STRIPED BASS PREDATION ON LISTED FISH WITHIN THE BAY-DELTA ESTUARY AND TRIBUTARY RIVERS

Expert Report

Coalition for a Sustainable Delta et al. v. Koch, E.D. Cal. Case No. CV 08-397-OWW

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Charles H. Hanson, Ph.D.
Hanson Environmental, Inc.
132 Cottage Lane
Walnut Creek, CA 94595

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1. INTRODUCTION AND CONCLUSIONS

Striped bass are a popular game fish introduced into the Sacramento-San Joaquin Bay-Delta estuary in the late 1800's. Striped bass are a large, long-lived, and widely distributed predator that preys on a variety of fish and macroinvertebrates, including fish listed for protection under the California (CESA) and/or federal Endangered Species Acts (FESA). These prey species include juvenile winter-run Chinook salmon (endangered under both CESA and FESA), spring-run Chinook salmon (threatened under both CESA and FESA), Central Valley steelhead (threatened under FESA), and delta smelt (endangered under CESA and threatened under FESA). For example, Nobriga and Feyrer (2007, p. 9) concluded that "striped bass likely remains the most significant predator of Chinook salmon, *Oncorhynchus tshawytscha* (Lindley and Mohr 2003) and threatened Delta smelt, *Hypomesus transpacificus* (Stevens 1966), due to its ubiquitous distribution in the Estuary and its tendency to aggregate around water diversion structures where these fishes are frequently entrained (Brown *et al.* 1996)".

The NMFS (2009b) draft Recovery Plan for Central Valley salmon and steelhead concludes that: (1) predation on winter-run Chinook salmon is a "major stressor" with very high importance (p. 42, 48), (2) restoring the ecosystem for anadromous salmonids will require, among other actions, "significantly reducing the nonnative predatory fishes that inhabit the lower river reaches and Delta" (p. 90), and (3) reducing abundance of striped bass and other non-native predators must be achieved to "prevent extinction or to prevent the species from declining irreversibly" (p. 157, 183, 190).

In this report I review prior studies of the diet of striped bass and CDFG's prior estimates of the predation by striped bass on listed fish. I then explain my estimates of predation by striped bass on listed fish, and I discuss how a reduction in striped bass abundance and predation resulting from deregulation would increase the survival of listed fish.

Conclusions of my analysis include:

1. CDFG's 1998 published estimates of striped bass predation on listed fish were based on many incorrect assumptions and omissions that tended to underestimate striped bass predation mortality.

2. Predation by striped bass in the rivers upstream of the Delta, particularly the Sacramento River, on juvenile emigrating salmon and steelhead is substantially higher than reflected in CDFG's published estimates. Striped bass predation in rivers tributary to the Delta appears to be the largest single cause of mortality of juvenile salmon migrating through the Delta.

3. The high rates of striped bass predation within the Sacramento River are supported by, inter alia, striped bass diet studies and recent survival studies that have shown high mortality of salmon and steelhead -- approximately 90% -- before they reach the Delta.

4. My estimates of striped bass predation on the listed species for the time periods used in CDFG's predation estimates are at least:

   (1) Winter-run Chinook salmon -- 21%;

   (2) Spring-run Chinook salmon -- 42%;

   (3) Central Valley steelhead -- 7-15%; and

   (4) Delta smelt -- 13%.

5. Mortality to these listed fish as a result of striped bass predation, particularly for salmonids, greatly increases the probability of their extinction and reduces the probability of species recovery.

6. Striped bass predation on delta smelt is probably minimal under the current conditions of record low population abundance of delta smelt, low densities, broad geographic distribution, and higher turbidity waters. But even minimal predation increases the probability of delta smelt extinction and reduces the probability of species recovery.

7. Assuming that elimination of the striped bass sport-fishing regulations would reduce the striped bass population by approximately 60-70%, striped bass predation mortality on the listed species would be reduced by at least the following approximate percentages:

   (1) Winter-run Chinook salmon by 14%;

   (2) Spring-run Chinook salmon by 27%;

   (3) Central Valley steelhead by 5-10%; and

   (4) Delta smelt by 0-3%.

8. The net population-level benefits of reducing striped bass predation would differ for the salmonids and delta smelt. For delta smelt, other predators are likely to replace striped bass, and other factors would minimize the net population-level benefits of a reduction in striped bass predation. Salmon and steelhead should benefit greatly from the reduction in striped bass predation, because there are few other predators within the rivers, fish screens have been installed in previously unscreened diversions, upstream habitat has been improved for salmon and steelhead spawning and rearing, and harvest of listed salmonids has been reduced. Reducing striped bass predation on juvenile salmon and steelhead in the rivers would substantially increase their abundance, decrease the probability of extinction, and improve the probability of recovery of the species.

9. Allowing fishermen to reduce striped bass predation via deregulation is probably the most efficient and cost-effective method to contribute to recovery of Central

Valley salmon and steelhead. Unless this is done, expensive management programs designed to improve their survival within the lower Delta are unlikely to save these listed species.

2. QUALIFICATIONS

My name is Charles H. Hanson. I am the owner of Hanson Environmental, Inc. located at 132 Cottage Lane, Walnut Creek, CA. My academic training includes a B.Sc. and M.Sc. in fisheries from the University of Washington, studies in environmental engineering at the Johns Hopkins University, and a Ph.D. in fisheries and ecology from the University of California, Davis. I am a life member and certified fishery biologist by the American Fisheries Society.

I have more than 31 years of experience in freshwater, estuarine, and marine biological studies. I have contributed to the study design, analysis, and interpretation of fisheries, stream habitat, and stream flow (hydraulic) data used to develop habitat restoration strategies, aquatic Habitat Conservation Plans, Endangered Species Act consultations, and environmental analyses. I have conducted research and analyses involving striped bass in the San Francisco Bay-Delta estuary since 1976 as well as prior research on striped bass in Chesapeake Bay and the Potomac River. I have also conducted evaluations of the effectiveness of various water diversion fish screening systems, assisted in fish screen design and permitting, and developed operational modifications to reduce organism losses while maintaining operational reliability of water projects and hydroelectric systems. I have directed numerous investigations and environmental impact analyses for projects and have participated as an expert witness on fisheries and water quality issues in numerous public hearings and litigation. I have been extensively involved in incidental take monitoring and investigations of endangered species, development of Recovery Plans, ESA consultations, listing decisions and identification of critical habitat. I served as a member of the USFWS Native Delta Fish Recovery Team, Central Valley Technical Recovery Team, USFWS Delta Smelt Recovery Team, National Marine Fisheries Service Central Valley Technical Recovery Team, Klamath Basin Sucker Status Review Team, numerous technical advisory committees, and as science advisor to settlement negotiations. I am currently participating in developing the Bay Delta Conservation Plan (BDCP) based on a Habitat Conservation Plan (HCP) that would contribute to the recovery of listed fish inhabiting the Bay-Delta estuary and tributary rivers. I have authored more than 75 technical and scientific reports.

A copy of my more detailed resume is included as Exhibit 1.

3. CDFG ESTIMATES OF STRIPED BASS PREDATION ON LISTED FISH

3.1 Background

Striped bass are a large non-native predatory fish introduced into the Bay-Delta estuary from the east coast over 100 years ago. Since their introduction, striped bass have preyed on native fish and other aquatic species inhabiting the estuary or using the estuary as a migratory corridor between coastal marine waters and upstream freshwater habitats. In recent years, however, several of the Delta's native fish species, including delta smelt, winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead have declined in abundance and are currently listed for protection under the CESA and/or the FESA. Over the past 150 years there have been increased stressors on the Bay-Delta aquatic ecosystem, such as: introductions of non-native predators and competitors, major changes to the quality and availability of physical habitat for aquatic species, levee construction and reclamation, construction of dams and reservoirs, water project operations, river and Delta water diversions, chemical contaminants, and other factors. The cumulative effects of these changes have resulted in the declines of many of the native fish. Predation mortality by striped bass represents a significant source of mortality to these listed fish.

Because of their large size, abundance, and predatory behavior, striped bass support one of the largest recreational fisheries within the Delta. CDFG has been a strong advocate for the protection of the striped bass fishery. In order to protect the striped bass population from overharvest by anglers and to maintain striped bass abundance, the California Fish and Game Commission has followed CDFG's recommendations and adopted a striped bass abundance policy and regulations to protect the striped bass population (e.g., minimum size of 18 inches, maximum bag limit of two fish per day) that are enforced and promoted by CDFG.

Striped bass reside in the Delta year-round, and therefore resident estuarine fish such as delta smelt, whose geographic distribution throughout their life span is within the Delta, are vulnerable to predation mortality. Close to half of the 1 to 1.5 million adult striped bass also migrate upstream from the Delta into the main tributary rivers, primarily during the winter and spring prior to spawning; although some striped bass reside in the rivers year-round (Stevens 1963). Striped bass spawning occurs in the spring within the main rivers such as the Sacramento River. While inhabiting the rivers, subadult and adult striped bass actively prey on juvenile Chinook salmon (Stevens 1963, Thomas, 1967, Merz 2003, Tucker *et al.* 1998, 2003). During the winter and spring when striped bass are most abundant in the rivers, juvenile Chinook salmon and steelhead are migrating downstream to the ocean; and it this co-occurrence of predatory striped bass and juvenile salmon and steelhead that promote predation on them.

The risk of predation on juvenile salmonids within the river is further increased by the narrow channel (typically 300-500 feet across and 30 feet deep or less) through which all of the juveniles must pass, which reduces the ability to avoid predation. Changes in the land use within the rivers to include riprap stabilized levees and structures such as bridges, marinas, water diversion structures, and others (Stevens 1963, Tucker *et al.* 1998, 2003) further increase the vulnerability of juvenile salmonids to predation within the rivers. The salmon populations begin as juveniles who must migrate through the Sacramento River and evade predation by striped bass and other predators. Central Valley steelhead are also primarily produced in the Sacramento River system, although small populations of steelhead also occur in other rivers. Studies have shown mortality of juvenile Chinook salmon and steelhead in the Sacramento River upstream of the Delta to be approximately 90% in recent years (MacFarlane *et al.* 2008, NMFS 2009). Striped bass are the major predator on salmon and steelhead within the Sacramento River (see Section 3.3.1 below).

A variety of studies have been conducted within the Bay-Delta to determine the diet of striped bass, their life history and population dynamics within the estuary and tributary rivers, and more recently the effects of striped bass predation mortality on listed fish (see summary of prior predation research presented in Exhibit 2). The earlier diet studies were primarily designed to collect basic information on the prey of striped bass and how the striped bass diet varied among age classes, seasonal periods, and locations within the estuary. Because striped bass are one of the most popular fish harvested by recreational anglers, CDFG has developed programs to estimate the abundance and age distribution of striped bass, promote striped bass abundance, assess mortality rates, and collect other information used in the management of the striped bass population. Results of several of the CDFG monitoring programs showed evidence of a declining trend in adult striped bass abundance between the 1960's and the 1980's. To increase the abundance of striped bass available to recreational anglers, CDFG initiated a striped bass hatchery program to augment natural reproduction within the estuary.

In recent years investigators and regulatory agencies have expressed concerns regarding the effects of predation by striped bass, in combination with other stressors, on the Pelagic organism Decline (POD – Baxter *et al.* 2008, Loboschefsky *et al*. 2009), increasing the probability of extinction for winter-run Chinook salmon (Lindley and Mohr 2003), effects on listed fish (NMFS and USFWS 1999), and predation mortality as a factor affecting fish inhabiting the Delta and tributary rivers (Nobriga and Feyrer 2007, Tucker et al 1998, 2003, MacFarlane *et al.* 2008, and many others). There has been increasing concern regarding the predation by striped bass and other fish on the survival of juvenile Chinook salmon, delta smelt, and other fish at predation hot spots such as the Red Bluff Diversion Dam and Clifton Court Forebay (Tucker *et al.* 1998, 2003, Gingras 1997, Clark *et al*. 2009, SJRGA 2007, 2008, and others). Even CDFG biologists have recommended reconsideration of the striped bass abundance policy (DFG26814, DFG37615). As noted above, NMFS's October 2009 draft Recovery Plan for salmon and steelhead identifies predation as a "major stressor" and calls for a significant reduction of striped bass and other non-native predators to prevent extinction of these species (NMFS 2009b).

This report will show that striped bass predation is a much greater cause of mortality of the listed species than previously reported by CDFG.

3.2 CDFG Predation Estimates

3.2.1 CDFG Published Predation Estimates

In order to obtain a permit to stock striped bass in the Delta and to address concerns regarding striped bass predation on listed fish, CDFG (1998 a,b) developed a series of estimates of the magnitude of striped bass predation mortality on listed fish. I have reviewed the reports and predation estimates prepared by CDFG, scientific information on predation by striped bass, results of specific predation studies conducted at various locations within the Bay-Delta system, and reports by investigators and regulatory agencies regarding the potential effects of striped bass predation on the abundance and survival of listed fish.

With the petitions and listings of winter-run Chinook salmon, spring-run Chinook salmon, Central Valley steelhead, and delta smelt under the CESA and/or FESA in the early 1990's, and the need to obtain incidental take authorization from NMFS and US Fish and Wildlife Service (USFWS) for the striped bass stocking program, CDFG prepared an evaluation of the predation mortality on listed fish based on population abundance during the period from 1993-1996. The analyses also considered various levels of striped bass hatchery augmentation in support of an incidental take application submitted by CDFG to NMFS and USFWS. The estimated levels of predation mortality on listed fish presented by CDFG in a 1998 draft and final Environmental Impact Report (EIR) and draft Conservation Plan and incidental take permit application, assuming various levels of striped bass abundance, without stocking, were as follows:

Estimated percentage mortality on listed fish by striped bass (CDFG 1998a, 1998b).

	Striped Bass Adult Abundance			
	515,000	**712,000(1)**	**765,000**	**1,100,000**
Delta smelt	**3.5%**	**4.9%**	**5.3%**	**7.6%**
Winter-run Chinook salmon	**4.0%**	**5.6%**	**6.0%**	**8.7%**
Spring-run Chinook salmon	**2.2%**	**3.2%**		**4.9%**
Central Valley steelhead	**<2.2%**	**<3.2%**		**<4.9%**

(1) 712,000 adult striped bass in 1994 was the lowest point in CDFG's estimate of striped bass population abundance. Abundance has averaged approximately 1 million adult striped bass in recent years – See Section 3.4.2. CDFG (1998a,b) stated that predation mortality on listed fish would increase or decrease in proportion to changes in striped bass abundance and the above predation estimates are proportional to the striped bass population abundance. The predation calculation spreadsheets (see PREDTION.WK4 included on the DVD) provided by David Kohlhorst, the CDFG biologist who produced these estimates, provide slightly higher predation estimates than those reported above.

The basic approach used by CDFG to estimate predation mortality by striped bass relied on results of diet studies conducted in the estuary during the early and mid-1960's (Stevens 1966, Thomas 1967) and the seasonal and geographic distribution of striped bass (ages 1, 2, and 3+). CDFG applied various adjustments to the calculations to reflect changes in prey abundance over time and different levels of striped bass abundance reflecting alternative hatchery stocking options.

In preparing the estimates of predation mortality by striped bass on listed fish, CDFG used results of two diet studies to estimate the frequency of occurrence of listed fish and other prey eaten by striped bass of different ages (age 1, age 2, and age 3+) by season in different geographic regions of the Delta and lower reaches of the Sacramento and San Joaquin Rivers. The diet studies, conducted by Stevens (1966) and Thomas (1967) primarily focused on the diet of striped bass collected from the Delta and Suisun Bay, with little data and no discussion of striped bass predation upstream within the Sacramento River. Delta smelt live their entire life in the Delta. The Delta is primarily a migratory corridor for juvenile salmon and steelhead. This is important because, as noted by Stevens (1963) in a diet study that was omitted from the CDFG predation analysis, the vulnerability of juvenile salmonids to striped bass predation is substantially lower in the Delta where channels are miles wide and the prey fish are not concentrated, in contrast to the tributary rivers where all of the juvenile salmon and steelhead are concentrated within narrow river channels.

The frequency of occurrence of various prey species in striped bass stomachs was then used in the CDFG calculation along with information and estimates of the abundance of age 1, 2, and 3+ striped bass within each of the regions used in the analysis during each season. The initial estimate of predation was based on (1) the abundance of striped bass of a specific age within a region during a season, and (2) the frequency of occurrence of the prey observed in the diet studies.

Based on the low 6% striped bass predation rate for winter-run Chinook salmon developed by CDFG, NMFS (Lindley and Mohr 2003) developed a model for winter-run Chinook salmon that estimated the probability of extinction and probability of recovery of winter-run Chinook salmon. The model estimated that an individual winter-run salmon had about a 9% chance of being eaten by a striped bass. The model estimated that winter-run salmon had a 23% probability of extinction (assuming density dependant survival) when the striped bass population was 0 and a 30% probability of extinction when the striped bass adult population abundance was 700,000 fish, a 7% increase in the probability of extinction. The model was also used to estimate the probability of winter-run salmon extinction assuming an adult striped bass abundance of 3 million adult striped bass. The probability of winter-run extinction increased from 30% assuming 700,000 adults to 55% assuming 3 million adult striped bass, a 25% increase in the risk of winter-run salmon extinction. The model estimated that the probability of recovery of winter-run salmon would decrease from approximately 14% to 10% at adult striped bass abundance levels of 0 and 700,000 fish, assuming density dependant survival. The model estimated that the probability of recovery decreased from 10% assuming 700,000 adult striped bass to 4% assuming 3 million adult striped bass in the population. Based on results of these and similar analyses, NMFS (1996) concluded that "The incremental increase in mortality that the winter-run Chinook salmon population would incur (estimated to be at least 3.5%) from DFG's proposal to increase striped bass stocking represents a new and significant impact to the population, and in NMFS's view has the potential to appreciably reduce the likelihood of survival and recovery of winter-run Chinook salmon" (DFG038312). As a result of the NMFS finding, the CDFG striped bass hatchery stocking program was later discontinued as an effort to increase striped bass abundance within the estuary.

3.2.2 CDFG Unpublished Predation Estimates

Documents provided by CDFG in this litigation (DFG03776 through DFG037766 attached to this report as Exhibit 3 Tables 1-4) show results of an unpublished bioenergetic-based analysis of striped bass predation on winter-run Chinook salmon. The bioenergetics approach used information on the abundance of striped bass and their seasonal and geographic distribution by age (ages 1-8+). The total amount of food consumed is then calculated. Using results of the diet studies, the total food biomass is allocated between fish biomass, and shrimp biomass. The fish biomass estimate is then allocated to the biomass that represent salmon and subsequently to the amount of biomass that were juvenile winter-run salmon. The number of juvenile winter-run salmon consumed is then estimated based on the mean weight of individual juvenile winter-run salmon within each region and season. The estimate of the number of winter-run salmon consumed within a year is then calculated as the sum of the seasonal estimates. Estimates of juvenile winter-run salmon predation by striped bass were made using the bioenergetic approach for 1993-1996. Results of the predation estimates are show below:

Juvenile Winter-run Salmon Predation by Striped Bass using Bioenergetics Approach

Year	Winter-run Salmon Abundance	Winter-run Salmon Consumed by Striped Bass	Striped Bass Predation Rate on Winter-run Salmon
1993	273,157	53,859	19.7%
1994	90,545	4,450	4.9%
1995	74,491	64,658	86.8%
1996	398,107	41,149	10.3%
Average	209,075	41,029	**30.0%**

Results of CDFG's bioenergetics approach to estimating striped bass predation on winter-run salmon were not disclosed in the 1998 CDFG EIR or incidental take application. CDFG's published predation estimate of 5.6% for winter-run salmon assuming a striped bass abundance of 712,000 fish, or 8.7% assuming 1.1 million adult striped bass (See Section 3.1) were substantially lower than the striped bass predation estimates developed based on the bioenergetics calculation presented above and in Exhibit 3. I could not determine from the available documents whether CDFG did similar bioenergetic estimates of predation on the other listed species, and I do not know why these bioenergetic estimates for winter-run salmon were not published.

3.3 Sources of Bias and Error in CDFG's Published Predation Estimates

I reviewed the detailed methods and assumptions used by CDFG in developing the striped bass predation estimates for listed fish presented in the draft and final EIR and associated incidental take application for the striped bass management program (CDFG 1998a; DFG023368 through DFG023899). I also reviewed the analysis of the CDFG predation estimates developed recently by CDFG (Dubois 2009). I also spoke with Dave Kohlhorst (CDFG retired) who developed the original CDFG predation estimates and obtained from Mr. Kohlhorst the spreadsheets

(PREDTION.WK4; a copy of the spreadsheet in included in the accompanying CD) used in the predation calculations. I describe some of the sources of error and bias in the previous CDFG predation estimates, which underestimated striped bass predation mortality:

3.3.1 Up-River Predation

The Sacramento River provides spawning and rearing habitat, and serves as the migratory pathway for adult and juvenile winter-run and spring-run Chinook salmon and Central Valley steelhead. The mainstem Sacramento River is currently the only spawning and rearing habitat for winter-run salmon (see Figure 1 for winter-run salmon distribution). Spring-run Chinook salmon are limited in their freshwater distribution to the Sacramento River and its tributaries (Figure 2). Central Valley steelhead predominately inhabit the Sacramento River and its tributaries, but also occur in the Cosumnes, Mokelumne, and San Joaquin river watersheds (Figure 3).

Figure 1. Sacramento River winter-run Chinook salmon distribution. Source: NMFS.

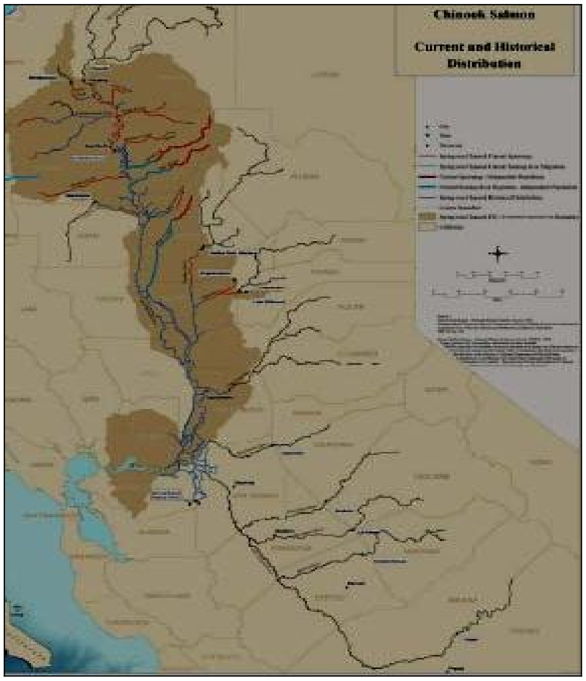


Figure 2. **Central Valley Spring-run Chinook salmon distribution. Source: NMFS.**

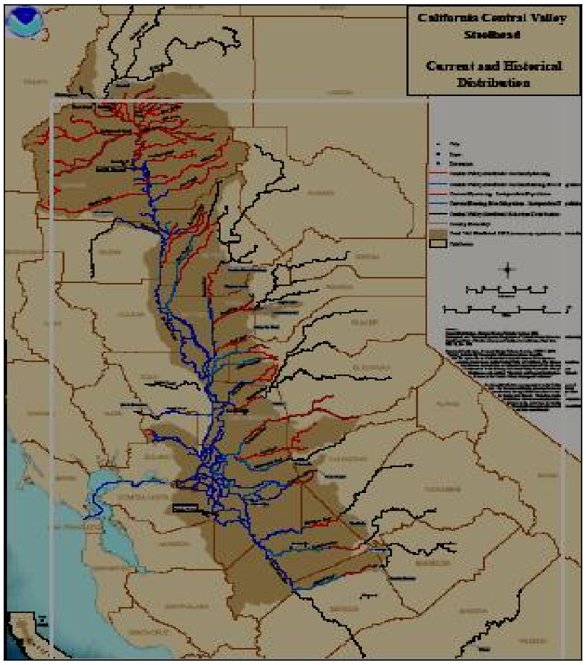


Figure 3. **Central Valley steelhead distribution. Source: NMFS.**

Subadult and adult striped bass have a broad geographic distribution within the estuary and the upstream reaches of the main tributary rivers. Several hundred thousand subadult and adult striped bass migrate upstream into areas such as the Sacramento River during the late winter and spring as part of their spawning migration (PREDTION.WK4 spreadsheets). These subadult and adult striped bass are known to forage on a variety of fish species within the upstream habitats, especially juvenile Chinook salmon (Tucker *et al.* 1998, 2003, Stevens 1963, Thomas 1967, Merz 2003). With so many striped bass inhabiting the river during the late winter and spring, and given the available food resources, striped bass must consume large numbers of salmon and steelhead (Tucker *et al.* 1998, Stevens 1963, Merz 2003). High striped bass consumption rates are consistent with the unpublished CDFG bioenergetic-based winter-run salmon predation estimates discussed in Section 3.2.1.

Stevens (1963) found that striped bass predation mortality was high in the lower Sacramento River with particularly high predation mortality occurring in the immediate vicinity of the Paintersville Bridge (located on the Sacramento River near Courtland). Stevens (1963) estimated that 39,000 to 78,000 juvenile Chinook salmon were preyed on by striped bass at the Paintersville Bridge alone during June, July, and August 1962. In the reach of the lower Sacramento River sampled by Stevens in June, juvenile Chinook salmon were the dominant prey in the diet of striped bass with 88.2% of the stomachs that contained prey having salmon (207 salmon were observed in 105 stomachs containing prey). Salmon in June were found to represent 86.5% of the food volume in striped bass stomachs (averaging approximately 2 salmon per bass that had prey in their stomach). At the Paintersville Bridge in June, salmon were present in 90.7% of the striped bass stomachs with food and comprised 82.4% of the diet. Salmon were also the dominant prey in striped bass stomachs collected from the Sacramento River in June by Stevens (1963) at the confluence of Sutter Slough and the Sacramento River and near Freeport. Juvenile salmon were also a major component in the striped bass diet in the Sacramento River in July and August sampling (Stevens 1963). Despite the high percentage of juvenile Chinook salmon in the diet of striped bass in the Sacramento River reported by Stevens (1963), there was no substantive discussion of this issue in the CDFG predation estimates.

The striped bass diet studies published by Stevens (1966) did not include sampling in areas upstream of the Delta (Isleton was the most upstream sampling site), although in his earlier paper Stevens (1963) found that predation mortality by striped bass on juvenile salmon further upstream in the Sacramento River was very high. Stevens (1963) attributed the low frequency of occurrence of juvenile salmon in the prior diet studies of striped bass to sampling only downstream within the Delta, rather than collecting striped bass from areas upstream within the Sacramento River.

Striped bass diet studies conducted by Thomas (1967) did include sampling within the Sacramento River upstream of the Delta. Thomas (1967) found that juvenile Chinook salmon were the major diet item in 45 bass collected from the river in the reach from Rio Vista upstream to the American River, representing a frequency of occurrence of 62%. Salmon comprised 65% of the stomach volume of striped bass collected.

Predation on juvenile Chinook salmon by striped bass and Sacramento pikeminnow has also been identified as a major source of juvenile salmon mortality associated with operation of the

Red Bluff Diversion Dam located on the Sacramento River (Tucker *et al.* 1998, 2003). Tucker *et al.* (1998) found that juvenile salmon outweighed other food types by a three to one margin in stomach samples of striped bass collected immediately downstream of the diversion dam.

In a striped bass predation study conducted on the lower Mokelumne River immediately downstream of the Woodbridge Irrigation District diversion dam, Merz (2003) estimated that a population of 200 to 500 striped bass was present in the May-June 1993 period of study with an estimated consumption rate of 1.8 to 3.3 juvenile Chinook salmon per bass per day. Based only on positively identified juvenile salmon in bass stomachs, it was estimated that striped bass predation losses ranged from 11 to 28% of the 1993 Mokelumne River juvenile salmon production. Combining the positively identified juvenile salmon with suspected salmon in the stomach contents (e.g., partially digested prey) the predation loss estimate for this location was estimated to be as high as 51% of the 1993 juvenile salmon outmigrants. Flows in the river during the late spring of 1993 were low, which may have contributed to increased predation by striped bass.

NMFS (2009a) long-term CVP and SWP BiOp also identifies predation by striped bass in the lower American River as a factor affecting survival of steelhead. The BiOp, citing studies conducted by SWRI (2001), concludes that striped bass inhabit the lower American River, a tributary to the Sacramento River, year-round and are abundant during the spring and early summer when juvenile steelhead are rearing and emigrating from the river, concluding that "striped bass predation on juvenile steelhead is considered to be a very important stressor to this population" (p. 294). NMFS's latest draft Recovery Plan for salmon and steelhead identifies predation as a "major stressor" and calls for a significant reduction of striped bass and other non-native predators to prevent extinction of these species (NMFS 2009b).

CDFG's predation estimates for juvenile winter-run and spring-run Chinook salmon within the upper Sacramento River are based on an <u>assumed</u> frequency of occurrence in the striped bass diet. During the spring emigration period for juvenile Chinook, the CDFG predation estimates assume an unreasonably low frequency of occurrence of 16.74% for age 1 and 2 striped bass inhabiting the upper Sacramento River and <u>0%</u> for ages 3 and above, which is impossibly low. The estimates also incorrectly assume that the maximum occurrence of a juvenile salmon in a striped bass stomach never exceeded 1 fish per day. These errors further underestimated predation rates on salmon and steelhead. NMFS and USFWS (1996) also expressed concerns that the level of predation mortality on winter-run Chinook salmon within the Sacramento River had been underestimated by CDFG.

The diet data collected by Thomas (1967) and Stevens (1963) represent the best available striped bass diet information for estimating levels of predation on listed Chinook salmon and steelhead within the upstream reaches of the Sacramento River. The effects of striped bass predation on listed salmon and steelhead within these upstream areas were not adequately included in the earlier CDFG predation estimates. This major omission depressed CDFG's predation estimates for winter-run and spring-run Chinook salmon and steelhead, but not for delta smelt that only occur downstream in the Delta.

The high frequency of juvenile salmon in the diet of striped bass in the spring within the Sacramento River (Thomas 1967) is consistent with results of juvenile salmon and steelhead survival studies in the Sacramento River. The importance of predation mortality on juvenile salmonids migrating downstream in the Sacramento River is highlighted by coded wire tag, and more recently acoustic tag survival studies, which have consistently shown high levels of mortality up river before the juvenile salmonids reach the Delta. For example, results of a recent acoustic tag survival study conducted using late fall-run Chinook salmon (as a surrogate for listed salmon) and steelhead showed 80% mortality for both species in 150 km of the Sacramento River (Coleman Hatchery to Ord Bend) with an estimated 90% loss by the point that these fish were entering the Delta (MacFarlane *et al.* 2008, NMFS 2009). Of the fish released in this test only 2% of the Chinook salmon and 7% of the juvenile steelhead were detected at the Golden Gate. MacFarlane *et al.* (2008) attributed the high mortality rate to water conditions noting "2007 was a dry year with low river flows, which may have resulted in high predation". The high mortality in the rivers reflected by these and other studies has important implication on the potential success of restoration programs designed to protect and improve conditions in the Delta. Actions are needed to reduce the high mortality rates in the river and thereby allow more juvenile salmon and steelhead the opportunity to successfully migrate downstream into the Delta where they would benefit further from current and future restoration actions.

Results of an experimental survival study conducted by USBR during April and May of 2009 (Bowen et al. 2009) in the lower San Joaquin River also showed high rates of predation on juvenile salmon by striped bass. The survival study was conducted in conjunction with testing the effectiveness of a non-physical barrier in reducing juvenile salmon migration into Old River. A total of 947 acoustically tagged juvenile salmon were released into the river in seven groups. The fish were then monitored several miles downstream at the Head Of Old River. DIDSON cameras and acoustic telemetry were also used to observe the released salmon and predators in the immediate vicinity of the non-physical barrier. Results of the study showed an average total mortality of juvenile salmon of 68% -- including 41% mortality before they reached the barrier, plus 27% near the barrier. The predation levels were so high that predation was found to offset much of the deterrent benefits of the barrier, and the authors recommended the removal of the predators. The DIDSON observations and acoustic telemetry showed that striped bass were the dominant predator on juvenile salmon. These results indicate that predation by striped bass is a significant source of mortality to juvenile salmon during their downstream migration and that predation may counteract the success of programs to restore the salmon and steelhead populations.

3.3.2 Predation Hot Spots

Under natural conditions, prey would avoid predation by use of naturally occurring cover and by avoiding areas where the prey are confined and/or subject to high water velocities and turbulence. During the past century, levee construction with riprap, various structures such as water diversions, piers and pilings, bridges, and other structures have created locations where listed fish and other aquatic species have increased vulnerability to predation by striped bass, and other predators. Striped bass forage in open water but also aggregate in areas where prey are concentrated or their ability to escape predation is reduced. There are an estimated 2,000 structures within the Delta that have the potential to serve as predation hot spots (Figure 4). CDFG (1998a) describes several of the predation hot spots and results of local studies of predation by striped bass. CDFG did not, however, account for the increased predation by

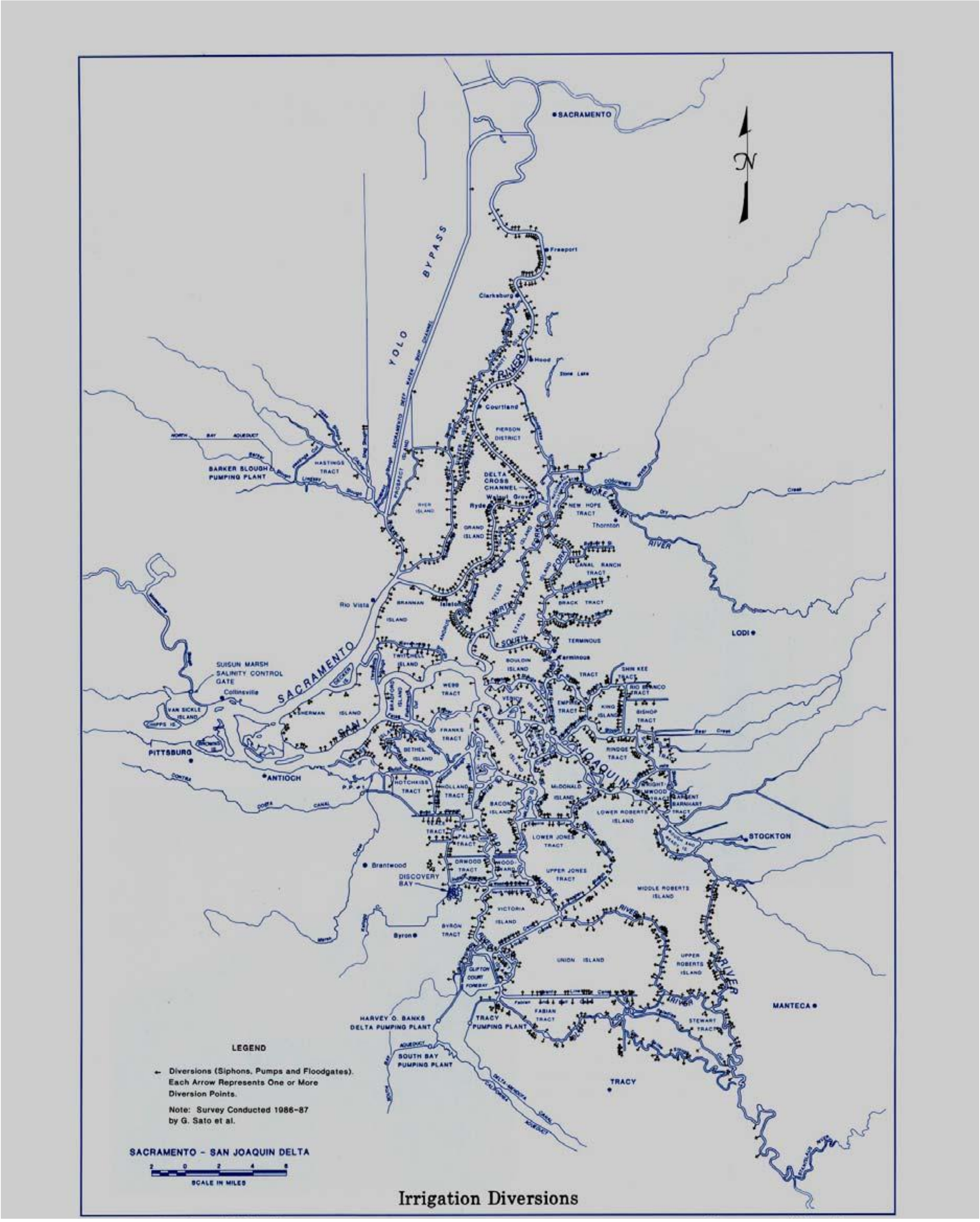


Figure 4. **Example of potential predation hot spots – irrigation diversion structures within the Delta. Source: DWR 1993 Delta Atlas.**

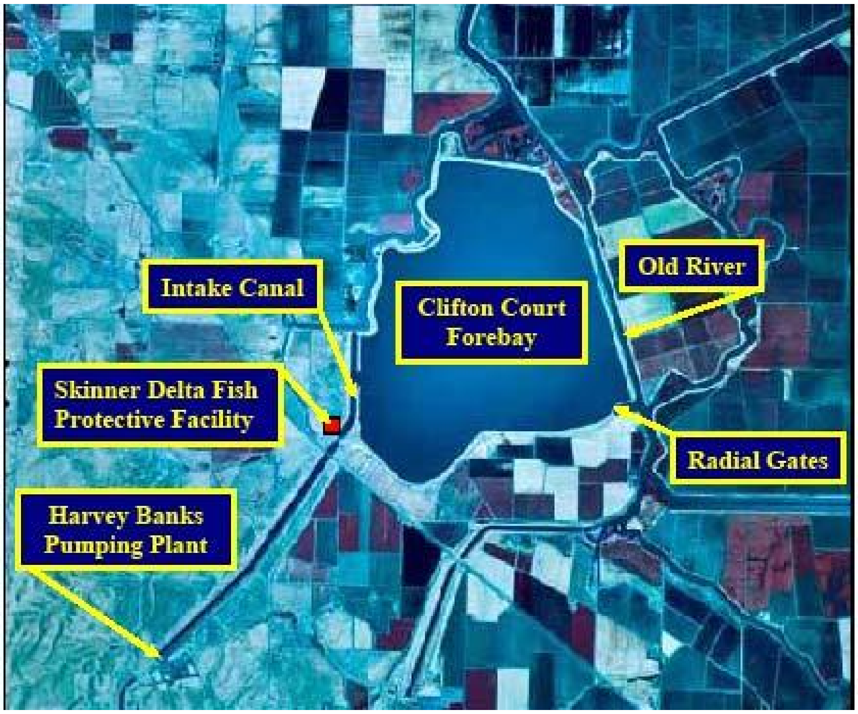


Figure 5. Aerial photograph of Clifton Court Forebay. Source: Clark *et al.*, 2009.

Figure 6a. SWP fish salvage return on Sherman Island. Source: DWR.

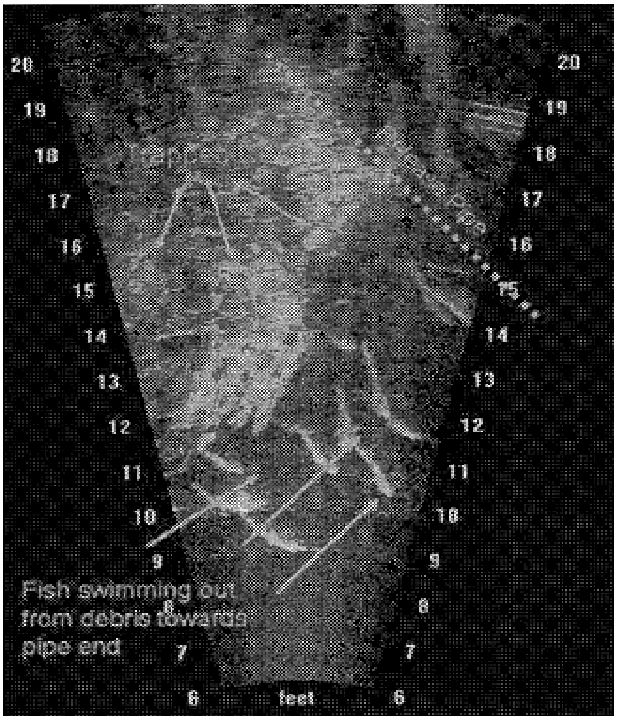


Figure 6b. Sideview DIDSON image of predators in the vicinity of the release pipe support structure. Source: Miranda *et al.,* 2009.

striped bass at these hot spots in its predation estimates, which caused an additional underestimate of predation mortality.

Predation by striped bass has been studied at a number of Bay-Delta predation hot spots including: (1) Clifton Court Forebay (shown in Figure 5), which is part of the SWP south Delta export facilities (Clark et al. 2009, Gingras 1997), (2) at the release locations for fish salvaged from the export facilities (Miranda et al. 2009), (3) near the Head of Old River on the lower San Joaquin River (SJRGA 2007, 2008, Bowen *et al.* 2009), (4) Sacramento River near the Paintersville Bridge (Stevens 1963), (5) at the Red Bluff Diversion Dam (Tucker et al. 1998, 2003), and (6) in the vicinity of the Delta Cross Channel gates (Low *et al*. 2006, Newman and Rice 1997) . Predation by striped bass has been most extensively studied within Clifton Court Forebay where, based on results of eight studies conducted with marked juvenile Chinook salmon, total predation losses ranged from 63% to 99% (Gingras 1997). The range of predation losses for juvenile Chinook salmon was similar to the predation losses estimated for yearling steelhead averaging 245 mm in length (78% to 82%; Clark *et al*. 2009).

Substantial predation losses of juvenile salmon and other listed fish at the SWP and CVP fish salvage release sites (a photograph showing the SWP release site and DIDSON camera image of predatory fish at the site are presented in Figure 6) has also been an issue. The NMFS (2009) Biological Opinion on long-term operations of the CVP and SWP (BiOp) reports that post release predation rates estimated by DWR are within the range of 10 to 30% for juvenile Chinook salmon (citing Orsi 1967, Pickard *et al.* 1982, and Greene 2008). Results of a more recent study of predation losses at the SWP release site at Horseshoe Bend on Sherman Island (Miranda *et al.* 2009, DFG077553 p. 158) concluded that "of the three predatory species present, predation by striped bass has the potential to have the greatest impact on fish at the release site based on average consumption requirements of each species". Results of field observations showed a marked increase in predation activity during and shortly following releases of salvaged fish.

The prey selection and diet studies on striped bass conducted by Stevens (1966) and Thomas (1967) that are the fundamental basis for the CDFG's predation estimates did not account for these locations of increased prey vulnerability to striped bass. In fact, many of the locations where high levels of predation have been observed, such as Clifton Court Forebay and the SWP/CVP salvage release sites, were not constructed at the time of CDFG's striped bass diet studies. As a result, the frequency of occurrence of various prey species in the striped bass diet studies used by CDFG underestimates predation. Unfortunately, the data currently available to me are not sufficient to add predation at these localized predation hot spots to the overall predation losses of listed fish. Therefore, my estimates also underestimate predation on listed fish.

3.3.3 Downstream Predation

The predation estimates developed by CDFG were focused primarily on the Delta, although both striped bass and juvenile salmon and steelhead occur further downstream in San Pablo and San Francisco Bays. Results of the diet studies conducted by Stevens (1966) did not include comprehensive coverage of these regions of the estuary. Thomas (1967) did include results of diet studies in the San Pablo and San Francisco Bay regions, however the CDFG estimates of predation were limited to the region upstream of Carquinez Straight (Dave Kohlhorst pers. com., PREDTION.WK4). Therefore the effects of additional striped bass predation on listed salmon and steelhead within these downstream areas was not included in the CDFG predation estimates. This source of bias would have a larger effect on the predation estimates for winter-run and spring-run Chinook salmon and steelhead, which migrate downstream within both San Pablo and San Francisco Bays, not for delta smelt that only occur upstream within the Delta.

3.3.4 Omission of Digested Prey and Digestion Rate

Adult striped bass in the various diet studies (Stevens 1963, 1966, Thomas 1967, Merz 2003, Tucker *et al.* 1998, Nobriga and Feyrer 2008) have been collected with techniques such as hook and line, traps, gill nets, and electrofishing. For some of these collection methods, such as gill netting, the striped bass were held for an undetermined length of time during which they were not foraging and any prey contained in the stomach would continue to be digested. Regardless of the means of capture, some striped bass contain digested prey. As part of the striped bass diet studies (Stevens 1966, Thomas 1967, Kohlhorst pers. com.), prey items that could not be positively identified to a specific species were not included in the analysis.

A second problem is that, depending on prey species and water temperature, the digestion rate within a bass stomach may make prey identification difficult or impossible within a relatively short time period (e.g., 4-12 hours; Buckel and Conover 1996, Johnson et al. 1992, Elliott and Persson 1978) after a predation event. Since only those prey that could be positively identified were included in CDFG's predation estimates, digestion contributed to underestimating predation rates on the listed species. Many Chinook salmon and smelt (particularly smaller individuals) that were preyed upon were not identified to species, and therefore predation rates for these species were substantially underestimated. For example, the predation estimates by striped bass on juvenile Chinook salmon in the lower Mokelumne River (Merz 2003) approximately doubled when suspected salmon that could not be positively identified were included in the estimate. It would have been possible to adjust the predation estimates developed by CDFG to account for partially digested prey, as was done in the predation study reported by Merz (2003).

The CDFG predation estimates also assume that prey are digested to an unidentified stage over a 24 hour period, but they provided no basis or justification for this assumption. The digestion rate for small prey, such as delta smelt or fry and young-of-the-year juvenile salmon, to an unidentifiable stage may be substantially shorter than 24 hours depending on water temperature. . Striped bass digestion rates would increase as water temperatures increase during the spring. Elliott and Persson (1978) discuss the importance of accurate digestion rate when estimating the actual daily consumption of prey by predatory fish. If the average digestion rate is 12 hours, for example, the consumption rate would be twice as large as assumed by CDFG. During the winter when water temperatures are cold and for larger prey such as yearling or older steelhead, this source of bias would not be expected to be as great. But CDFG made no effort to correct for digested prey or actual digestion rates, and CDFG did not acknowledge these sources of bias in its predation estimates.

3.3.5 Omission of Regurgitated Prey

Striped bass often regurgitate their stomach contents during the process of being captured, held, and handled (Johnson *et al*. 1992). This caused CDFG to further underestimate predation rates on the listed species. But CDFG made no effort to correct for regurgitated prey, and CDFG did not acknowledge this source of bias in its predation estimates.

3.3.6 Assumed Single Frequency of Occurrence

CDFG incorrectly assumed that no matter how many prey were positively identified within the stomach contents of a striped bass, predation had occurred on only one individual of the prey species (Dubois 2009; Kohlhorst pers. com. 2009). Striped bass often eat multiple individuals of a prey species, particularly in those locations where one species of prey is concentrated, such as juvenile Chinook salmon migrating downstream in the rivers and at predation hot-spots. Figure 7a-c shows three photographs of striped bass stomach contents in which multiple salmon fry and smolts and a large steelhead/rainbow trout were present. CDFG documented in their 2002 annual report to NMFS that an adult striped bass (420 mm) collected in May 2002 at Miller Ferry Bridge had 39 juvenile salmonids in its stomach (DFG022703). Even when a striped bass stomach was observed to contain more than one of a prey species (e.g., 5, 10, or more) it was assumed in the predation calculations that only one prey had been consumed. This obvious error by CDFG further underestimated predation.

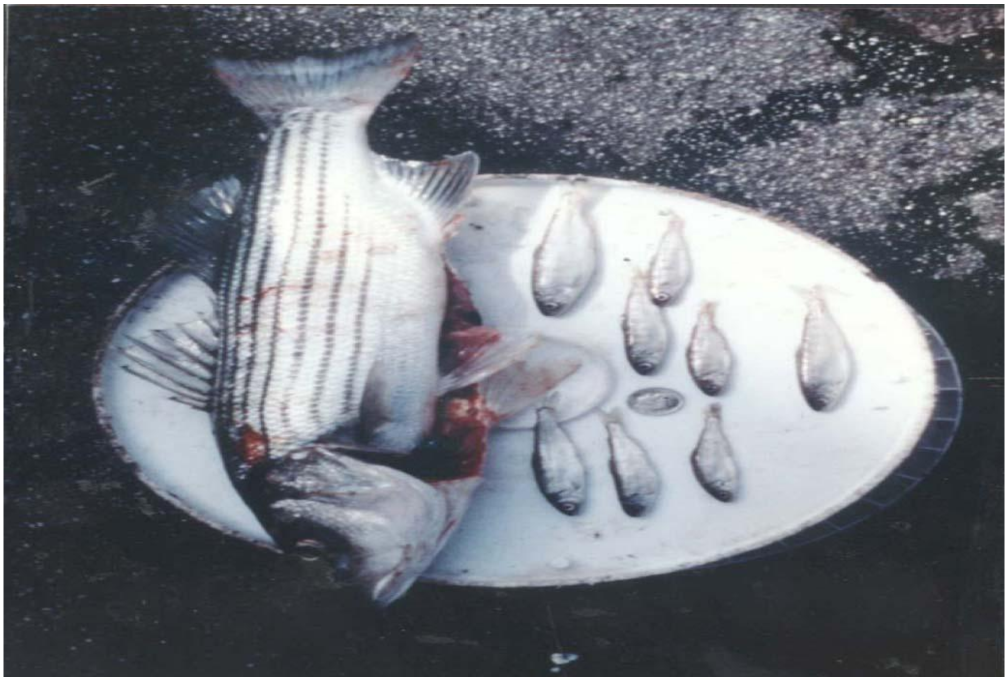


Figure 7a. Striped bass stomach contents. Source: Darryl Hayes at:

http://science.calwater.ca.gov/pdf/workshops/SP_workshop_predation_Hayes_052805.pdf

Figure 7b. Striped bass stomach contents. Source: Darryl Hayes at: http://science.calwater.ca.gov/pdf/workshops/SP_workshop_predation_Hayes_052805.pdf

Figure 7c. Striped bass stomach contents showing predation on steelhead/rainbow trout. Source: Doug Demko, FISHBIO.

The effect of this error is probably greatest for striped bass preying on juvenile winter-run and spring-run Chinook salmon and steelhead within the riverine reaches of the upper and lower Sacramento River. For example, Thomas (1967) reported that 62 juvenile Chinook salmon were present in the stomachs of 45 striped bass sampled. Stevens (1963) observed 207 juvenile Chinook salmon in 105 bass stomachs for an average consumption rate of 2 salmon per bass. Based on the results from Thomas (1967), and assuming a one day digestion rate, each striped bass inhabiting the upper Sacramento River in the spring would consume, on average, 1.4 juvenile salmon. If the digestion rate was assumed to be 12 hours to an unidentifiable stage as discussed above, each striped bass could have consumed 2.8 juvenile salmon per day. This predation estimate is consistent with Merz's predation rate for juvenile Chinook salmon on the lower Mokelumne River of 1.8 to 3.3 salmon per bass per day. In the Mokelumne River study, 199 striped bass were collected in the river downstream of Woodbridge Dam with a total of 335 juvenile salmon (1.7 salmon per bass per day).

3.3.7 Prey Selection/Availability

One of the greatest sources of uncertainty in estimating more current levels of striped bass predation on listed fish species is the absence of robust diet studies reflecting current prevalence of both striped bass and prey species within tributary rivers and Delta. The diet study results used by CDFG were based on surveys conducted in the early and mid-1960's (Stevens 1966, Thomas 1967). There have been a number of significant changes in the estuary habitats and abundance and composition of prey since that time. For example, a number of predation hot-spots such as Clifton Court Forebay and the release of fish salvaged from the SWP export facilities did not exist when the early diet studies were being conducted. The adult striped bass population has decreased in abundance, as have a number of other predator and prey species within the estuary. These and other changes have made it difficult to extrapolate predation estimates with confidence to current conditions. The CDFG predation estimates were developed based on striped bass population estimates and other adjustments to the period from 1993 to 1996. In estimating the percentage of a listed fish that was preyed on by striped bass, CDFG estimated the number of the listed species that were preyed on in a year compared to the abundance of the listed species in that year.

Both bias in the estimate of prey consumption and estimates of prey availability significantly affect the resulting estimate of predation mortality. For example, in estimating predation mortality for delta smelt in 1994, CDFG estimated that 253,509 delta smelt were consumed by striped bass over the course of one year. Based on results of four special fishery studies conducted on June 14, July 3, July 18, and November 17, 1994, CDFG developed estimates of delta smelt abundance for each of the surveys. Two sets of assumptions were made for the vertical distribution of delta smelt in the water column: either (1) delta smelt only occur in the top 6 feet of the water column where sampling with the Kodiak trawl occurred or (2) smelt occurred uniformly throughout the entire depth of the water column. Delta smelt abundance estimates were generated for each assumption and sampling date as shown below.

Estimated delta smelt abundance based on Kodiak trawl sampling in 1994.

Survey Date	Assumes delta smelt only in top 6 feet of water	Assumes delta smelt are uniformly distributed throughout water column	Average Abundance
6/14/1994	**2,079,541**	**7,526,823**	**4,803,182**
7/3/1994	**783,832**	**2,839,317**	**1,807,075**
7/18/1994	**975,773**	**3,605,160**	**2,290,467**
11/17/1994	**377,510**	**1,406,246**	**891,878**

In developing the 1994 predation estimate for delta smelt, CDFG used the average abundance based on the two alternative assumptions regarding the vertical distribution of the delta smelt within the water column. To estimate the annual percentage predation mortality, the estimated prey consumption (253,509 delta smelt) was divided by the <u>highest</u> average abundance estimate (June 14, 1994) to estimate a predation rate of 5.3% ((253,509/4,803,182)*100 = 5.3%). This calculation assumes that all of the striped bass predation occurred only in the month of June. In reality, striped bass predation on delta smelt occurs throughout the year, since both species are present in the Delta throughout the year. By limiting the predation calculation to only the high delta smelt abundance estimate, the resulting estimate of predation in 1994 by striped bass was significantly underestimated.

3.3.8 Prey Field Adjustment

To account for changes in the abundance of listed fish between the 1960's and 1990's, CDFG used several techniques to develop prey adjustment factors. CDFG selected a prey field adjustment based on a ratio of FMWT indices estimated for 1963 (back-calculated by regression analysis since there was no FMWT survey conducted in 1963) and the mid 1990's. To show the importance of the prey field adjustment for delta smelt, consider that with the prey field adjustment, the predation estimate was 253,509 (5.3%), but without the adjustment the predation estimate was 2,272,915 (53.6%) (DFG025865).

CDFG explored three alternative methods to adjust prey field for delta smelt to reflect differences in the abundance of delta smelt between the early 1960's when the diet studies were conducted and the mid-1990's when the predation estimates were based. The first method used the ratio of FMWT catch of delta smelt averaged between 1982 and 1992 divided by the average for 1967 to 1981 separately for each geographic region. The second method used the average

FMWT catch from 1967 to 1981 minus the average from 1982 to 1992 divided by 14 (the number of years between 1973 and 1987) by geographic region. The third approach used the ratio of the 1994 FMWT catch divided by the estimated 1963 FMWT index. Since there was no FMWT in 1963 the estimate the 1963 index was back-calculated using a regression analysis. Only the third method was used in the published predation estimates for delta smelt. By using only the third method for prey field adjustment the resulting estimate of striped bass predation on delta smelt was approximately one-half the estimate using the first or second method of adjustment. There was no discussion or explanation by CDFG why only the third method of adjustment was selected over alternative methods or the implication for the resulting lower predation estimates.

3.3.9. Results

These analyses show that predation is much higher than the original CDFG predation estimates. Unfortunately, the available data is not sufficient to quantify and correct most of these errors.

3.4 Sources of Uncertainty

In addition to the sources of error and bias in the CDFG striped bass predation estimates, there are also sources of uncertainty. Many of the parameters used in calculating predation rates are estimated from various fishery surveys. These parameter estimates have various levels of uncertainty. In addition, the processes that influence the vulnerability of a listed fish to predation vary in response to changes in environmental conditions such as river flow and turbidity, vary in response to changes in the abundance and distribution of both predators and prey, and other factors. The influences of some of these sources of uncertainty on the estimates of predation mortality of the listed fish are briefly discussed below.

3.4.1 Prey Field Adjustments

Results of the striped bass diet studies are affected by the abundance of each prey species. Changes in prey abundance affect the predation rates both at the time when the diet study was performed and for the time period when the predation estimates are derived. Since the early 1960's the abundance of prey species such as delta smelt has declined significantly. These changes in prey abundance over time, and the lack of current diet study information for striped bass from the various regions of the Delta and tributary rivers, adds uncertainty estimating predation. Results of recent fishery surveys have shown that the delta smelt population is at record low levels of abundance (resulting in the species being up-listed under CESA from threatened to endangered status in 2008). At these low population levels, it would be difficult to quantitatively detect the occurrence of delta smelt in the diet of striped bass without an extremely large sample of striped bass, but CDFG has not published any recent extensive striped bass diet studies.

3.4.2 Population Estimates for Striped Bass

The predation estimates developed by CDFG are sensitive to the population abundance estimates and geographic distribution of striped bass ages 1, 2, and 3+. Through the mark-recapture program, CDFG is able to develop quantitative estimates of striped bass abundance for those fish 3 years and older that are represented in recaptures by the recreational fishery. Figure 8 shows results of the adult striped bass abundance estimates. Results of the mark-recapture abundance estimates over the period from 2000 through 2007 (DFG084398) have averaged 1.47 million adult striped bass (ages 3+) and 1.08 million legal striped bass (18 inches and larger). Because the population estimates are based on tag returns from anglers, the most recent years have a great degree of uncertainty (provisional and subject to change as more tags are returned over time) than estimates from several years ago that include more time for recapture in the recreational fishery. The greater the number of tagged fish that are recaptured the greater the accuracy of the abundance estimates.

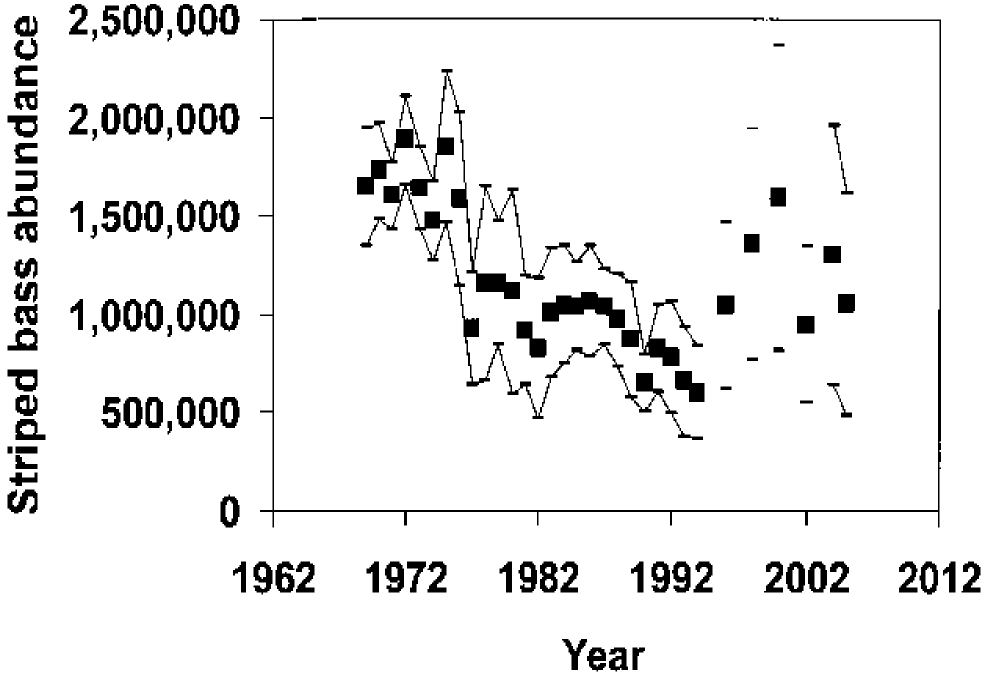


Figure 8. Estimated abundance of adult striped bass, 1969-2005. The official estimate is shown as black squares; the 95% confidence interval is shown as dashes connected by lines when estimates were made in consecutive years. Source: CDFG - Nobriga 2009.

Striped bass ages 1 and 2, are not part of the population that is harvested legally by anglers (minimum legal size is 18 inches) and, therefore there are no quantitative estimates of abundance or distribution of these subadult bass. Results of the diet studies (Stevens 1966, Thomas 1967) showed that subadult striped bass are actively preying on juvenile Chinook salmon and delta smelt. To include estimates of predation by subadult striped bass, CDFG back-calculated age specific abundance by assuming a constant survival rate of 25% for survival from age 1 to age 2 and a 40% survival rate from age 2 to age 3. Using the abundance estimate for age 3 striped bass, estimates were then developed for ages 1 and 2. CDFG provided no analysis of the method used to estimate age-specific survival rates, how these rates vary among years or other bases for the subadult abundance estimates.

To illustrate importance of the estimates of age specific abundance of predatory striped bass, I have used CDFG data to estimate striped bass abundance by age class. The population estimates for striped bass in 1992 were:

Age 1	**4,801,360**
Age 2	**860,835**
Age 3 and older	**1,040,775**
Total (ages 1+)	**6,702,970**

Based on these estimates the total population of striped bass that were potentially preying on listed fish was 6,702,970 striped bass, with the majority (84%) being subadult fish whose abundance was estimated based on the assumed survival rates. These abundance estimates may under or over estimate the actual abundance of predators inhabiting the estuary at any given time, which also directly affects the estimated level of predation on each of the listed fish.

In addition to the estimates of age 1 and 2 striped bass abundance, the CDFG predation calculations also assumed a geographic and seasonal distribution for the occurrence of these sub-adult striped bass within the estuary. The actual geographic distribution was unknown.

3.4.3 Listed Species Abundance

The trend in abundance of winter-run Chinook salmon, as reflected in spawning adults, is shown in Figure 9. Winter-run adult abundance declined substantially during the 1970's and 1980's reaching the lowest level in the early 1990's. Beginning in the late 1990's and continuing through 2006 adult winter-run salmon showed an increasing trend. Adult abundance declined in 2007 and 2008, which is thought to be a response to poor ocean rearing conditions for juvenile salmon in recent years (NMFS 2009a).

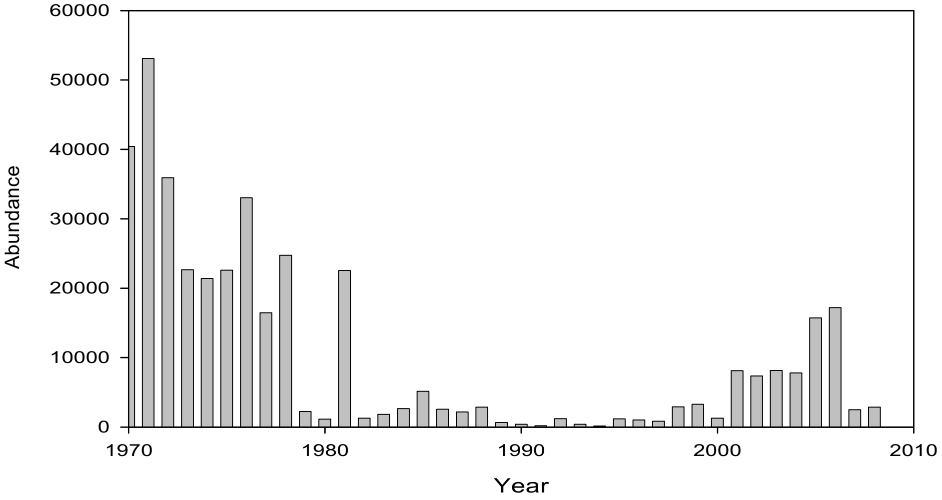


Figure 9. **Annual adult winter-run salmon returns to the Sacramento River. Source: CDFG GranTab and NMFS 2009a.**

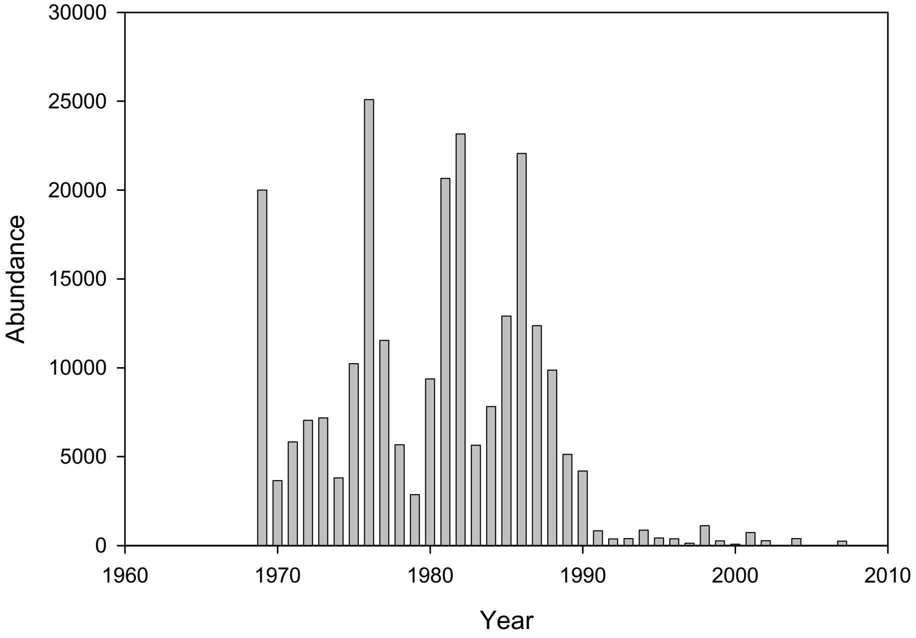


Figure 10. **Annual adult spring-run salmon returns to the Sacramento River system. Source: CDFG GranTab.**

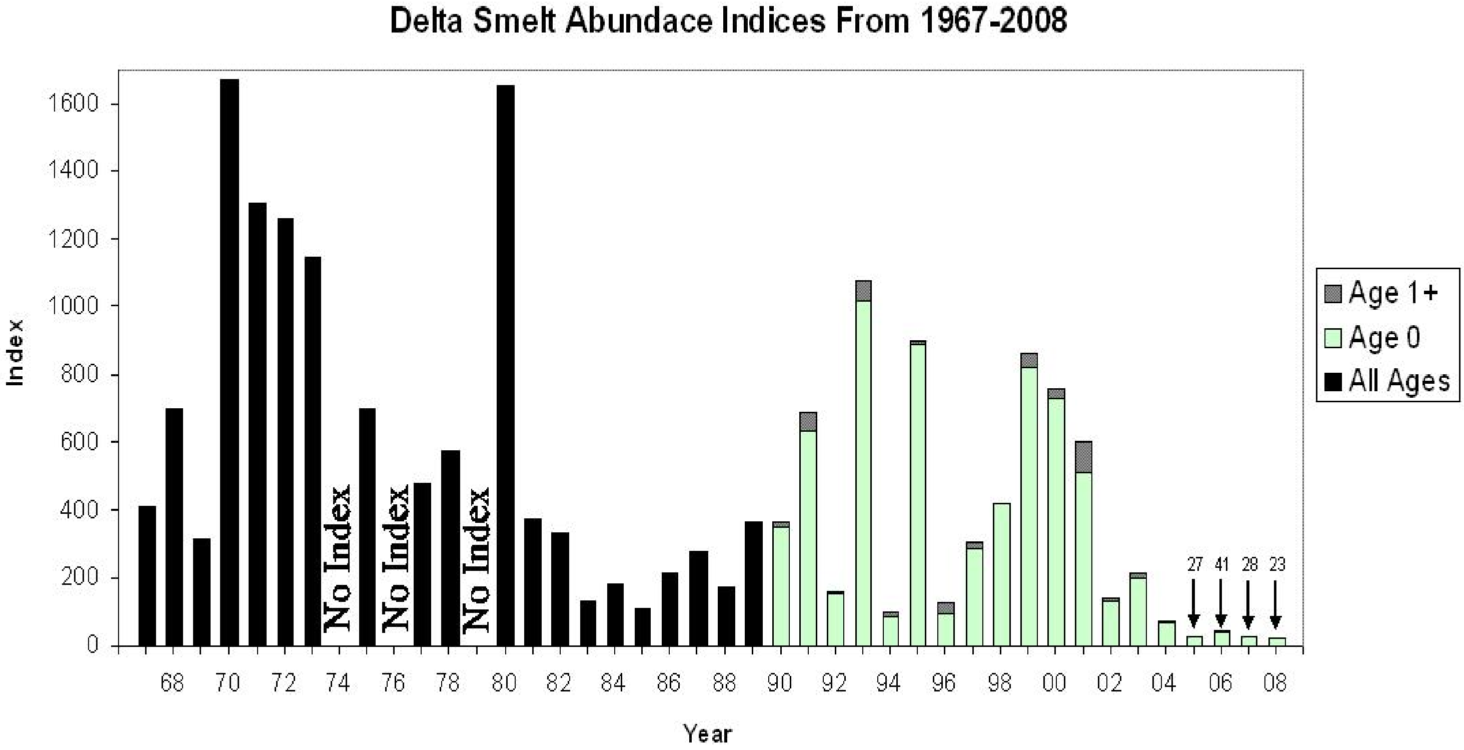


Figure 11. Annual estimates of delta smelt abundance in the FMWT. Source: CDFG Bay-Delta website.

The trend in abundance of spring-run Chinook salmon, as reflected in spawning adults, is shown in Figure 10. Spring-run adult abundance has been characterized by relatively high variability with periodic strong year classes followed by weak year classes. Adult spring-run salmon was lowest during the 1990's followed by an increase in abundance between 1999 and 2006. Unlike winter-run salmon, spring-run adult abundance did not show a marked decline in 2007 or 2008.

No comprehensive estimates are available for Central Valley steelhead. Limited data are available on juvenile steelhead collected in various fishery surveys and on adult steelhead returning to the upper Sacramento River based on counts at the Red Bluff Diversion Dam fish ladder. Over the past decade the Red Bluff Diversion Dam gates have been kept open for a more of the year, which has reduced the reliability of fish ladder counts.

The trends in abundance of delta smelt are reflected in results of the Fall Midwater Trawl (FMWT) collections made each year in September-December. Results of the FMWT surveys from 1967 through 2008 are shown in Figure 11. Delta smelt abundance fluctuated substantially among years. Although delta smelt abundance reached low levels in some years (e.g., 1992, 1994, 1996) the abundance recovered in subsequent years. Beginning in 2002 the delta smelt abundance has remained at low levels, with the lowest indices of abundance on record occurring during 2005-2008. These record low levels of abundance for delta smelt, and other pelagic organisms, reflect the Pelagic Organism Decline (POD).

4. REVISED ESTIMATES OF STRIPED BASS PREDATION ON LISTED FISH

In the following section I analyze predation mortality by striped bass on winter-run Chinook salmon, spring-run Chinook salmon, Central Valley steelhead, and delta smelt. I begin with the analytic framework developed by the earlier CDFG predation estimates with revised or corrected assumptions based on the best available scientific data and our current understanding of striped bass and the listed fish inhabiting the Bay-Delta system.

4.1 Winter-run Chinook salmon

Winter-run Chinook salmon spawn and juveniles rear in the mainstem Sacramento River. The primary spawning area is located on the Sacramento River between Redding and Red Bluff. Juvenile winter-run salmon also rear further downstream in the mainstem Sacramento River. Juvenile winter-run Chinook salmon migrate downstream from their rearing habitat during the late winter and spring months through the mainstem Sacramento River and Delta to enter the coastal marine waters. During their downstream migration these juvenile salmon are vulnerable to predation by striped bass and other predatory fish including pikeminnow in the river and largemouth bass within the Delta (Nobriga and Feyrer 2007). CDFG developed estimates of predation mortality on juvenile winter-run Chinook salmon based on data available for 1993-1996. CDFG assumed that the frequency of occurrence of winter-run salmon in the diet of striped bass in the lower reaches of the Sacramento River would be 1.2% in the fall, 16.74% in spring, and 2.24% in summer for striped bass age 1 and 2, and that striped bass ages 3+ would not forage at all on juvenile winter-run salmon in the Sacramento River during the fall, winter, or spring, and that the frequency of occurrence in summer would be 2.24%. The basis for these assumptions was not presented in the 1998 draft or final CDFG EIR or incidental take application. The CDFG predation estimates also incorrectly assumed that the consumption rate of juvenile salmon would never exceed 1 salmon per bass.

Based on these assumptions CDFG estimated that striped bass predation (assuming a 1994 striped bass abundance of 712,000 adults) on juvenile winter-run Chinook salmon averaged 5.6%. CDFG estimated a predation rate separately for each of the four years included in the analysis that ranged from 0.9% (1993) to 16% (1995) reflecting differences among years in the timing of winter-run outmigration and changes in striped bass abundance and distribution (PREDTION.WK4). With a striped bass population abundance of 1.1 million fish, which is similar to the current population estimates (Section 3.2), the predation on winter-run Chinook salmon estimated by CDFG was 8.7%.

As discussed above, CDFG assumptions of the frequency of occurrence of juvenile salmon in the striped bass diet within the river reaches of the Sacramento River are substantially lower than the results of the two diet studies within the river. Stevens (1963) identified substantially higher predation rates for juvenile salmon by striped bass in the Sacramento River between Rio Vista and Freeport (discussed above). Thomas (1967) also collected striped bass from the Sacramento River upstream of Rio Vista into the lower American River during the spring. Thomas (1967) reported that juvenile salmon had a frequency of occurrence of 62% in the striped bass (n=45) sampled and represented the dominant prey (65% of the striped bass diet by volume). Results of a striped bass diet study conducted on the Mokelumne River (Merz 2003) showed that 335 juvenile salmon were eaten by 199 striped bass representing an average consumption rate of 1.7 salmon per bass during the spring. Stevens (1963) reported a juvenile salmon consumption of 207 salmon present in 119 striped bass stomachs containing prey representing an average consumption rate in the lower Sacramento River during June of 1.7 salmon per bass. For purposes of reanalyzing juvenile winter-run Chinook salmon predation rates, based on these diet studies, I used a frequency of occurrence of 62% for striped bass ages 1+ and an average consumption rate of 1.5 salmon per bass. I based my estimate of the number of juvenile salmon eaten (1.5 salmon per bass) on the prey consumption rates reported by Stevens 1963; 2 salmon per bass), Thomas (1967; 1.4 salmon per bass), and Merz (2003; 1.7 salmon per bass)

Juvenile winter-run Chinook salmon migrate downstream in the Sacramento River during the winter and early spring months. Although striped bass are present in the river during the winter months, the available diet studies do not provide data on the frequency of occurrence of juvenile salmon in the striped bass diet in the winter. Results of acoustic and coded wire tagging studies, however, have shown high mortality of juvenile salmonids within the river during the winter months. Since there are no diet study data on striped bass within the upper river during the winter, I cannot estimate the contribution of striped bass predation to the total mortality, but the omission of winter predation would result in an underestimation of predation on juvenile winter-run Chinook salmon.

In Section 3.2, I discuss a number of factors that contributed to underestimating striped bass predation mortality on juvenile winter-run Chinook salmon. For most of the errors and sources of bias in developing predation estimates, the available data are insufficient to quantitatively revise the predation estimates to account for the sources of bias. As a consequence of the lack of data to correct many of these sources of bias, the estimates that I present below also underestimate predation rates on listed fish. I have revised the predation estimates to correct those two sources of bias where sufficient data exist. The results of my re-analysis of winter-run predation in 1993-1996, assuming the same seasonal distribution of winter-run Chinook salmon migration as CDFG, are shown below:

Striped bass predation on juvenile winter-run Chinook salmon.

	Adult Striped Bass (ages 3+) Abundance	**CDFG Original Estimates**		**Corrected for Frequency of Occurrence in the Upper Sacramento River (62% in Spring) and Number of Prey (1.5 fish) per Striped Bass**	
Analysis Year		Number Winter-run Salmon Lost to Striped Bass Predation	Percentage	Number Winter-run Salmon Lost to Striped Bass Predation	Percentage
1993	1,040,775	2,564	0.9	2,564	0.9
1994	776,333	2,493	2.8	10,655	11.8
1995	1,192,247	11,887	16.0	49,459	66.4
1996	1,003,000	3,837	1.0	13,256	3.3
Average	1,003,089	5,195	5.2	18,984	**20.6**

CDFG provided no confidence intervals for their predation estimates. For the reasons discussed in Section 3, there is high uncertainty in estimating striped bass predation rates. Since CDFG does not provide confidence intervals for the parameters used in the estimates, I have not been able to estimate confidence intervals for these estimates. But I am confident that my estimates are more accurate, since I corrected two of the errors in the CDFG estimates, and the other errors led CDFG to further underestimate predation.

Results of these analyses show that the risk of predation mortality by striped bass, particularly in the mid- and upper reaches of the Sacramento River, is substantially greater than indicated by the published CDFG predation estimates. While this corrected average predation rate of 20.6% is substantially higher than CDFG's published predation estimates for winter-run Chinook salmon (4 to 9%) it is lower than CDFG's unpublished bioenergetics based analysis that generated an average predation rate estimate of 30% for winter-run salmon (see Section 3.2.2).

Analyses of striped bass predation have assumed that predation varies in direct proportion to the abundance of striped bass (CDFG 1998a,b, Lindley and Mohr 2003). In the predation calculation presented here I have also assumed that predation on listed fish varies directly in response to striped bass abundance. Results of my analyses, using the same analytic framework and basic assumptions as CDFG and assuming an adult striped bass population of approximately 1 million fish, with the exception of corrections for upstream frequency of occurrence in the striped bass diet and average number of prey per bass, was approximately 21%. As discussed in Section 3.2, CDFG incorrectly assumed much lower estimates of salmon in the diet of striped bass within the Sacramento River, assumed that striped bass would never prey on more than one salmon per day, omitted predation on juvenile salmon migrating during the winter, and the effects of digestion and regurgitation of prey. Had CDFG predation rate estimates taken into account these factors, their predation estimate would be substantially greater than the 5.6%-8.7% reported by CDFG.

These estimates are consistent with the findings discussed in Section 3.3.1 that juvenile salmon represent the major prey for striped bass within the river during the spring and early summer. These results are also consistent with the findings of prior coded wire tag studies, and more recent results of acoustic tagging experiments, that consistently show high levels of mortality (80-90%) for juvenile salmon migrating downstream in the Sacramento River. Only 2% of the juvenile Chinook salmon and 7% of the juvenile steelhead released up river were detected migrating through the Golden Gate (McFarlane *et al.* 2008). Results of similar acoustic tag survival studies conducted using late fall-run Chinook salmon during the winter in 2007 and 2008 found survival rates for fish released into the Sacramento River near Sacramento, and migrating downstream through the Delta, to range from less than 10% survival to approximately 60% survival depending on migration route (Perry and Skalski 2008, 2009). Bowen et al. (2009) also reported high levels (68% loss) mortality to juvenile salmon in only a short section of the lower San Joaquin River during the spring. Field observations by Bowen et al. (2009) documented that predation by striped bass was a major source of salmon mortality (see Section 3.3.1). These and other acoustic tag studies support the finding that predation by striped bass in the Sacramento River represents a major source of mortality to migrating juvenile winter-run Chinook salmon.

The higher predation estimates of CDFG's unpublished bioenergetics analysis and this report have major implications for the survival and management of this endangered species. NMFS identified an allowable level of take of juvenile winter-run Chinook salmon as a result of direct export losses (as measured through salvage of juvenile salmon at the SWP and CVP export facilities) to be 1% of the estimated number of juvenile winter-run salmon migrating through the Sacramento River as a warning level (yellow light) and a 2% take would trigger reconsultation and major changes to SWP and CVP export operations (red light). NMFS now recommends a significant reduction of striped bass and other non-native predators to prevent extinction of salmon and steelhead (NMFS 2009b).

Lindley and Holsinger (1996), and subsequently Lindley and Mohr (2003), prepared analyses of the effect of striped bass predation mortality on winter-run Chinook salmon as part of the NMFS review of the CDFG proposed striped bass management plan. A statistical model was developed to estimate the effects of managing the adult striped bass population at levels of 512,000 fish, 700,000 fish, and 3 million fish. The model was then used to estimate the change in the probability of winter-run Chinook salmon recovery, and the probability of winter-run salmon extinction. The model assumed the low predation rates developed by CDFG. The model was used to estimate recovery and extinction probability based on assumptions of density dependant and density independent survival. I only discuss results of the density dependant model below since, in my opinion, it best reflects conditions in the upper river. The density dependant model predicted a 23% extinction risk if no striped bass were present in the estuary, which increased to 28% at a striped bass population of 512,000 adults, to 30% at a striped bass population of 700,000 fish and to 55% if the striped bass population increased to 3 million fish. The model predicted that the probability of winter-run salmon recovery was approximately 14% with no striped bass predation, which decreased to 11% at a striped bass population of 512,000 adults, to 10% at a striped bass population of 700,000 adults, and to 4% at a striped bass population of 3 million adults. These results show that, even using the CDFG low predation estimates: (1) striped bass predation increases the risk of extinction and reduces the probability of recovery when the striped bass population abundance increases, (2) a reduction in striped bass contributes to a reduction in the risk of extinction, and (3) if higher corrected predation rates on juvenile winter-run Chinook salmon (approximately 20% based on my estimates to 30% based on CDFG's bioenergetic estimates) were introduced into the model, the incremental risk of extinction attributable to predation would greatly increase.

4.2 Spring-run Chinook Salmon

Spring-run Chinook salmon spawn and rear in major tributaries to the Sacramento River such as Mill, Butte, Clear, and Deer Creeks, the Feather River, and the mainstem Sacramento River. Juvenile spring-run Chinook salmon migrate downstream from their rearing habitat during the late winter and spring months through the mainstem Sacramento River and Delta to enter the coastal marine waters. During their downstream migration these juvenile salmon are vulnerable to predation by striped bass and other predatory fish including pikeminnow in the river and largemouth bass in the Delta (Nobriga and Feyrer 2007). CDFG developed estimates of predation mortality on juvenile spring-run Chinook salmon based on data available for 1993-1994. CDFG assumed that the frequency of occurrence of spring-run salmon in the diet of striped bass in the upper reaches of the Sacramento River would be 1.2% in the fall, 16.74% in spring, and 2.24% in summer for striped bass ages 1 and 2, and that striped bass ages 3+ would not forage at all on spring-run salmon in the Sacramento River during the fall, winter, or spring, and that the frequency of occurrence in summer would be 2.24%. CDFG also incorrectly assumed that striped bass consumed 0 spring-run Chinook salmon in the winter. The basis for these assumptions was not supported by CDFG in the 1998 draft or final EIR or incidental take application. The CDFG predation estimates also assumed incorrectly that the consumption rate of juvenile salmon would never exceed 1 salmon per bass. Assuming an adult striped bass population abundance of 712,000 fish, CDFG estimated the predation loss in 1994 to be 3.2%. The predation estimates assuming an adult striped bass population abundance of 1.1 million striped bass was 4.9% (CDFG 1998 a, b).

As discussed in Section 4.1, the assumptions of the frequency of occurrence of juvenile salmon in the striped bass diet within the river reaches of the Sacramento River used in the CDFG estimates are substantially lower than the results of the diet studies of predation within the river. For purposes of reanalyzing juvenile spring-run Chinook salmon predation rates, I assumed a frequency of occurrence of 62% for striped bass ages 1+ and an average consumption rate of 1.5 salmon per bass.

The results of my re-analysis of spring-run predation in 1994 are shown below:

Striped bass predation on juvenile spring-run Chinook salmon.

	Adult Striped Bass (ages 3+) Abundance	**CDFG Original Estimates**		**Corrected for Frequency of Occurrence in the Upper Sacramento River (62% in Spring) and Number of Prey (1.5 fish) per Striped Bass**	
Analysis Year		Number Spring-run Salmon	Percentage	Number Spring-run Salmon	Percentage
1994	1,003,000	45,806	6.6(1)	292,045	**42.3**

(1)This unpublished estimate is 1.7% higher than the published predation estimate by CDFG. I was unable to determine from the available records why the differences exist.

Based on results of these analyses it is my opinion that the risk of predation mortality by striped bass, particularly in the upper reaches of the Sacramento River during the late winter and spring period of juvenile outmigration, is substantially greater than indicated by the earlier CDFG predation estimates. Results of my analyses, using the same analytic framework and basic assumptions as CDFG and assuming a striped bass population of approximately 1 million adults, with the exception of corrections for upstream frequency of occurrence in the striped bass diet and average number of prey per bass, was approximately 42%.

As discussed in Section 4.1, NMFS identified an allowable level of take of juvenile spring-run Chinook salmon as a result of direct export losses to be 1% as a warning level (yellow light) and a 2% take would trigger reconsultation and major changes to SWP and CVP export operations (red light).

As discussed in Section 4.1, these results are consistent with the diet study findings that juvenile salmon represent the major prey resource for striped bass within the river during the spring and early summer. These results are also consistent with the findings of survival studies that consistently show high levels of mortality for juvenile salmon migrating downstream in the Sacramento River. MacFarlane *et al.* (2008) reported that only 2% of the juvenile Chinook salmon and 7% of the juvenile steelhead released in these studies were detected migrating through the Golden Gate.. These and other survival studies have shown low survival for juvenile Chinook salmon migrating downstream through the Sacramento River and Delta that are consistent with the finding of my analysis that predation by striped bass in the Sacramento River represents a substantial, and is probably the largest source of mortality for juvenile spring-run Chinook salmon.

4.3 Central Valley Steelhead

Prior striped bass diet studies have not identified steelhead as an element in the diet of striped bass (Stevens 1963, 1966, Thomas 1967, Nobriga and Feyrer 2008). To my knowledge, the results of the Clifton Court Forebay survival studies (Clark *et al.* 2009) are the first to quantitatively estimate predation mortality on juvenile steelhead within the Delta. Several factors may contribute to the absence of steelhead in these prior studies. Juvenile steelhead migrate downstream at age 1 or 2, and the juveniles are substantially larger than juvenile migrating salmon and therefore may be less vulnerable to predation by smaller subadult striped bass. Larger juvenile steelhead also have greater swimming ability to avoid predation. Also, the prior diet studies focused on predation within the Delta and did not sample striped bass extensively from the upstream rivers where the predation risk to steelhead would be higher. Results of a predation study conducted using juvenile steelhead within Clifton Court Forebay (Clark *et al.* 2009) clearly demonstrated that juvenile steelhead are preyed on by striped bass. Predation within the forebay on steelhead (referred to as pre-screen mortality) was estimated using acoustic tags placed on both juvenile steelhead released into the forebay as well as adult striped bass collected from within the forebay, as well as from juvenile steelhead tagged using PIT tags. Results of this study estimated that losses of juvenile steelhead were 78% (CI +/- 4%). The loss estimate for juvenile steelhead was similar to the results of previous studies using juvenile Chinook salmon that also showed losses in excess of 80% (Gingras 1997).

Based on the seasonal timing of juvenile steelhead emigration, their similarities to juvenile Chinook salmon (particularly those that migrate downstream as yearlings), the results of the Clifton Court Forebay predation study, and results of acoustic tag survival studies conducted on the Sacramento River using juvenile steelhead that showed greater than 80% mortality in a 150 km reach of the river and 93% loss before pass the Golden Gate (MacFarlane *et al.* 2008), it is my opinion that predation by striped bass on steelhead would be below the range described for spring-run and winter-run Chinook salmon. A striped bass would only consume one steelhead because of their larger size, consequently. Larger juvenile steelhead are probably only eaten by large striped bass (age 3+). The predation rate on juvenile steelhead would be expected to be reduced to approximately 7 to 15%.

There is a high degree of uncertainty in estimating the predation rate on juvenile steelhead based on the lack of data regarding the contribution of steelhead to the diet of striped bass within the Sacramento River. Although the sample size of acoustic tagged steelhead (n=200) released in the survival study conducted by MacFarlane *et al.* (2008) is small, the high mortality rate for juvenile steelhead within the Sacramento River indicates that predation mortality on juvenile steelhead, like other salmonids, is a larger factor than previously thought.

4.4 Delta Smelt

CDFG estimated predation on delta smelt based on information available for the period 1993 and 1994. The predation estimates included in the CDFG PREDTION.WK4 spreadsheets for delta smelt included annual predation losses of 2,862,594 and 3,387,591, which were subsequently adjusted by CDFG using various changes to striped bass abundance and geographic distribution to estimate a delta smelt predation loss of 253,509 (approximately one order of magnitude lower than the original estimates) in 1994. The predation loss estimate reported by CDFG in the 1998 draft and final EIR and incidental take permit application for delta smelt in 1994 was 253,509 fish, representing a percentage loss of 5.3% (based on the highest level of delta smelt abundance (June) estimated for the year) which I discuss in Section 3.2.

The estimate of predation mortality on delta smelt developed by CDFG in 1994 (5.3%) underestimated the actual predation rate based on a number of factors discussed in Section 3.2. For example, delta smelt are a small fish that would be rapidly digested to a point where it would not have been positively identified, and therefore not included in CDFG's estimates for predation. Further, as discussed in Section 3.2, CDFG used the highest estimated population abundance estimate (June 14, 1994) when delta smelt are in the early juvenile lifestage and more abundant than during the remainder of the year. Had the predation rate estimate taken into account that delta smelt live their entire life in the Delta and are vulnerable to striped bass predation year-round, the predation rate estimate would be substantially greater than the 5.3% reported by CDFG as discussed below.

Assuming that striped bass predation occurs on juvenile, subadult, and adult delta smelt (e.g., assuming that striped bass do not prey extensively on larval smelt) and using the average abundance estimates from CDFG presented above, the abundance of delta smelt by season can be estimated. I assumed that the average of the June and July estimates would represent delta smelt abundance in the spring and summer and that the November estimate would reflect delta smelt abundance in the fall and winter. I then used the seasonal distribution in delta smelt consumption by striped bass developed by D. Kohlhorst (presented in the PREDTION.XLS spreadsheet). The corrected results are presented below:

Seasonal period	**Percentage delta smelt consumption**	**Estimated number of delta smelt consumed (assuming a total of 253,509 from CDFG)**	**Estimated delta smelt abundance**	**Percentage predation mortality on delta smelt**
Spring-Summer	19%	48,167	2,966,908	1.6%
Fall-Winter	81%	205,342	891,878	23.0%
Average				**13.1%**

These calculations, which have been based on CDFG consumption and abundance estimates, show that predation mortality may have a substantially greater effect on subadult and adult delta smelt during the fall and winter, when the population abundance is lower, and prior to spawning, when compared to the lower estimates of predation losses during the spring and summer on the more abundant juvenile delta smelt. In terms of the risk of extinction resulting from striped bass predation mortality, predation on pre-spawning adult delta smelt would have a substantially greater population effect than predation on juvenile smelt. The predation estimates developed and presented by CDFG used an overall annual average which does not take into account the natural survival of delta smelt or the increased value of the loss of a pre-spawning adult to the reproduction and population dynamics of the species.

Since the earlier CDFG predation loss estimates were made, the delta smelt population abundance, as reflected in the CDFG FMWT surveys, has declined significantly, probably due to striped bass predation and many other stressors. Delta smelt abundance indices in recent years have been the lowest recorded. As a result of this decline in delta smelt abundance, delta smelt have been included in the Pelagic Organism Decline (POD) and have recently been reclassified under the California Endangered Species Act (CESA) from threatened to endangered status. Results of a recent striped bass diet study (Nobriga and Feyrer 2008), although having a small sample size of striped bass, did not detect delta smelt in striped bass stomachs sampled. These results are consistent with a finding that delta smelt are currently at such low abundance in the Delta that results of such small fishery surveys are not sensitive enough to confidently detect occurrence at the current low densities.

On the other hand, observations on the diet of approximately 70-100 striped bass collected by hook and line on the lower Mokelumne River in the vicinity of Willow Berm Marina between 2000 and 2004 showed that at least two delta smelt had been consumed (J. Merz, pers. com.). The stomach contents from these striped bass are available but have not been processed. If the frequency of occurrence of delta smelt in the diet of these striped bass had been extrapolated to the entire Delta, the resulting predation rate by striped bass would have been very high. Because of the limited geographic distribution and small sample size it is not appropriate to extrapolate these results to the Delta or to the entire delta smelt population. These results do, however, show that predation by striped bass on delta smelt may currently be higher than reflected in the diet study by Nobriga and Feyrer (2008).

These results are consistent with a finding that delta smelt are currently at such low abundance in the Delta that results of such small fishery surveys are not sensitive enough to confidently detect occurrence at the current low densities. Based on the current low abundance of delta smelt inhabiting the Delta, it is my opinion that quantitative extrapolation of predation rates based on striped bass diet studies conducted in the early 1960's, and the relatively low sample size of striped bass collected by Nobriga and Feyrer (2008), would not provide reliable estimates of current delta smelt predation losses. It is possible that as the delta smelt population abundance has declined in recent years, predation by striped bass has declined, with the striped bass switching to more abundant alternative prey species. However, at the current low abundance of delta smelt, any incremental mortality would have adverse population impacts to delta smelt and increase their risk of extinction.

As discussed in the POD investigations (Baxter *et al.* 2008, Loboschefsky *et al.* 2009, and others), the Bay-Delta ecosystem, and many of the aquatic species, have declined. There are a variety of stressors and factors that have contributed to these conditions. Predation by striped bass has been identified as one factor that has contributed to the observed declines (Baxter *et al.*

2008). When an ecosystem or species is healthy and robust, it is better able to withstand the effects of various sources of mortality, including predation. When the species is stressed and its health and abundance are depressed, the species is more vulnerable to the adverse effects of stressors, such as predation mortality (Lindley *et al*. 2007, NMFS 2009a).

Larval and juvenile striped bass forage on zooplankton, which also represents the food supply for larval, juvenile, and adult delta smelt (Bennett 2005). There has been evidence that zooplankton densities within the Delta have declined in recent years and that limited food resources may be an important factor affecting the health and abundance of delta smelt (Baxter *et al.* 2008). Foraging by larval and early juvenile striped bass contributes to an incremental reduction in zooplankton within the Delta during the spring and early summer, but I do not believe that competition between delta smelt and young striped bass for food resources is a major factor controlling delta smelt abundance.

In my opinion, the current level of predation mortality by striped bass is probably not the primary stressor to delta smelt. Delta smelt inhabit the Delta year-round, but are distributed over relatively large areas, particularly within Suisun Bay, and appear to preferentially associate with higher turbidity waters that would likely reduce the risk of detection by predators. Striped bass predation on the current population of delta smelt is probably less than 5%. But even a small amount of predation may increase the already high risk of delta smelt extinction and reduce the probability of delta smelt recovery.

5. CONCLUSION: BENEFITS OF REDUCED BASS PREDATION

The extinction probability model developed by Lindley and Mohr (2003) shows that a reduction in the striped bass population would increase the probability of survival of winter-run Chinook salmon, especially if the modeling assumed higher striped bass predation. In contrast, it has been argued (Nobriga 2009) that a reduction in striped bass abundance and predation may not appreciably benefit listed fish, because some other predators would increase in abundance and increase their predation on the listed species. Within the lower Delta, a reduction in striped bass abundance could increase the abundance of other predatory fish such as largemouth bass or inland silversides that prey on delta smelt. Predicting the biological response to a reduction in striped bass abundance in the lower Delta is complex because of the numbers of predatory fish and their interactions.

Within the upper most Sacramento River upstream of the Red Bluff Diversion Dam, resident trout/steelhead are the most abundant predator on salmonids – primarily feeding on eggs and rearing juveniles. But predatory trout and steelhead are limited to only the upper most reach where seasonal water temperatures remain cold (NMFS 2009a). As the juvenile salmon and steelhead migrate downstream within most of the length of the Sacramento River, however, there are only two dominant predator species, which prey on juvenile salmonids: striped bass and Sacramento pikeminnow. These two species have different life histories, habitat preferences, and geographic distributions. Pikeminnow live their entire life in the upstream freshwater reaches of the river, while striped bass predominantly migrate upstream from the brackish and marine regions of the estuary into the river during the late winter and spring when juvenile salmon are numerous and migrating downstream. There is no evidence to suggest that striped bass predation controls pikeminnow population abundance, in part, because of the geographic and temporal separation between the two species. Further, pikeminnow are a native species that has co-evolved with Chinook salmon, and juvenile Chinook salmon is not a key component in the pikeminnow diet during most of the year (Tucker *et al.* 1998). In addition, adult striped bass are larger than pikeminnow and can consume larger prey such as yearling and older salmonids (see Figure 7c), and the striped bass population has a substantially greater biomass that consumes a greater biomass of prey. Pikeminnow inhabiting the Sacramento River use the juvenile salmonids as a prey resource during the emigration period, but the abundance of pikeminnow is limited by prey availability during those periods of the year when juvenile salmonids are not available as prey. Consequently, the pikeminnow cannot substantially increase their population abundance, even if the striped bass population decreased due to deregulation. In summary, a reduction in striped bass abundance and predation should result in a similar reduction in total mortality to juvenile winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead.

Bennett (2009) demonstrates that elimination of the striped bass fishing regulations would result in a 60-70% reduction in the overall abundance of striped bass inhabiting the Bay-Delta. For simplicity I assume that deregulation would reduce bass abundance by 65%. This is consistent with prior conclusions of CDFG. Delisle and Stevens (1993) concluded that deregulation of the striped bass fishery would substantially reduce large striped bass and decimate the fishery in the Sacramento River spawning areas. Since almost all striped bass predation on salmonids occurs in the upriver areas, decimating the population of adult striped bass inhabiting the upper Sacramento River could almost eliminate all striped bass predation on salmonids, not only 65% of it. The previous analyses conducted by CDFG as part of the 1998 draft and final EIR and incidental take permit application, as well as the extinction and recovery model developed by Lindley and Mohr (2003), assume that striped bass predation mortality on listed fish will change in direct proportion to striped bass abundance. Assuming only a proportional reduction in predation mortality, a 65% reduction in striped bass abundance would result in the following approximate reductions in predation mortality of the three listed salmonid species, based on my predation estimates in Section 4:

(1) Winter-run salmon – from 21% to 7% – a benefit of 14%;

(2) Spring-run salmon – from 42% to 15% – a benefit of 27%;

(3) Central Valley steelhead – from 7-15% to 2-5% – a benefit of 5 to 10%.

Had I been able to correct for the other errors and omissions in the CDFG predation calculations, the expected benefits would be greater.

A reduction in striped bass abundance on the order of 60-70% would, in my opinion, contribute to a proportional reduction in the total mortality of juvenile winter-run and spring-run Chinook salmon and Central Valley steelhead. Although a variety of factors affect the survival of emigrating juvenile salmonids within the river and Delta, losses as a result of striped bass predation, are in my opinion, a major factor, if not the dominant factor, affecting survival of migrating juvenile salmonids. Reducing striped bass predation mortality on listed salmonids would substantially reduce the risk of their extinction and increase the probability of recovery of these species.

In contrast, at the current low population level of delta smelt, their broad geographic distribution within the more turbid areas of the Delta, and the abundance of other predators on delta smelt inhabiting the Delta, I would expect that a reduction in the striped bass population would not significantly reduce predation mortality on delta smelt. However, at the low population level of delta smelt, even a small increase in survival resulting from a reduction in predation mortality would be important to avoiding extinction and contributing to the probability of recovery.

Striped bass and Chinook salmon, steelhead, and delta smelt have co-existed within the Bay-Delta system for over a century. Predators and their prey typically establish a dynamic equilibrium in abundance. As long as the ecosystem is healthy and the prey populations are robust, predation mortality becomes one of the factors affecting population dynamics of the prey species. But, when multiple stressors reduce the health, fitness, survival, and abundance of the prey, and damage the ecosystem, the prey populations decline (NMFS 2009a). Within the Bay-Delta there is no doubt that prey populations such as delta smelt, salmon, steelhead, and other species have suffered the effects of a variety of stressors. Land use changes, contaminants, invasive species, predation, water project operations, changes in aquatic habitat quality and availability, depleted food supplies, and other stressors have damaged the ecosystem. Stressors such as predation mortality increase in importance when the health of the species and the ecosystem is degraded.

Predation by striped bass is not the sole cause of the declines in listed fish, but it may be the largest cause of mortality to salmon and steelhead. NMFS now recommends a significant reduction of striped bass and other non-native predators to prevent extinction of the salmon and steelhead (NMFS 2009b). Reducing striped bass abundance through deregulation would substantially reduce predation mortality and benefit the populations of winter-run and spring-run Chinook salmon and steelhead. Allowing fishermen to reduce striped bass predation via deregulation is probably the most efficient and cost-effective method to contribute to recovery of Central Valley salmon and steelhead. Unless this is done, expensive management programs designed to improve their survival within the lower Delta are unlikely to save these listed species.

4. SUPPLEMENTAL OPINIONS

I am informed that CDFG document production and discovery are continuing. Consequently, I may supplement or modify my opinions, and I may respond to the opinions of others in this case.

5. COMPENSATION

My compensation for all work in this case is $180.00 per hour.

6. LITERATURE CITED

Baxter, R., R. Bruer, L. Brown, M. Chotkowski, F. Feyrer, B. Herbold, P. Hrodey, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. Interagency Ecological Program 2008 work plan to evaluate the decline of pelagic species in the Upper San Francisco Estuary.

http://www.science.calwater.ca.gov/pdf/workshops/POD/POD_workplan_2008_060208.pdf

Bennett, D.H. 2009. Expert Report of Dr. David H. Bennett Per Rule 26(a)(2). Coalition for a Sustainable Delta et al. v. Koch, E.D. Cal. Case No. 08-397. September, 2009

Bennett, W.A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science. Vol. 3, Issue 2, Article 1. Available: http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1 (September 2005).

Bowen, M.D., S. Hiebert, C. Hueth, and V. Maisonneuve. 2009. 2009 effectiveness of a non-physical fish barrier at the divergence of the Old and San Joaquin Rivers (CA). Draft Report. Tech. Memo. 86-68290-11. U.S. Bureau of Reclamation

Brown, R. S. Greene, P. Coulston and S. Barrow. 1996. An evaluation of the effectiveness of fish salvage operations at the intake of the California aqueduct, 1979 – 1993. In: Hollibaugh JT, editor. San Francisco Bay: The Ecosystem. Pacific Division, American Association for the Advancement of Science, San Francisco, CA. p 497–518.

Buckel, J.A. and D.O. Conover. 1996. Gastric evacuation rates of piscivorous young-of-the-year bluefish. Trans. Amer. Fish. Soc. 125: 591-599.

CDFGa (California Department of Fish and Game).1998. Draft Striped Bass Management Program Environmental Impact Report and Draft Conservation Plan for the California Department of Fish and Game Striped Bass Management Program, prepared pursuant to Section 10(a)(1)(B).

CDFGb (California Department of Fish and Game).1998. Final Striped Bass Management Program Environmental Impact Report,

Clark, K.W., M.D. Bowen, R.B. Mayfield, K.P. Zehfuss, J.D. Taplin, and C.H. Hanson. 2009. Quantification of pre-screen loss of juvenile steelhead in Clifton Court Forebay. Fishery Improvements Section Bay-Delta Office CA Department of Water Resources In collaboration with: National Marine Fisheries Service Central Valley Fish Facilities Review Team Interagency Ecological Program Management Team.

Delisle, G. and D. Stevens. 1993. Internal CDFG memo regarding effects of changes in striped bass management and regulations.

DuBois, J. 2009. Metadata for consumption of delta smelt by striped bass as calculated predation.

Elliott, J.M. and L. Persson. 1978. The estimation of daily rates of food consumption for fish. J. Animal Ecology 47:977-991.

Gingras, M. 1997. Mark/recapture experiments in Clifton Court Forebay to estimate pre-screening loss to juvenile fish: 1976-1993. Interagency Ecological Program for the San

Francisco Bay/Delta Estuary, a cooperative program of California Department of Water Resources and California Department of Fish and Game.

Gingras, M. and M. McGee. 1997. A telemetry study of striped bass emigration from Clifton Court Forebay: Implication for predator enumeration and control. Interagency Ecological Program for the San Francisco Bay/Delta Estuary, a cooperative program of California Department of Water Resources and California Department of Fish and Game.

Greene, S. 2008. Declaration of Sheila Greene in response to the July 24, 2008 Scheduling Order. Document 402. Pacific Coast Federation of Fishermen's Association/Institute for Fisheries Resources et al. v. Carlos M. Gutierrez et al.

Johnson, J.H., A.A. Nigro, and R. Temple. 1992. Evaluating enhancement of striped bass in the context of potential predation on anadromous salmonids in Coos Bay, Oregon. Trans. Amer. Fish. Soc. 12: 103-108.

Kohlhorst, D. June 17, 2009 pers. com. to Chuck Hanson.

Lindley, S. and L. Holsinger. 1996. Striped bass predation impact on Sacramento River winter Chinook. National Marine Fisheries Service Southwest Region, Long Beach, California.

Lindley, S.T. and M.S. Mohr. 2003. Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*). Fish. Bull. 101:321-331.

Lindley, Steven T.; Robert S. Schick; Ethan Mora; Peter B. Adams; James J. Anderson; Sheila Greene; Charles Hanson; Bernie P. May; Dennis McEwan; R Bruce MacFarlane; Christina Swanson; and John G. Williams. 2007. Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science. Vol. 5, Issue 1 (February), Article 4. http://repositories.cdlib.org/jmie/sfews/vol5/iss1/art4

Loboschefsky, E., G. Benigno, T. Sommer, T. Ginn, A. Massoudieh, K. Rose and F. Loge. 2009. Striped bass prey consumption in the San Francisco Bay-Delta from 1969-2004. Prepared for: Department of Civil and Environmental Engineering, University of California, Davis.

Low, A.F., J. White, and E. Chappell. 2006. Relationship of Delta Cross Channel gate operations to loss of juvenile winter-run Chinook salmon at the CVP/SWP Delta facilities.

MacFarlane, B.R., A.P. Kimley, S.L. Lindley, A.J. Ammann, P.T. Sandstrom, C.J. Michel, E.D. Chapman. 2008. Survival and migratory patterns of Central Valley juvenile salmonids: Progress report. NOAA Fisheries, Southwest Fisheries Center, Santa Cruz, California.

Merz, J.E. 2003. Striped bass predation on juvenile salmonids at the Woodbridge Dam Afterbay, Mokelumne River, California. Unpublished draft document. East Bay Municipal Utility District. 4 pages plus 6 figures.

Merz, J.E. October 5-7, 2009 pers. com. with Chuck Hanson.

Miranda et al. 2009. Element 2: Release site predation study. Department of Water Resources Fishery Improvements Unit, Department of Fish and Game Fish Facilities unit, and the U.S. Bureau of Reclamation Fisheries and Wildlife Resources Group.

National Marine Fisheries Service (NMFS). 1996. Letter to CDFG re: California Department of Fish and Game's Striped Bass Management Program. National Oceanic and Atmospheric Administration National Marine Fisheries Service Southwest Region.

National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS). 1996. Letter to CDFG re: California Department of Fish and Game's Striped Bass Management Program.

National Marine Fisheries Service (NMFS). 2009a. NMFS Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State Water Project. June 2009.

National Marine Fisheries Service (NMFS). 2009b. Public draft Recovery Plan for the evolutionarily significant units (ESU) of Sacramento River winter-run Chinook salmon and spring-run Chinook salmon and the distinct population segment of Central Valley steelhead. October 2009.

Newman, K. and J. Rice. 1997. A statistical model for the survival of Chinook salmon smolts outmigrating through the lower Sacramento-San Joaquin system.

Nobriga, M.L. 2009. Declaration of Matthew L. Nobriga in opposition to plaintiff's motion for summary adjudication of issues. Submitted to Eastern District Court for the Eastern District of California. May 19, 2009.

Nobriga, M.L., and F. Feyrer. 2007. Shallow-water piscivore-prey dynamics in the Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science. Available at: http://repositories.cdlib.org. (June 2008).

Nobriga, M.L., T.R. Sommer, F. Feyrer and K. Fleming. 2008. Long term trends in summertime habitat suitability for delta smelt (*Hypomesus transpacificus*) San Francisco Estuary and Watershed Science. 6:1. http://repositories.cdlib.org/jmie/sfews/vol6/iss1/art1.

Nobriga, M.L., and F. Feyrer. 2008. Diet composition in San Francisco Estuary striped bass: Does trophic adaptability have its limits? Environmental Biology Fish 83: 495-503.

Nobriga, M.L., F. Feyrer, R.D. Baxter and M. Chotkowski. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass. Estuaries 28:776-785.

Orsi, J. 1967. Predation study report, 1966-1967. California Department of Fish and Game.

Perry, R.W. and Skalski, J.R. 2008. Migration and survival of juvenile Chinook salmon through the Sacramento-San Joaquin River Delta during the winter of 2006-2007. University of Washington.

Perry, R.W. and Skalski, J.R. 2009. Survival and migration of juvenile Chinook salmon in the Sacramento-San Joaquin River Delta during the winter of 2007-2008. University of Washington.

Pickard, A., A. Grover, and F. Hall. 1982. An evaluation of predator composition at three locations on the Sacramento River. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Technical Report No. 2. 20 pages.

San Joaquin River Group Authority (SJRGA). 2007. 2006 Annual technical report on implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. Prepared for the California Water Resources Control Board in compliance with D-1641. January 2007.

San Joaquin River Group Authority (SJRGA). 2008. 2007 Annual technical report on implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. Prepared for the California Water Resources Control Board in compliance with D-1641. January 2008.

Stevens, D.L. 1963. Food habits of striped bass, *Roccus saxatilis* (Walbaum) in the Sacramento-Rio Vista area of the Sacramento River. University of California.

Stevens 1966. Food habits of striped bass (*Roccus saxatilis*) in the Sacramento-San Joaquin Delta. Pages 68-96 *in* J.L. Turner and D.W. Kelley, eds. Ecological studies of the Sacramento-San Joaquin Estuary, part II: fishes of the Delta. CDFG Fish. Bull.136.

Surface Water Resources, Inc. 2001. Aquatic Resources of the Lower American River; Baseline Report. Draft. Prepared for Lower American River Fisheries and Instream Habitat (FISH) Working Group. February 2001.

Thomas, J.L. 1967. The diet of juvenile and adult striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin river system. California Department of Fish and Game 53(1):49-62.

Tucker, M.E., C.M. Williams and R.R. Johnson. 1998. Abundance, food habits and life history aspects of Sacramento squawfish and striped bass at the Red Bluff Diversion Complex, including the Research Pumping Plant, Sacramento River, California, 1994-1996. Red Bluff Research Pumping Plant Report Series, Volume 4. U.S. Fish and Wildlife Service, Red Bluff, California.

Tucker, M.E., C.D. Martin and P.D. Gaines. 2003. Spatial and temporal distribution of Sacramento pikeminnow and striped bass at the Red Bluff Diversion Complex, including the Research Pumping Plant, Sacramento River, California: January 1997 to August, 1998. Red Bluff Research Pumping Plant Report Series, Volume 10. U.S. Fish and Wildlife Service, Red Bluff, California.

7. INFORMATION CONSIDERED

A DVD containing additional information that I considered in developing the opinions expressed above is included with this expert report.

Exhibit 1. Resume of Charles H. Hanson

Senior Fishery Biologist

Education

Ph.D.	Ecology and Fisheries Biology, University of California, Davis, 1980
M.S.	Fisheries Biology, University of Washington, 1973
B.S.	Fisheries Biology, University of Washington, 1972

Certification

Certified Fisheries Biologist

American Fisheries Society

Experience

Dr. Hanson has more than 31 years of experience in freshwater, estuarine, and marine biological studies. Dr. Hanson has contributed to the study design, analysis, and interpretation of fisheries, stream habitat, and stream flow (hydraulic) data used to develop habitat restoration strategies, Habitat Conservation Plans, Endangered Species Act consultations, and environmental analyses. Dr. Hanson has conducted evaluations of the effectiveness of various water diversion fish screening systems, assisted in fish screen design and permitting, and developed operational modifications to reduce organism losses while maintaining operational reliability of the water projects and hydroelectric systems. He has directed numerous investigations and environmental impact analyses for projects sited in freshwater, estuarine, and marine environments of the San Francisco Bay/Delta, the central and northern California Coast, Puget Sound, Hudson River, and Chesapeake Bay. Dr. Hanson has participated as an expert witness on fisheries and water quality issues in numerous public hearings and superior court litigation. Dr. Hanson has been extensively involved in incidental take monitoring and investigations of endangered species, development of Recovery Plans, consultations, listing decisions and identification of critical habitat, and preparation of aquatic Habitat Conservation Plans. Dr. Hanson served as a member of the USFWS Native Delta Fish Recovery Team, Central Valley Technical Recovery Team, 2007 USFWS Delta Smelt Recovery Team, numerous technical advisory committees, and as science advisor to settlement negotiations. Dr. Hanson has directed studies on the effects of selenium on waterbird reproduction and designed compensation wetland habitat. Dr. Hanson has also participated in the development of adaptive management programs including real-time monitoring, management of power plant cooling water and other diversion operations, and the San Joaquin River Vernalis Adaptive Management Plan (VAMP). Dr. Hanson has authored more than 75 technical and scientific reports.

1991-Present ***Senior Biologist/Principal*, Hanson Environmental, Inc.**

Provides services in the design, execution, and interpretation of biological monitoring, fishery sampling, and regulatory compliance programs. Prepares technical compliance reports and exhibits for submittal to regulatory agencies, public hearings, and litigation. Presents findings to the public and press and presents expert witness testimony in litigation and regulatory hearings. Develops the design, implementation, and performance monitoring of habitat enhancement and mitigation projects to benefit fish and wildlife.

1982-1991 ***Senior Biologist, Vice President*, TENERA, L.P**

Provided services related to the collection, analysis, and interpretation of biological and engineering data, preparation of documents submitted to regulatory agencies, presentation of findings to the public and press, and presentation of expert testimony in regulatory hearings.

1978-1982 ***Senior Scientist*, Ecological Analysts, Inc.**

Responsible for the collection, analysis, and interpretation of data on the abundance, distribution, and dynamics of various fisheries and invertebrate populations for use in evaluating the impact of power plant operations on aquatic populations for more than ten coastal and estuarine power plant sites in California. Prepared various regulatory environmental exhibits, technical reports, and generic and site-specific analyses of biological and engineering information for the applicability of alternative cooling water intake technologies.

1975-1978 ***Research Assistant*, University of California, Davis**

Conducted extensive investigations into behaviorally selected and energetically optimal swimming speeds of juvenile fish in relationship to selected microhabitats to help in establishing a data base and methodology for determining instream flow criteria. Conducted laboratory studies on the swimming performance and behavioral responses of fish to hydraulic gradients to develop biological design criteria for water intake systems.

1973-1975 ***Research Scientist*, The Johns Hopkins Universit**y

Conducted fishery and zooplankton surveys in freshwater and marine environments along the Atlantic coast. Evaluated the acute and chronic effects of exposure to elevated water temperatures on freshwater and marine fish and invertebrates. Developed onsite and mobile bioassay laboratory facilities.

1969-1973 ***Research Assistant*, University of Washington**

Conducted bioassays to determine the synergism between elevated water temperature and duration of exposure on the toxicity of chlorine to two species of salmon. Determined the effectiveness of various techniques, including use of chlorine and thermal shock treatment in minimizing colonization by marine fouling organisms. Evaluated the acute and chronic effects of exposure to elevated water temperature on freshwater and marine fish and invertebrates. Participated in the evaluation of the behavioral attraction and avoidance of response of juvenile fish to thermal and chemical gradients.

Professional Associations

American Fisheries Society (Life Member)

American Institute of Fisheries Research Biologists (past Program Committee Chairman)

Pacific Fisheries Biologists (past Program Chairman)

Who's Who in the West

San Francisco Bay and Estuarine Society (past President)

Technical Advisory Committees

State Water Resources Control Board Striped Bass Workshop

American River Technical Advisory Committee

Mokelumne River Technical Advisory Committee

Santa Ynez River Technical Advisory Committee

Bay-Delta Oversight Committee (BDOC) Aquatic Resources

USFWS Delta Native Fish Recovery Team

CVPIA Striped Bass Technical Team

NMFS Central Valley Salmonid Technical Recovery Team

Litigation:

During the past four years I have testified as an expert witness in the following proceedings:

Natural Resources Defense Council v. Rodgers Case S-88-1658
Natural Resources Defense Council v. Kempthorne, E.D. Cal Case No. 05-1207

Pacific Coast Federation of Fishermen's Association v. Guitierrez, E.D. Cal Case No. 06-245

San Luis & Delta-Mendota Water Authority; Westlands Water District v. Salaza Case No. 1:09-CV-00407-OWW-DLB

Publications:

Davies, R.M., **C.H. Hanson**, and L.D. Jensen. 1976. Entrainment of zooplankton into a mid-Atlantic power plant - delayed and sublethal effects in Thermal Ecology II (G.W. Esch and R.W. McFarlane, eds.), pp. 349-357. U.S. Energy Res. and Develop. Admin., Report No. CONF-750425.

Davis, D.E., **C.H. Hanson**, R.B. Hansen. 2007. Constructed Wetland Habitat for American Avocet and Black-necked Stilt Foraging and Nesting. Journal of Wildlife Management. In publication.

Hanson, C.H. and C.P. Walton. 1990. Potential effects of dredging on early life stages of striped bass (*Morone saxatillis*) in the San Francisco Bay area: An Overview. Pages 39-57 In Effects of Dredging on anadromous Pacific coast fishes. Wash. Sea Grant.

Hanson, C.H. and E. Jacobsen. 1985. Orientation of juvenile Chinook salmon and bluegill to low water velocities under high and low light levels. California Fish and Game 71(2):110-113.

Hanson, C.H. and H.W. Li. 1983. Behavioral response of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) to trash rack bar spacing. California Fish and Game 69(1):18-22.

Hanson, C.H., J.R. White, and H.W. Li. 1977. An alternative approach for developing intake velocity design criteria. Trans. Calif.-Nev. Wildl. Soc.:10-18.

Hanson, C.H., J.R. White, and H.W. Li. 1977. Entrapment and impingement of fish by power plant cooling-water intakes: an overview. Mar. Fish. Rev. 39(10):7-17.

Hanson, C.H. 1976. Commentary - ethics in the business of science. Ecology 57(4):627-628.

Hanson, C.H. and J. Bell. 1976. Subtidal and intertidal marine fouling on artificial substrata in northern Puget Sound, Washington. NOAA Fish. Bull. 74(2):377-385.

Hanson, C.H., J. Coil, B. Keller, J. Johnson, J. Taplin, and J. Monroe. 2004. Assessment and Evaluation of the Effects of Sand Mining on Aquatic Habitat and Fishery Populations of Central San Francisco Bay and the Sacramento-San Joaquin Estuary. Prepared for Hanson Aggregates Mid-Pacific, Inc., RMC Pacific Materials, Inc., and Jerico Products/Morris Tug and Barge. Final Report. September 2004.

Lindley, S.T., C. R. Schick, E. Mora, P.B. Adams, J. J. Anderson, S. Greene, **C. Hanson**, B. May, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science. Vol. 5, Issue 1 (February 2007). Article 4. http://repositories.cdlib.org/jmie/sfews/vol5/iss1/art4/.

Stober, Q.J. and **C.H. Hanson**. 1974. Toxicity of chlorine and heat to pink and Chinook salmon. Trans. Am. Fish. Soc. 103(3):569-577.

Stober, Q.J., **C.H. Hanson**, and P.B. Swierkowski. 1974. Sea water filtration and fouling control in a model rapid-sand filter for exclusion of fish from power plant cooling systems, in Proceedings, Second Workshop on Entrainment and Intake Screening. Cooling Water Studies for Electric Power Research Institute (RP-49) (L.D. Jensen, ed.) pp. 317-334. Rept. No. 15. Dept. of Geography and Environmental Eng., Johns Hopkins University, Baltimore.

Tanji, K., D. Davis, **C. Hanson**, A. Toto, R. Higashi, and A. Amrhein. Evaporation ponds as a drainwater disposal management option. Irrigation and Drainage Systems. Vol. 16, No. 4 (November 2002). Pages 279-295.

Dr. Hanson has also authored more than 75 technical and scientific reports.

Exhibit 2. Prior research on striped bass predation on listed fish species.

Striped Bass Predation on Listed Species – Prior Research			
Authors and Affiliation	**Year**	**Title**	**Key Findings**
Clark (DWR) Bowen (USBR) Mayfield (CDFG) Zehfuss (CDFG) Taplin (Hanson Env.) Hanson (Hanson Env.)	**2009**	**Quantification Of Pre-Screen Loss Of Juvenile Steelhead In Clifton Court Forebay**	**This is the first study in the Delta to quantify and document predation on juvenile steelhead by striped bass. The study area was limited to Clifton Court Forebay. Estimated that predation mortality on juvenile steelhead was 78% (+- 4%) to 82% (+- 3%) within the forebay. Prior diet studies had not shown that steelhead were preyed on by striped bass. In prior diet studies, juvenile steelhead were not observed in striped bass stomach samples and steelhead were assumed to be large and not preyed on. This study demonstrated that predation mortality could be substantially higher than suggested by diet studies. Adult striped bass were tagged and their movement recorded using acoustic tags. Striped bass were able to move out of the forebay when the radial gates were open.**
Gingras (CDFG)	**1997**	**Mark/Recapture Experiments In Clifton Court Forebay To Estimate Pre-Screening Loss To Juvenile Fish: 1976-1993**	**This study is a compilation of results of mark-recapture studies done using juvenile Chinook salmon and juvenile striped bass released into Clifton Court Forebay. Pre-screen losses for juvenile salmon (8 studies) ranged from 63-99%; pre-screen losses for striped bass (2 studies) ranged from 70-94%. Results were used to refine the pre-screen losses for juvenile Chinook salmon used in the SWP mitigation calculations. Mark-recapture studies were performed using hatchery reared juvenile salmon and striped bass. There were a number of questions about the experimental design but the results all showed similar loss patterns.**
Gingras and McGee (CDFG)	**1997**	**A Telemetry Study Of Striped Bass Emigration**	**Pre-screen losses in Clifton Court Forebay were attributable primarily to predation by subadult and adult striped bass. Acoustic tags were used**

		From Clifton Court Forebay: Implication For Predator Enumeration And Control	to assess the movement of striped bass within the forebay. Results of the Acoustic tag studies demonstrate that subadult and adult striped bass can migrate into and out of Clifton Court Forebay (open exchange with the Delta) during periods when the radial gates are open. Based on these results DWR decided that harvest and removal of striped bass would not be effective in controlling pre-screen losses within the forebay. Kano (1990) and Brown *et al.* (1995) report on the species and abundance of predatory fish inhabiting Clifton Court Forebay. Striped bass and catfish are the two dominant predatory fish. Results of Clark *et al.* (2009) also showed that striped bass can move out of the forebay.
Baxter (CDFG) Breuer (DWR) Brown (USGS) Chotkowski (USBR), Feyrer (DWR Herbold (USEPA) Hrodey USFWS) Mueller-Solger DWR) Nobriga (CALFED) Sommer (DWR) Souza (CDFG)	2008	Interagency Ecological Program 2008 Work Plan To Evaluate The Decline Of Pelagic Species In The Upper San Francisco Estuary	This report presents a synthesis of information and hypotheses regarding the potential factors contributing to the POD. The work plan outlines the conceptual model for the POD and identifies various studies and monitoring programs. The plan identifies elevated predation mortality and food limitations as important mechanisms but provides no quantification. The plan describes POD studies to model striped bass predation in the Delta and effects of predation on POD species (pg 25). The plan also includes population modeling of delta smelt and striped bass as important studies (pg 27). Information on studies that are being funded or linked to POD investigations are described (pg. 30). The 2008 plan is an expansion of the 2007 POD work plan. Although qualitative, the plan shows the conceptual model for POD studies and research.
Lindley (NMFS) Mohr (NMFS)	2003	Modeling The Effect Of Striped Bass On The Population Viability Of Sacramento River Winter-Run Chinook Salmon	CDFG proposed to stock striped bass into the Delta to increase the bass population and support the recreational fishery. Concern was expressed about the potential impacts of the program on recovery (or extinction) of listed fish such as winter-run Chinook salmon. A statistical modeling approach was used to assess the potential risk of increased predation by striped bass on declines in abundance and recovery of winter-run salmon. The model estimated that at a striped bass population

			abundance level of 1,000,000 adults an individual juvenile winter-run salmon had a 9% chance of being eaten by a striped bass. The probability of winter-run extinction (assuming a density dependant model) was 23% assuming no striped bass, 28% assuming a striped bass population of 512,000 fish and 30% assuming a striped bass population of 700,000 fish (the probability of extinction increased to 55% at a striped bass abundance of 3 million). The probability that winter-run salmon will recover decreased from 11% at a bass abundance of 512,000 to 10% at a bass abundance of 700,000 (the probability of recovery was 4% at a bass abundance of 3 million). The relative change in extinction and recovery was similar assuming a density independent model but the absolute estimates were different. The paper concludes that striped bass eradication would not be enough to ensure recovery of winter-run salmon, but that increases in bass abundance would be expected to increase the risk of extinction and reduce the probability of recovery.
Merz (EBMUD)	**2003**	**Striped Bass Predation On Juvenile Salmonids At The Woodbridge Dam Afterbay, Mokelumne River, California**	**The report documents predation by striped bass on juvenile fall-run Chinook salmon on the Mokulumne River during the spring outmigration period. At a water temperature of 15 C the report estimates that striped bass in the lower Mokelumne River consume 1.8 to 3.3 juvenile salmon per day. The estimated predation mortality in spring of 1993 attributed to striped bass predation ranged from 11-28% of the juvenile salmon migrants (based on diet samples that contained identified juvenile salmon) with a maximum estimate of 51.1 % (based on positively identified and suspected salmon in striped bass stomachs). The report documents predation hot spots during the spring in rivers where juvenile salmon are migrating and that predation mortality can be high. The study was limited to a small area in spring 1993. Results were consistent with the hypothesis that adult striped bass migrate upstream into the rivers to spawn during the spring where they prey on juvenile salmon and other fish**

			migrating downstream within the rivers. Results of this and other diet studies have shown a greater risk of striped bass predation on salmon within the rivers than further downstream within the broader reaches of the estuary.
Nobriga (CALFED) Feyrer (DWR)	2007	Shallow-Water Piscivore-Prey Dynamics In California's Sacramento-San Joaquin Delta	Results of field studies (March-October 2001 and 2003) conducted within the Delta showed that striped bass eat mostly fish in the summer and fall (across all sizes of bass) and that even relatively small bass prey on fish. Striped bass were wide spread and collected at all sites sampled in both years. Diet study results showed that juvenile salmon are preyed on during the spring migration period in relatively low frequency: delta smelt were not reported to occur in the diet study for striped bass. The study concludes that striped bass likely remain the most significant predator on Chinook salmon and delta smelt among the three predator species studied due to its ubiquitous distribution in the estuary and its tendency to aggregate at water diversion structures. The study does not quantitatively estimate predation mortality striped bass.
Bennett (UCD)	2005	Critical Assessment Of The Delta Smelt Population In The San Francisco Estuary, California	This report presents a synthesis and analysis of information on the life history and factors affecting the population dynamics of delta smelt. The study documents depressed liver glycogen levels and other histopathology suggesting food limitation effects on larval delta smelt growth and survival. Drought conditions may increase the likelihood and/or severity of food-limitation effects. The report offers only a brief and qualitative discussion of competition and predation effects by non-native species. The report does not quantify or specifically address the potential effects of either competition or predation by striped bass on delta smelt.
Nobriga (DWR) Feyrer (DWR) Baxter (CDFG) Chotkowski	2005	Fish Community Ecology In An Altered River Delta: Spatial Patterns In	Analysis of results of fishery surveys conducted within the Delta showed that the highest abundance of striped bass was found in fishery samples collected from habitats dominated by turbid open water where the highest densities of

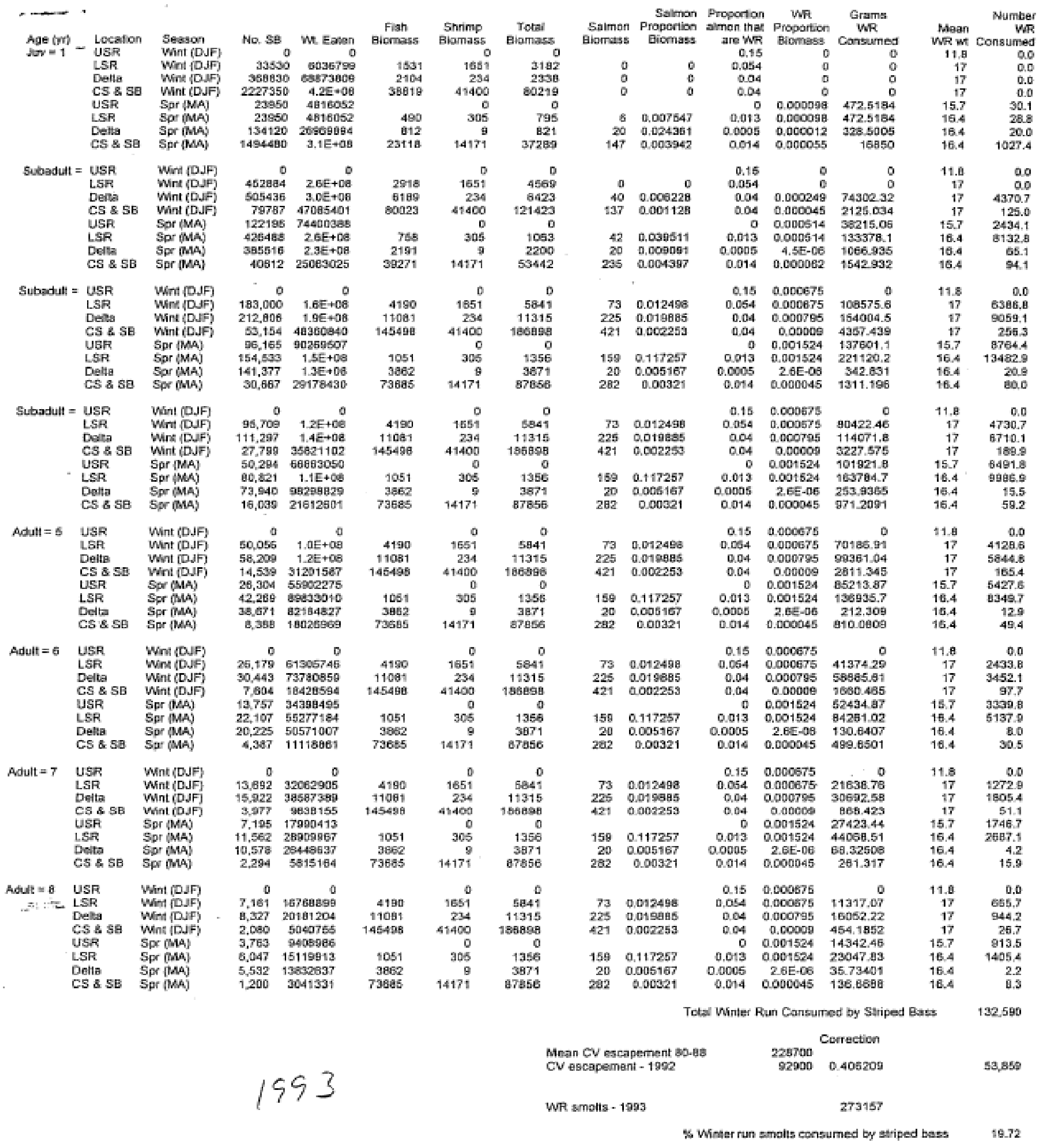
(USBR)		**Species Composition, Life History Strategies, And Biomass**	**delta smelt, juvenile Chinook salmon, and splittail were also observed. Special status fish were less common in habitats dominated by submerged aquatic vegetation (SAV). The study does not quantify predation losses on delta smelt or other listed fish.**
National Marine Fisheries Service (NMFS)	**2009**	**NMFS Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project**	**Describes the effects of water project operations on habitat conditions and the predicted response of winter-run and spring-run Chinook salmon, Central Valley steelhead, and green sturgeon.**
CDFG	**1998**	**Draft Striped Bass Management Program EIR and Incidental Take Permit Application. The final EIR was issued in June 1998.**	**The draft striped bass management plan and associated draft conservation plan for striped bass management program provides a summary of the striped bass diet studies conducted through the early 1990's within the estuary and rivers. The plan provides estimates of the percentage loss to winter-run and spring-run Chinook salmon, steelhead, delta smelt, and splittail attributable to striped bass predation as a function of striped bass population abundance. The EIR identifies striped bass predation mortality as significant. The conservation plan includes key conservation strategies that would be used to reduce the adverse impacts of striped bass predation in the event that special status species abundance declines below prescribed thresholds (no mention of altering the harvest regulations as a conservation action). The EIR and incidental take permit application estimates that predation mortality on winter-run salmon would be 5.6% (4.8-6.5%) at a bass population of 712,000 and 4% (3.4-4.7%) at a bass population of 515,000. Estimated predation mortality on spring-run salmon would be 3.2% at a bass population of 712,000. Estimated predation mortality on Central Valley steelhead would be 3.2 to 5.6% at a bass population of 712,000. Estimated predation mortality on delta smelt would be 4.9% at a bass population**

			of 712,000. The EIR and incidental take application provides quantitative estimates of the relationship between striped bass abundance and predation mortality of listed fish within the Bay-Delta. The EIR reports that these predation estimates were reviewed by NMFS and USFWS prior to publication of the draft EIR. Appendix E to the EIR provides a brief discussion of the methods and assumptions used in deriving predation mortality estimates.
Stevens (U.C. Berkeley)	**1963**	**Food Habits of Striped Bass, *Roccus saxatilis* (Walbaum) in the Sacramento-Rio Vista Area of the Sacramento River. University of California.**	**Results of striped bass diet study conducted in the Sacramento River between Rio Vista and Sacramento showed that juvenile Chinook salmon were the dominant prey of striped bass during June with predation extending through August. Predation rates by striped bass were increased in the vicinity of the Paintersville Bridge. The study concluded that predation by striped bass occurs on juvenile Chinook salmon and recommended that future striped bass predation/diet studies extend further upstream within the Sacramento River where predation on juvenile salmon was found to be high compared to predation further downstream in the Delta where channels are wider and juvenile salmon have a lower risk of being detected by striped bass when compared to the confined river channel.**
Stevens (CDFG)	**1966**	**Food habits of striped bass (*Roccus saxatilis*) in the Sacramento-San Joaquin Delta. Pages 68-96 *in* J.L. Turner and D.W. Kelley, eds. Ecological studies of the Sacramento-San Joaquin Estuary, part II: fishes of the Delta. CDFG Fish. Bull.136.**	**Striped bass diet study conducted within the Delta and Suisun Bay. Striped bass diet was estimated for various regions of the Delta by season. Striped bass were not collected in the Sacramento River upstream of Isleton. The study results provided part of the basis used by CDFG in estimating striped bass predation mortality on listed fish in the 1998 EIR and incidental take application prepared for the striped bass management program.**

Thomas	**1967**	**The diet of juvenile and adult striped bass, *Roccus saxatlis*, in the Sacramento-San Joaquin river system. California Department of Fish and Game 53(1):49-62.**	**Striped bass diet study conducted within the Delta and Suisun Bay but also included striped bass sampled for diet in the Sacramento River in the reach from Rio Vista to the confluence with the American River. Striped bass diet was estimated for various regions of the Delta by season. The study did not sample striped bass in the river during the winter but did sample during the spring. Study results showed that juvenile salmon were the dominant prey of striped bass in the river during the spring with a frequency of occurrence of 62% based on a sample of 45 striped bass. The study results provided part of the basis used by CDFG in estimating striped bass predation mortality on listed fish in the 1998 EIR and incidental take application prepared for the striped bass management program.**
Bowen (USBR) **Hiebert (USBR)** **Hueth (SAIC)** **Maisonneuve (SAIC)**	**2009**	**2009 effectiveness of a non-physical fish barrier at the divergence of the Old and San Joaquin Rivers (CA)**	**Experimental study in the lower San Joaquin River that used acoustic tags to monitor juvenile salmon migration and response to the barrier. Results showed high levels of predation.**
Perry (Univ. Washington) **Skalski (Univ. Washington)**	**2008 and 2009**	**Survival and migration route probabilities of juvenile Chinook salmon in the Sacramento-San Joaquin River Delta during the winter**	**Results of acoustic tag studies were used to determine the migration route and mortality rates of juvenile salmon. The studies were limited to the reach of the Sacramento River downstream of Sacramento. Results showed high mortality rates for some of the migration pathways.**

Exhibit 3. **Results of CDFG unpublished bioenergetic estimates of striped bass predation on winter-run salmon.**

Table 1. CDFG bioenergetic predation estimate on winter-run salmon: 1993.



Age (yr)	Location	Season	No. SB	Wt. Eaten	Fish Biomass	Shrimp Biomass	Total Biomass	Salmon Biomass	Salmon Proportion Biomass	Proportion almon that are WR	WR Proportion Biomass	Grams WR Consumed	Mean WR wt	Number WR Consumed
Juv = 1	USR	Wint (DJF)	0	0		0	0			0.15	0	0	11.8	0.0
	LSR	Wint (DJF)	33530	6036799	1531	1651	3182	0	0	0.054	0	0	17	0.0
	Delta	Wint (DJF)	368830	68873809	2104	234	2338	0	0	0.04	0	0	17	0.0
	CS & SB	Wint (DJF)	2227350	4.2E+08	38819	41400	80219	0	0	0.04	0	0	17	0.0
	USR	Spr (MA)	23950	4816052		0	0			0	0.000098	472.5184	15.7	30.1
	LSR	Spr (MA)	23950	4816052	490	305	795	6	0.007547	0.013	0.000098	472.5184	16.4	28.8
	Delta	Spr (MA)	134120	26969894	812	9	821	20	0.024361	0.0005	0.000012	328.5005	16.4	20.0
	CS & SB	Spr (MA)	1494480	3.1E+08	23118	14171	37289	147	0.003942	0.014	0.000055	16850	16.4	1027.4
Subadult =	USR	Wint (DJF)	0	0		0	0			0.15	0	0	11.8	0.0
	LSR	Wint (DJF)	452884	2.6E+08	2918	1651	4569	0	0	0.054	0	0	17	0.0
	Delta	Wint (DJF)	505436	3.0E+08	6189	234	6423	40	0.006228	0.04	0.000249	74302.32	17	4370.7
	CS & SB	Wint (DJF)	79787	47085401	80023	41400	121423	137	0.001128	0.04	0.000045	2125.034	17	125.0
	USR	Spr (MA)	122196	74400388		0	0			0	0.000514	38215.06	15.7	2434.1
	LSR	Spr (MA)	426468	2.6E+08	758	305	1063	42	0.039511	0.013	0.000514	133378.1	16.4	8132.8
	Delta	Spr (MA)	385516	2.3E+08	2191	9	2200	20	0.009091	0.0005	4.5E-06	1066.935	16.4	65.1
	CS & SB	Spr (MA)	40812	25063025	39271	14171	53442	235	0.004397	0.014	0.000062	1542.932	16.4	94.1
Subadult =	USR	Wint (DJF)	0	0		0	0			0.15	0.000675	0	11.8	0.0
	LSR	Wint (DJF)	183,000	1.6E+08	4190	1651	5841	73	0.012498	0.054	0.000675	108575.6	17	6386.8
	Delta	Wint (DJF)	212,806	1.9E+08	11081	234	11315	225	0.019885	0.04	0.000795	154004.5	17	9059.1
	CS & SB	Wint (DJF)	53,154	48360840	145498	41400	186898	421	0.002253	0.04	0.00009	4357.439	17	256.3
	USR	Spr (MA)	96,165	90269507		0	0			0	0.001524	137601.1	15.7	8764.4
	LSR	Spr (MA)	154,533	1.5E+08	1051	305	1356	159	0.117257	0.013	0.001524	221120.2	16.4	13482.9
	Delta	Spr (MA)	141,377	1.3E+08	3862	9	3871	20	0.005167	0.0005	2.6E-06	342.831	16.4	20.9
	CS & SB	Spr (MA)	30,667	29178430	73685	14171	87856	282	0.00321	0.014	0.000045	1311.196	16.4	80.0
Subadult =	USR	Wint (DJF)	0	0		0	0			0.15	0.000675	0	11.8	0.0
	LSR	Wint (DJF)	96,709	1.2E+08	4190	1651	5841	73	0.012498	0.054	0.000675	80422.46	17	4730.7
	Delta	Wint (DJF)	111,297	1.4E+08	11081	234	11315	225	0.019885	0.04	0.000795	114071.8	17	6710.1
	CS & SB	Wint (DJF)	27,799	35621102	145498	41400	186898	421	0.002253	0.04	0.00009	3227.575	17	189.9
	USR	Spr (MA)	50,294	66663050		0	0			0	0.001524	101921.8	15.7	6491.8
	LSR	Spr (MA)	80,821	1.1E+08	1051	305	1356	159	0.117257	0.013	0.001524	163784.7	16.4	9986.9
	Delta	Spr (MA)	73,940	98298829	3862	9	3871	20	0.005167	0.0005	2.6E-06	253.9365	16.4	15.5
	CS & SB	Spr (MA)	16,039	21612601	73685	14171	87856	282	0.00321	0.014	0.000045	971.2091	16.4	59.2
Adult = 5	USR	Wint (DJF)	0	0		0	0			0.15	0.000675	0	11.8	0.0
	LSR	Wint (DJF)	50,056	1.0E+08	4190	1651	5841	73	0.012498	0.054	0.000675	70186.91	17	4128.6
	Delta	Wint (DJF)	58,209	1.2E+08	11081	234	11315	225	0.019885	0.04	0.000795	99361.04	17	5844.8
	CS & SB	Wint (DJF)	14,539	31201567	145498	41400	186898	421	0.002253	0.04	0.00009	2811.345	17	165.4
	USR	Spr (MA)	26,304	55902275		0	0			0	0.001524	85213.87	15.7	5427.6
	LSR	Spr (MA)	42,269	89833010	1051	305	1356	159	0.117257	0.013	0.001524	136935.7	16.4	8349.7
	Delta	Spr (MA)	38,671	82184827	3862	9	3871	20	0.005167	0.0005	2.6E-06	212.309	16.4	12.9
	CS & SB	Spr (MA)	8,388	18026969	73685	14171	87856	282	0.00321	0.014	0.000045	810.0809	16.4	49.4
Adult = 6	USR	Wint (DJF)	0	0		0	0			0.15	0.000675	0	11.8	0.0
	LSR	Wint (DJF)	26,179	61305746	4190	1651	5841	73	0.012498	0.054	0.000675	41374.29	17	2433.8
	Delta	Wint (DJF)	30,443	73780859	11081	234	11315	225	0.019885	0.04	0.000795	58665.61	17	3452.1
	CS & SB	Wint (DJF)	7,604	18428594	145498	41400	186898	421	0.002253	0.04	0.00009	1660.465	17	97.7
	USR	Spr (MA)	13,757	34398495		0	0			0	0.001524	52434.87	15.7	3339.8
	LSR	Spr (MA)	22,107	55277184	1051	305	1356	159	0.117257	0.013	0.001524	84261.02	16.4	5137.9
	Delta	Spr (MA)	20,225	50571007	3862	9	3871	20	0.005167	0.0005	2.6E-06	130.6407	16.4	8.0
	CS & SB	Spr (MA)	4,367	11118861	73685	14171	87856	282	0.00321	0.014	0.000045	499.6501	16.4	30.5
Adult = 7	USR	Wint (DJF)	0	0		0	0			0.15	0.000675	0	11.8	0.0
	LSR	Wint (DJF)	13,692	32062905	4190	1651	5841	73	0.012498	0.054	0.000675	21636.76	17	1272.9
	Delta	Wint (DJF)	15,922	38587389	11081	234	11315	225	0.019885	0.04	0.000795	30692.58	17	1805.4
	CS & SB	Wint (DJF)	3,977	9638155	145498	41400	186898	421	0.002253	0.04	0.00009	868.423	17	51.1
	USR	Spr (MA)	7,195	17990413		0	0			0	0.001524	27423.44	15.7	1746.7
	LSR	Spr (MA)	11,562	28909867	1051	305	1356	159	0.117257	0.013	0.001524	44068.51	16.4	2687.1
	Delta	Spr (MA)	10,578	26449637	3862	9	3871	20	0.005167	0.0005	2.6E-06	68.32508	16.4	4.2
	CS & SB	Spr (MA)	2,294	5815164	73685	14171	87856	282	0.00321	0.014	0.000045	261.317	16.4	15.9
Adult = 8	USR	Wint (DJF)	0	0		0	0			0.15	0.000675	0	11.8	0.0
	LSR	Wint (DJF)	7,161	16768899	4190	1651	5841	73	0.012498	0.054	0.000675	11317.07	17	665.7
	Delta	Wint (DJF)	8,327	20181204	11081	234	11315	225	0.019885	0.04	0.000795	16052.22	17	944.2
	CS & SB	Wint (DJF)	2,080	5040755	145498	41400	186898	421	0.002253	0.04	0.00009	454.1852	17	26.7
	USR	Spr (MA)	3,763	9408986		0	0			0	0.001524	14342.46	15.7	913.5
	LSR	Spr (MA)	6,047	15119913	1051	305	1356	159	0.117257	0.013	0.001524	23047.83	16.4	1405.4
	Delta	Spr (MA)	5,532	13832637	3862	9	3871	20	0.005167	0.0005	2.6E-06	35.73401	16.4	2.2
	CS & SB	Spr (MA)	1,200	3041331	73685	14171	87856	282	0.00321	0.014	0.000045	136.6688	16.4	8.3

Total Winter Run Consumed by Striped Bass 132,590

		Correction	
Mean CV escapement 80-88	228700		
CV escapement - 1992	92900	0.406209	53,859

WR smolts - 1993 273157

% Winter run smolts consumed by striped bass 19.72

1993

Table 2. CDFG bioenergetic predation estimate on winter-run salmon: 1994.

Age (yr)	Location	Season	No. SB	Wt. Eaten	Fish Biomass	Shrimp Biomass	Total Biomass	Salmon Biomass	Salmon Proportion Biomass	Proportion almon that are WR	WR Proportion Biomass	Grams WR Consumed	Mean WR wt	Number WR Consumed
Juv = 1	USR	Wint (DJF)	0	0		0	0			0.0079	0	0	11.8	0.0
	LSR	Wint (DJF)	33530	6036799	1531	1651	3182	0	0	0.001	0	0	17	0.0
	Delta	Wint (DJF)	368830	66873809	2104	234	2338	0	0	0.001	0	0	17	0.0
	CS & SB	Wint (DJF)	2227350	4.2E+08	38819	41400	80219	0	0	0.0469	0	0	17	0.0
	USR	Spr (MA)	23950	4816052		0	0			0.0017	5.3E-06	25.4433	15.7	1.6
	LSR	Spr (MA)	23950	4816052	490	305	795	6	0.007547	0.0007	5.3E-06	25.4433	16.4	1.6
	Delta	Spr (MA)	134120	26969894	812	9	821	20	0.024361	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	1494480	3.1E+08	23118	14171	37289	147	0.003942	0.0075	0.00003	9026.787	16.4	550.4
Subadult = 2	USR	Wint (DJF)	0	0		0	0			0.0079	0	0	11.8	0.0
	LSR	Wint (DJF)	452864	2.6E+08	2918	1651	4569	0	0	0.001	0	0	17	0.0
	Delta	Wint (DJF)	505436	3.0E+08	6189	234	6423	40	0.006228	0.001	6.2E-06	1857.558	17	109.3
	CS & SB	Wint (DJF)	79787	47085401	80023	41400	121423	137	0.001128	0.0469	0.000053	2491.602	17	146.6
	USR	Spr (MA)	122196	74400388		0	0			0.0017	0.000028	2057.734	15.7	131.1
	LSR	Spr (MA)	426488	2.6E+08	758	305	1063	42	0.039511	0.0007	0.000028	7181.896	16.4	437.9
	Delta	Spr (MA)	385516	2.3E+08	2191	9	2200	20	0.009091	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	40612	25063025	39271	14171	53442	235	0.004397	0.0075	0.000033	826.5705	16.4	50.4
Subadult = 3	USR	Wint (DJF)	0	0		0	0			0.0079	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	183,000	1.6E+08	4190	1651	5841	73	0.012498	0.001	0.000012	2010.659	17	118.3
	Delta	Wint (DJF)	212,806	1.9E+08	11081	234	11315	225	0.019885	0.001	0.00002	3850.111	17	226.5
	CS & SB	Wint (DJF)	53,154	48360840	145498	41400	186898	421	0.002253	0.0469	0.000106	5109.097	17	300.5
	USR	Spr (MA)	96,165	90269507		0	0			0.0017	0.000082	7409.289	15.7	471.9
	LSR	Spr (MA)	154,533	1.6E+08	1051	305	1356	159	0.117257	0.0007	0.000082	11906.47	16.4	726.0
	Delta	Spr (MA)	141,377	1.3E+08	3862	9	3871	20	0.005167	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	30,667	29176430	73685	14171	87856	282	0.00321	0.0075	0.000024	702.4265	16.4	42.8
Subadult = 4	USR	Wint (DJF)	0	0		0	0			0.0079	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	95,709	1.2E+08	4190	1651	5841	73	0.012498	0.001	0.000012	1489.305	17	87.6
	Delta	Wint (DJF)	111,297	1.4E+08	11081	234	11315	225	0.019885	0.001	0.00002	2851.796	17	167.8
	CS & SB	Wint (DJF)	27,799	35821102	145498	41400	186898	421	0.002253	0.0469	0.000106	3784.332	17	222.6
	USR	Spr (MA)	50,294	66863050		0	0			0.0017	0.000082	5488.095	15.7	349.6
	LSR	Spr (MA)	80,821	1.1E+08	1051	305	1356	159	0.117257	0.0007	0.000082	8819.178	16.4	537.8
	Delta	Spr (MA)	73,940	98298829	3862	9	3871	20	0.005167	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	16,039	21612601	73685	14171	87856	282	0.00321	0.0075	0.000024	520.2906	16.4	31.7
Adult = 5	USR	Wint (DJF)	0	0		0	0			0.0079	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	50,056	1.0E+08	4190	1651	5841	73	0.012498	0.001	0.000012	1299.758	17	76.5
	Delta	Wint (DJF)	58,209	1.2E+08	11081	234	11315	225	0.019885	0.001	0.00002	2484.026	17	146.1
	CS & SB	Wint (DJF)	14,539	31201587	145498	41400	186898	421	0.002253	0.0469	0.000106	3296.302	17	193.9
	USR	Spr (MA)	26,304	55902275		0	0			0.0017	0.000082	4588.439	15.7	292.3
	LSR	Spr (MA)	42,269	89833010	1051	305	1356	159	0.117257	0.0007	0.000082	7373.462	16.4	449.6
	Delta	Spr (MA)	38,671	82184827	3862	9	3871	20	0.005167	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	8,388	18026969	73685	14171	87856	282	0.00321	0.0075	0.000024	433.9719	16.4	26.5
Adult = 6	USR	Wint (DJF)	0	0		0	0			0.0079	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	26,179	61306746	4190	1651	5841	73	0.012498	0.001	0.000012	766.1906	17	45.1
	Delta	Wint (DJF)	30,443	73780859	11081	234	11315	225	0.019885	0.001	0.00002	1467.14	17	86.3
	CS & SB	Wint (DJF)	7,604	18428594	145498	41400	186898	421	0.002253	0.0469	0.000106	1946.895	17	114.5
	USR	Spr (MA)	13,787	34398495		0	0			0.0017	0.000082	2823.416	15.7	179.8
	LSR	Spr (MA)	22,107	55277184	1051	305	1356	159	0.117257	0.0007	0.000082	4537.132	16.4	276.7
	Delta	Spr (MA)	20,225	50571007	3862	9	3871	20	0.005167	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	4,387	11118861	73685	14171	87856	282	0.00321	0.0075	0.000024	267.6697	16.4	16.3
Adult = 7	USR	Wint (DJF)	0	0		0	0			0.0079	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	13,692	32062905	4190	1651	5841	73	0.012498	0.001	0.000012	400.7177	17	23.6
	Delta	Wint (DJF)	15,922	38587389	11081	234	11315	225	0.019885	0.001	0.00002	767.3144	17	45.1
	CS & SB	Wint (DJF)	3,977	9638155	145498	41400	186898	421	0.002253	0.0469	0.000106	1018.226	17	59.9
	USR	Spr (MA)	7,195	17990413		0	0			0.0017	0.000082	1476.647	15.7	94.1
	LSR	Spr (MA)	11,562	28909967	1051	305	1356	159	0.117257	0.0007	0.000082	2372.92	16.4	144.7
	Delta	Spr (MA)	10,578	26448637	3862	9	3871	20	0.005167	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	2,294	5815164	73685	14171	87856	282	0.00321	0.0075	0.000024	139.9813	16.4	8.5
Adult = 8	USR	Wint (DJF)	0	0		0	0			0.0079	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	7,161	16768899	4190	1651	5841	73	0.012498	0.001	0.000012	209.5754	17	12.3
	Delta	Wint (DJF)	8,327	20181204	11081	234	11315	225	0.019885	0.001	0.00002	401.3064	17	23.6
	CS & SB	Wint (DJF)	2,080	5040755	145498	41400	186898	421	0.002253	0.0469	0.000106	532.5322	17	31.3
	USR	Spr (MA)	3,763	9408986		0	0			0.0017	0.000082	772.2862	15.7	49.2
	LSR	Spr (MA)	6,047	15119913	1051	305	1356	159	0.117257	0.0007	0.000082	1241.037	16.4	75.7
	Delta	Spr (MA)	5,532	13832637	3862	9	3871	20	0.005167	0	0	0	16.4	0.0
	CS & SB	Spr (MA)	1,200	3041331	73685	14171	87856	282	0.00321	0.0075	0.000024	73.21543	16.4	4.5

Total Winter Run Consumed by Striped Bass 7,188

		Correction	
Mean CV escapement 80-88	228700		
CV escapement - 1993	141600	0,619152	4,450

1994

WR smolts - 1994 90545

% Winter run smolts consumed by striped bass 4.92

Table 3. CDFG bioenergetic predation estimate on winter-run salmon: 1995.

Age (yr)	Location	Season	No. SB	Wt. Eaten	Fish Biomass	Shrimp Biomass	Total Biomass	Salmon Biomass	Salmon Proportion Biomass	Proportion slmon that are WR	WR Proportion Biomass	Grams WR Consumed	Mean WR wt	Number WR Consumed
Juv = 1	USR	Wint (DJF)	0	0		0	0			0.0171	0	0	11.8	0.0
	LSR	Wint (DJF)	33530	6036799	1531	1651	3182	0	0	0.0184	0	0	17	0.0
	Delta	Wint (DJF)	368830	66873809	2104	234	2338	0	0	0.0015	0	0	17	0.0
	CS & SB	Wint (DJF)	2227350	4.2E+08	38819	41400	80219	0	0	0.0673	0	0	17	0.0
	USR	Spr (MA)	23950	4816052		0	0			0.0067	0.000103	494.3269	15.7	31.5
	LSR	Spr (MA)	23950	4816052	490	305	795	6	0.007547	0.0136	0.000103	494.3269	16.4	30.1
	Delta	Spr (MA)	134120	26959894	812	9	821	20	0.024361	0.0002	4.9E-06	131.4002	16.4	8.0
	CS & SB	Spr (MA)	1494480	3.1E+08	23118	14171	37289	147	0.003942	0.0164	0.000065	19738.57	16.4	1203.6
Subadult =	USR	Wint (DJF)	0	0		0	0			0.0171	0	0	11.8	0.0
	LSR	Wint (DJF)	452884	2.6E+08	2918	1651	4569	0	0	0.0184	0	0	17	0.0
	Delta	Wint (DJF)	505436	3.0E+08	6189	234	6423	40	0.006228	0.0015	9.3E-06	2786.337	17	163.9
	CS & SB	Wint (DJF)	79787	47085401	80023	41400	121423	137	0.001128	0.0673	0.000076	3575.37	17	210.3
	USR	Spr (MA)	122196	74400368		0	0			0.0067	0.000537	39976.83	15.7	2546.4
	LSR	Spr (MA)	426488	2.6E+08	758	305	1063	42	0.039511	0.0136	0.000537	139534	16.4	8508.2
	Delta	Spr (MA)	385516	2.3E+08	2191	9	2200	20	0.009091	0.0002	1.8E-06	426.774	16.4	26.0
	CS & SB	Spr (MA)	40612	25083025	39271	14171	53442	235	0.004397	0.0164	0.000072	1807.434	16.4	110.2
Subadult =	USR	Wint (DJF)	0	0		0	0			0.0171	0.00023	0	11.8	0.0
	LSR	Wint (DJF)	183,000	1.6E+08	4190	1651	5841	73	0.012498	0.0184	0.00023	36996.13	17	2176.2
	Delta	Wint (DJF)	212,806	1.9E+08	11081	234	11315	225	0.019885	0.0015	0.00003	5775.167	17	339.7
	CS & SB	Wint (DJF)	53,154	48380840	145498	41400	186898	421	0.002253	0.0673	0.000152	7331.39	17	431.3
	USR	Spr (MA)	96,165	90269507		0	0			0.0067	0.001595	143951.9	15.7	9168.9
	LSR	Spr (MA)	154,533	1.5E+08	1051	305	1356	159	0.117257	0.0136	0.001595	231325.7	16.4	14105.2
	Delta	Spr (MA)	141,377	1.3E+08	3862	9	3871	20	0.005167	0.0002	1.0E-06	137.1324	16.4	8.4
	CS & SB	Spr (MA)	30,667	29178430	73685	14171	87856	282	0.00321	0.0164	0.000053	1535.973	16.4	93.7
Subadult =	USR	Wint (DJF)	0	0		0	0			0.0171	0.00023	0	11.8	0.0
	LSR	Wint (DJF)	95,709	1.2E+08	4190	1651	5841	73	0.012498	0.0184	0.00023	27403.21	17	1612.0
	Delta	Wint (DJF)	111,297	1.4E+08	11081	234	11315	225	0.019885	0.0015	0.00003	4277.693	17	251.6
	CS & SB	Wint (DJF)	27,799	35821102	145498	41400	186898	421	0.002253	0.0673	0.000152	5430.395	17	319.4
	USR	Spr (MA)	50,294	66963050		0	0			0.0067	0.001595	106625.9	15.7	6791.5
	LSR	Spr (MA)	80,821	1.1E+08	1051	305	1356	159	0.117257	0.0136	0.001595	171344	15.4	10447.8
	Delta	Spr (MA)	73,940	96298829	3862	9	3871	20	0.005167	0.0002	1.0E-06	101.5746	16.4	6.2
	CS & SB	Spr (MA)	16,039	21612601	73685	14171	87856	282	0.00321	0.0164	0.000053	1137.702	16.4	69.4
Adult = 5	USR	Wint (DJF)	0	0		0	0			0.0171	0.00023	0	11.8	0.0
	LSR	Wint (DJF)	50,056	1.0E+08	4190	1651	5841	73	0.012498	0.0184	0.00023	23915.54	17	1406.8
	Delta	Wint (DJF)	58,209	1.2E+08	11081	234	11315	225	0.019885	0.0015	0.00003	3726.039	17	219.2
	CS & SB	Wint (DJF)	14,539	31201587	145498	41400	186898	421	0.002253	0.0673	0.000152	4730.088	17	278.2
	USR	Spr (MA)	26,304	55902275		0	0			0.0067	0.001595	89146.81	15.7	5678.1
	LSR	Spr (MA)	42,269	89833010	1051	305	1356	159	0.117257	0.0136	0.001595	143255.8	16.4	8735.1
	Delta	Spr (MA)	38,671	82184827	3862	9	3871	20	0.005167	0.0002	1.0E-06	84.92361	16.4	5.2
	CS & SB	Spr (MA)	8,388	18026969	73685	14171	87856	282	0.00321	0.0164	0.000053	946.952	16.4	57.9
Adult = 6	USR	Wint (DJF)	0	0		0	0			0.0171	0.00023	0	11.8	0.0
	LSR	Wint (DJF)	26,179	61305746	4190	1651	5841	73	0.012498	0.0184	0.00023	14097.91	17	829.3
	Delta	Wint (DJF)	30,443	73780859	11081	234	11315	225	0.019885	0.0015	0.00003	2200.711	17	129.5
	CS & SB	Wint (DJF)	7,604	18428594	145498	41400	186898	421	0.002253	0.0673	0.000152	2793.732	17	164.3
	USR	Spr (MA)	13,757	34398495		0	0			0.0067	0.001595	54854.95	15.7	3493.9
	LSR	Spr (MA)	22,107	55277184	1051	305	1356	159	0.117257	0.0136	0.001595	88149.99	16.4	5375.0
	Delta	Spr (MA)	20,225	50571007	3862	9	3871	20	0.005167	0.0002	1.0E-06	52.25627	16.4	3.2
	CS & SB	Spr (MA)	4,387	11118861	73685	14171	87856	282	0.00321	0.0164	0.000053	585.3044	16.4	35.7
Adult = 7	USR	Wint (DJF)	0	0		0	0			0.0171	0.00023	0	11.8	0.0
	LSR	Wint (DJF)	13,692	32062905	4190	1651	5841	73	0.012498	0.0184	0.00023	7373.206	17	433.7
	Delta	Wint (DJF)	15,922	38587389	11081	234	11315	225	0.019885	0.0015	0.00003	1150.972	17	67.7
	CS & SB	Wint (DJF)	3,977	9638155	145498	41400	186898	421	0.002253	0.0673	0.000152	1461.122	17	85.9
	USR	Spr (MA)	7,195	17990413		0	0			0.0067	0.001595	28689.14	15.7	1827.3
	LSR	Spr (MA)	11,562	28909967	1051	305	1356	159	0.117257	0.0136	0.001595	46102.44	16.4	2811.1
	Delta	Spr (MA)	10,578	26448637	3862	9	3871	20	0.005167	0.0002	1.0E-06	27.33003	16.4	1.7
	CS & SB	Spr (MA)	2,294	5815164	73685	14171	87856	282	0.00321	0.0164	0.000053	306.1142	16.4	18.7
Adult = 8	USR	Wint (DJF)	0	0		0	0			0.0171	0.00023	0	11.8	0.0
	LSR	Wint (DJF)	7,161	16768899	4190	1651	5841	73	0.012498	0.0184	0.00023	3856.187	17	226.8
	Delta	Wint (DJF)	8,327	20181204	11081	234	11315	225	0.019885	0.0015	0.00003	601.9582	17	35.4
	CS & SB	Wint (DJF)	2,080	5040755	145498	41400	186898	421	0.002253	0.0673	0.000152	764.1667	17	45.0
	USR	Spr (MA)	3,763	9408986		0	0			0.0067	0.001595	15004.42	15.7	955.7
	LSR	Spr (MA)	6,047	15119913	1051	305	1356	159	0.117257	0.0136	0.001595	24111.58	16.4	1470.2
	Delta	Spr (MA)	5,532	13832637	3862	9	3871	20	0.005167	0.0002	1.0E-06	14.29361	16.4	0.9
	CS & SB	Spr (MA)	1,200	3041331	73685	14171	87856	282	0.00321	0.0164	0.000053	160.0977	16.4	9.8

Total Winter Run Consumed by Striped Bass 93,061

		Correction	
Mean CV escapement 80-88	228700		
CV escapement - 1994	158900	0.694797	64,658
WR smolts - 1995		74491	

% Winter run smolts consumed by striped bass 86.80

1995

Table 4. CDFG bioenergetic predation estimate on winter-run salmon: 1996.

Age (yr)	Location	Season	No. SB	Wt. Eaten	Fish Biomass	Shrimp Biomass	Total Biomass	Salmon Biomass	Salmon Proportion Biomass	Proportion almon that are WR	WR Proportion Biomass	Grams WR Consumed	Mean WR wt	Number WR Consumed
Juv = 1	USR	Wint (DJF)	0	0		0	0			0.024	0.00003	0	11.8	0.0
	LSR	Wint (DJF)	33530	8036799	1531	1651	3182	0	0	0.0042	0	0	17	0.0
	Delta	Wint (DJF)	368830	68873809	2104	234	2338	0	0	0.0108	0	0	17	0.0
	CS & SB	Wint (DJF)	2227350	4.2E+08	38818	41400	80219	0	0	0.043	0	0	17	0.0
	USR	Spr (MA)	23950	4816052		0	0			0.0021	5.3E-06	25.4433	15.7	1.6
	LSR	Spr (MA)	23950	4816052	490	305	795	6	0.007547	0.0085	0.000064	308.9543	16.4	18.8
	Delta	Spr (MA)	134120	26969894	812	9	821	20	0.024361	0.0011	0.000027	722.7012	16.4	44.1
	CS & SB	Spr (MA)	1494480	3.1E+08	23118	14171	37289	147	0.003942	0.0182	0.000072	21905	16.4	1335.7
Subadult =	USR	Wint (DJF)	0	0		0	0			0.024	0.00003	0	11.8	0.0
	LSR	Wint (DJF)	452984	2.6E+08	2918	1651	4569	0	0	0.0042	0	0	17	0.0
	Delta	Wint (DJF)	505436	3.0E+08	6189	234	6423	40	0.006228	0.0108	0.000067	20061.83	17	1180.1
	CS & SB	Wint (DJF)	79787	47085401	80023	41400	121423	137	0.001128	0.043	0.000049	2284.412	17	134.4
	USR	Spr (MA)	122196	74400388		0	0			0.0021	0.00003	2199.749	15.7	140.1
	LSR	Spr (MA)	426488	2.6E+08	758	305	1063	42	0.039511	0.0085	0.000336	87208.73	16.4	5317.6
	Delta	Spr (MA)	385516	2.3E+08	2191	9	2200	20	0.009091	0.0011	0.00001	2347.257	16.4	143.1
	CS & SB	Spr (MA)	40612	25063025	39271	14171	53442	235	0.004397	0.0182	0.00008	2005.811	16.4	122.3
Subadult =	USR	Wint (DJF)	0	0		0	0			0.024	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	183,000	1.6E+08	4190	1651	5841	73	0.012498	0.0042	0.000052	8444.769	17	496.8
	Delta	Wint (DJF)	212,806	1.9E+08	11081	234	11315	225	0.019885	0.0108	0.000215	41581.2	17	2446.0
	CS & SB	Wint (DJF)	53,154	48360840	145498	41400	186898	421	0.002253	0.043	0.000097	4684.246	17	275.5
	USR	Spr (MA)	96,165	90269507		0	0			0.0021	0.000082	7409.289	15.7	471.9
	LSR	Spr (MA)	154,533	1.5E+08	1051	305	1356	159	0.117257	0.0085	0.000997	144578.6	16.4	8815.8
	Delta	Spr (MA)	141,377	1.3E+08	3862	9	3871	20	0.005167	0.0011	5.7E-06	754.2282	16.4	46.0
	CS & SB	Spr (MA)	30,667	29178430	73685	14171	87856	282	0.00321	0.0182	0.000058	1704.555	16.4	103.9
Subadult =	USR	Wint (DJF)	0	0		0	0			0.024	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	95,709	1.2E+08	4190	1651	5841	73	0.012498	0.0042	0.000052	6255.08	17	367.9
	Delta	Wint (DJF)	111,297	1.4E+08	11081	234	11315	225	0.019885	0.0108	0.000215	30799.39	17	1811.7
	CS & SB	Wint (DJF)	27,799	35821102	145498	41400	186898	421	0.002253	0.043	0.000097	3469.643	17	204.1
	USR	Spr (MA)	50,294	66863050		0	0			0.0021	0.000082	5488.095	15.7	349.6
	LSR	Spr (MA)	80,821	1.1E+08	1051	305	1356	159	0.117257	0.0085	0.000997	107090	16.4	6529.9
	Delta	Spr (MA)	73,940	98298829	3862	9	3871	20	0.005167	0.0011	5.7E-06	558.8604	16.4	34.1
	CS & SB	Spr (MA)	16,039	21812601	73685	14171	87856	282	0.00321	0.0182	0.000058	1262.572	16.4	77.0
Adult = 5	USR	Wint (DJF)	0	0		0	0			0.024	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	50,056	1.0E+08	4190	1651	5841	73	0.012498	0.0042	0.000052	5458.982	17	321.1
	Delta	Wint (DJF)	58,209	1.2E+08	11081	234	11315	225	0.019885	0.0108	0.000215	26827.48	17	1578.1
	CS & SB	Wint (DJF)	14,539	31201587	145498	41400	186898	421	0.002253	0.043	0.000097	3022.196	17	177.8
	USR	Spr (MA)	26,304	55802275		0	0			0.0021	0.000082	4588.439	15.7	292.3
	LSR	Spr (MA)	42,289	89833010	1051	305	1356	159	0.117257	0.0085	0.000997	89534.89	16.4	5459.4
	Delta	Spr (MA)	38,671	82184827	3862	9	3871	20	0.005167	0.0011	5.7E-06	467.0799	16.4	28.5
	CS & SB	Spr (MA)	8,388	18026969	73685	14171	87856	282	0.00321	0.0182	0.000058	1053.105	16.4	64.2
Adult = 6	USR	Wint (DJF)	0	0		0	0			0.024	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	26,179	61305746	4190	1651	5841	73	0.012498	0.0042	0.000052	3218.001	17	189.3
	Delta	Wint (DJF)	30,443	73780859	11081	234	11315	225	0.019885	0.0108	0.000215	15845.12	17	932.1
	CS & SB	Wint (DJF)	7,604	18428594	145498	41400	186898	421	0.002253	0.043	0.000097	1785	17	105.0
	USR	Spr (MA)	13,757	34398495		0	0			0.0021	0.000082	2823.416	15.7	179.8
	LSR	Spr (MA)	22,107	55277184	1051	305	1356	159	0.117257	0.0085	0.000997	55093.74	16.4	3359.4
	Delta	Spr (MA)	20,225	50571007	3862	9	3871	20	0.005167	0.0011	5.7E-06	287.4095	16.4	17.5
	CS & SB	Spr (MA)	4,387	11118861	73685	14171	87856	282	0.00321	0.0182	0.000058	649.5452	16.4	39.6
Adult = 7	USR	Wint (DJF)	0	0		0	0			0.024	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	13,692	32062905	4190	1651	5841	73	0.012498	0.0042	0.000052	1683.014	17	99.0
	Delta	Wint (DJF)	15,922	38587389	11081	234	11315	225	0.019885	0.0108	0.000215	8286.996	17	487.5
	CS & SB	Wint (DJF)	3,977	9638155	145498	41400	186898	421	0.002253	0.043	0.000097	933.5547	17	54.9
	USR	Spr (MA)	7,195	17990413		0	0			0.0021	0.000082	1476.647	15.7	94.1
	LSR	Spr (MA)	11,562	28909957	1051	305	1356	159	0.117257	0.0085	0.000997	28814.03	16.4	1757.0
	Delta	Spr (MA)	10,578	26448637	3862	9	3871	20	0.005167	0.0011	5.7E-06	150.3152	16.4	9.2
	CS & SB	Spr (MA)	2,294	5815164	73685	14171	87856	282	0.00321	0.0182	0.000058	339.7121	16.4	20.7
Adult = 8	USR	Wint (DJF)	0	0		0	0			0.024	0.000012	0	11.8	0.0
	LSR	Wint (DJF)	7,161	16768899	4190	1651	5841	73	0.012498	0.0042	0.000052	880.2165	17	51.8
	Delta	Wint (DJF)	8,327	20161204	11081	234	11315	225	0.019885	0.0108	0.000215	4334.099	17	254.9
	CS & SB	Wint (DJF)	2,080	5040755	145498	41400	186898	421	0.002253	0.043	0.000097	486.2491	17	28.7
	USR	Spr (MA)	3,763	9408986		0	0			0.0021	0.000082	772.2862	15.7	49.2
	LSR	Spr (MA)	6,047	15119913	1051	305	1356	159	0.117257	0.0085	0.000997	15069.74	16.4	918.9
	Delta	Spr (MA)	5,532	13832637	3862	9	3871	20	0.005167	0.0011	5.7E-06	78.61483	16.4	4.8
	CS & SB	Spr (MA)	1,200	3041331	73685	14171	87856	282	0.00321	0.0182	0.000058	177.6894	16.4	10.8

Total Winter Run Consumed by Striped Bass			47,053
		Correction	
Mean CV escapement 80-88	228700		
CV escapement - 1995	200000	0.874506	41,149
WR smolts - 1996		398107	
% Winter run smolts consumed by striped bass			10.34

1996