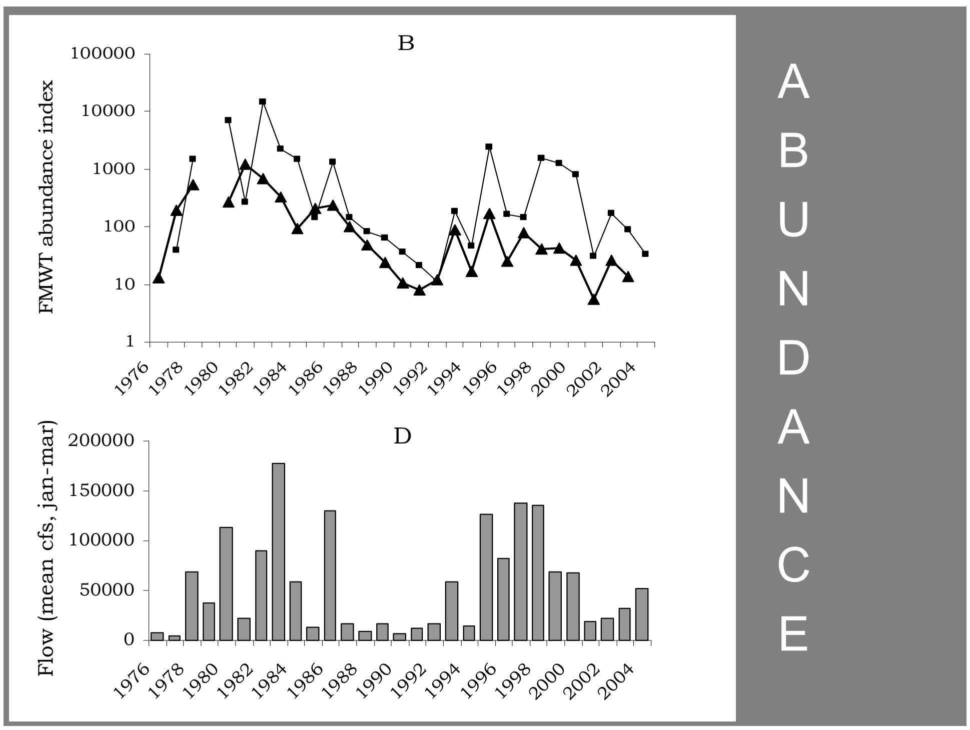

Figure 5.3. Abundance of longfin smelt population correlates positively over time with freshwater flows (Rosenfield)

Another significant impact to longfin smelt may be temperature. The thermal tolerance of longfin smelt has not been established, but seasonal migration away from hotter, shallower water in the summer suggests that high temperatures may be a stressor (Rosenfield, Baxter). At water temperatures above 20°C, populations appear to decline precipitously (Baxter). Participants discussed the possibility that populations in San Francisco Bay are declining because water temperatures may be slightly too warm, especially given that this is the southern extent of longfin smelt range. The lack of monitoring of other longfin smelt populations prevents scientists from making a comparison across populations.

Invasive species may also be contributing to the decline of longfin smelt. Randy Baxter (CDFG) hypothesized that the establishment of the invasive clam *Corbula amurensis* caused a step decline in the relationship between longfin smelt survival and freshwater outflows so that for a given flow volume fewer fish survived (Figure 5.4).

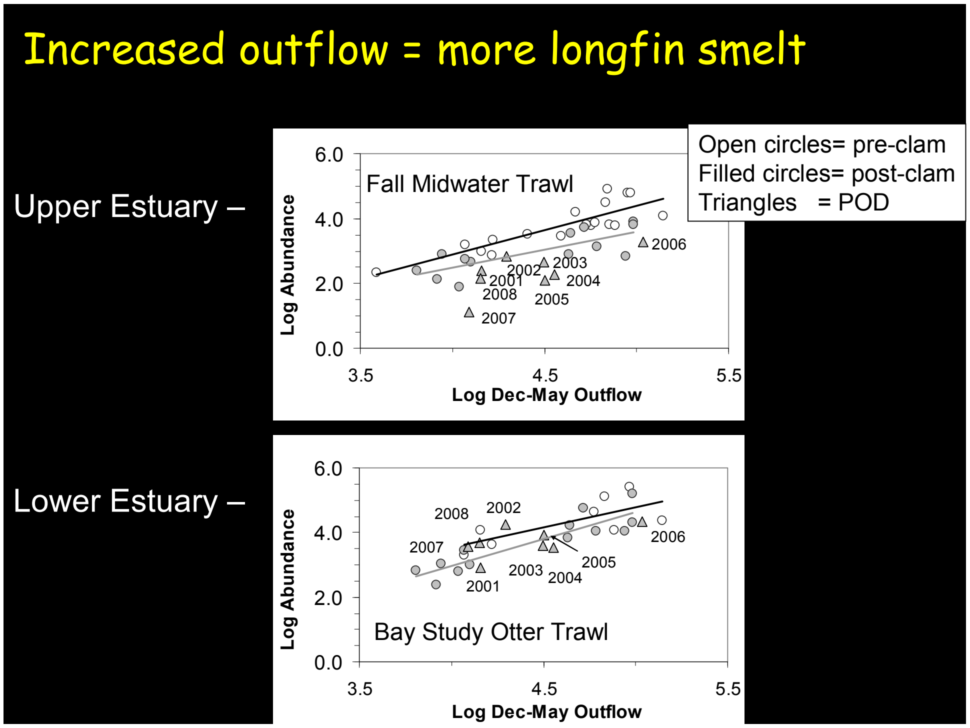

Figure 5.4. Longfin smelt abundance is correlated with winter Delta outflow. However smelt have been less abundant at a given outflow, since the invasion of *Corbula amurensis*. This is illustrated by the lower trend line (light line, grey symbols) since the invasion (Baxter).

5.2. *Concerns of stakeholders*

A panel of stakeholders identified concerns and engaged in discussion with the scientists and regulators regarding ongoing challenges of managing dredging and longfin smelt. The panel was composed of Anne Whittington (Port of Oakland), B.K. Cooper (Western Dock Enterprises), J.T. Wick (Port Sonoma), Jordan Gold (Mari-Gold Consulting), and Jon Rosenfield (The Bay Institute). Multiple stakeholders expressed frustration with the permitting system, current lack of knowledge, and lack of certainty regarding the true impact of dredging on longfin smelt. They described delays in permit approvals that left them with an extremely limited window to dredge. One dredging contractor expressed concern that this limited window forced his employees to work extended hours to complete all of the necessary dredging, and could pose a safety hazard. Attempts to minimize and mitigate for take were described, including a monitoring program that found only a single smelt entrained in a suction dredge, but did not result in a dredging application approval. Dredgers would like more specific guidance from the state on how to meet the requirements for mitigation and minimization. Other stakeholders also expressed frustration at the lack of guidance on meeting permitting requirements.

Stakeholders also expressed concern that dredging might be unfairly blamed for the decline in longfin smelt populations despite a lack of evidence connecting dredging to the decline of longfin smelt. They emphasized the need to look at other more significant threats. However, Bill Brostoff (USACE) noted that even minimal impacts become important if they are numerous enough.

In response to stakeholder concerns, Jennifer DeLeon (CDFG) emphasized that the stakeholders do have a lot of control in the permitting process because they can choose how to meet the standard. Permitting for a new species is an evolving process, and in time, standard concepts and procedures for longfin smelt will develop. She suggested that the future may lie in program-level permitting. She advised stakeholders that it might be more efficient to first minimize potential impacts to listed species through the California Environmental Quality Act (CEQA) process, before proceeding with applying for an incidental take permit required under the California Endangered Species Act (CESA). In some instances, mitigation measures employed for CEQA will reduce or eliminate the possibility of take, and save project proponents the time required to apply for an incidental take permit under CESA. Stakeholders should contact the regional manager (Scott Wilson for the Bay-Delta region, and Becky Ota for the marine region) for detailed advice on meeting the regulations.

5.3. *Future research needs, and potential solutions*

To protect longfin smelt, research is needed to identify the most significant threats. The research presented suggested that dredging results in very low levels of entrainment for longfin smelt, and that shrimp trawling and decreased freshwater flows may be greater threats. Future studies on effects of shrimp trawling, and possible management interventions seem warranted. There is also a need for ongoing monitoring to establish current population levels, preferred habitats, and potential impacts from dredging. Drs. Rosenfield and Hobbs emphasized the need to look at indirect impacts as well, including habitat modification resulting from dredging (Table 4.1). Dr. Israel suggested building a framework describing the different types of impacts and corresponding monitoring approaches (perhaps modeled after the approach used by Dr. Parsley for green sturgeon). Stakeholders and managers could use this to identify the important research priorities.

Dr. Israel discussed the potential of using real-time monitoring and management to more accurately track and avoid longfin smelt. However, as Dr. Rosenfield pointed out, this may have limited utility on a project by project level. It may be more useful to use research to build a more comprehensive picture of fish movements throughout the Bay, particularly in shallow regions. Real-time monitoring might be valuable for a large-scale project, but otherwise might not be the most cost-effective approach because it would not be applicable elsewhere (Baxter). Instead, a large-scale Bay-wide program might be more effective.

As with green sturgeon, future applied research should focus on developing effective management strategies for this species. Suggested directions for future research topics include the following; however, prioritization of these topics was not addressed[7]:

1. Identify required spawning micro-habitat.

[7] The need for future activities to prioritize among and critically evaluate these suggestions is discussed in Part 6. Next Steps.

2. Confirm whether longfin smelt in San Francisco Bay constitute a genetically distinct population from the Lake Washington population, which would provide a basis for federal listing.
3. Measure entrainment levels from clamshell dredging as compared to other methods to establish whether the type of dredging affects impact.
4. Measure and model impacts of channel deepening on vertical stratification and consequent vertical migration.
5. Monitor and model distribution of longfin smelt in areas that are not currently dredged or sampled. For example, develop a sampling program covering shoreline habitat across the axis of the Bay in order to increase understanding of longfin smelt use of shallow areas. Use of this habitat is currently poorly understood.
6. Develop methods to understand and measure indirect impacts of dredging on longfin smelt, including invasive species and harm by large vessels, including propeller strikes.
7. Evaluate impacts not related to dredging, such as:
    a. Global warming
    b. Change in salinity levels and freshwater outflow
    c. Shrimp trawling and other non-dredging forms of take

In addition to research, participants identified the need for greater collaboration and communication between dredgers, regulators, researchers, and the CDFG. An employee of USACE emphasized the need for communication with smaller dredgers and harbor masters who may not understand the regulations. Mr. Gold observed that monitoring programs need to coordinate with dredgers to develop appropriate methods to monitor take.

To support additional research, stakeholders suggested pooling resources and developing a more integrated regional approach rather than focusing on each permit individually. Several participants indicated that a programmatic restoration and monitoring program is needed to improve the health of the species. Stakeholders also observed that initial payments to cover research may result in savings to dredgers over the course of a project.

6. NEXT STEPS

The two symposia provided a summary of the general conceptual understanding of green sturgeon and longfin smelt, including some of the latest research findings and discussion of potential dredging impacts. A listing of potential future studies was also developed for both species (Table 4.1, Table 5.1). Symposium participants included scientists, managers, and stakeholders interested in the ongoing management of these two species.

These symposia provided the first opportunity for the presenting scientists to consider the potential impacts of dredging activities on longfin smelt. For green sturgeon as well, there seemed to have been limited prior coordination between the scientists and local managers. Additional prioritization and coordination between scientists and stakeholders are warranted in developing conceptual models and research programs for green sturgeon and longfin smelt.

We recommend that the LTMS host a workshop to follow up on the ideas and research directions identified during the symposia. One of the major goals of this workshop will be to facilitate discussions targeted towards specific LTMS management needs, rather than the general research findings of the presenters. This will provide LTMS managers the opportunity to evaluate management scenarios while at the same time considering potential benefits or implications of future research. In addition to active participants from the LTMS program, local scientists that presented at the symposium and dredging operators should also attend. This group should include individuals who are familiar with the practical challenges of dredging and mitigation activities, and are also comfortable engaging in detailed discussions with regulators and academic scientists.

The following three topics could provide a framework for outcomes of the workshop:

1. A refined conceptual model that a) identifies the circumstances (e.g., timing) in which impacts from dredging activities on green sturgeon and longfin smelt could be avoided; and b) identifies the relative importance of dredging activities among other limiting factors important to species recovery (e.g., contaminants from stormwater, ocean conditions). This should include specific assessment of spatial and temporal variation of species occurrence during different life stages, in addition to assessment of types of dredging activity.
2. Critical evaluation of potential management and mitigation activities that are likely to have greatest benefit for the species. These mitigation activities might not even be directly related to dredging, but could still allow the dredging community to work in partnership with other agencies to reduce the major stressors to recovery of the listed species (as identified in the conceptual model).
3. A focused research and management agenda for the species, to prioritize among the wide range of potential studies (e.g., Tables 4.1 and 5.1), based on those likely to have greatest benefit for management. This should not just consider research studies, but also integration of current research findings into tools that would be useful for managers. Tools worthy of consideration include predictive or

descriptive models of species distribution, and potential impacts of various dredging activities. Another potential tool is the establishment of innovative institutional arrangements for mitigation implementation across jurisdictional boundaries (model examples include municipal and industrial pollution prevention programs, toxic hot-spot remediation efforts).

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