Annotated Bibliography on Aquatic Fish Resources in the Sacramento San-Joaquin Bay-Delta in reference to River Flow Objectives at Vernalis

U.S. Fish and Wildlife Service
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Introduction

This annotated bibliography summarizes a broad range of literature relevant to aquatic resources in the Sacramento-San Joaquin Bay-Delta with emphasis on environmental factors controlling species abundance and distribution. Sources include scientific journals and reports, agency reports and agency plans. Summaries include either the original abstracts or relevant sections for each source. References were included in 5 objectives of the 1995 Bay Delta Plan: 1) Export limit objectives, 2) delta outflow objectives, 3) Rio Vista flow objectives, 4) Vernalis flow objectives and 5) Vernalis day pulse flow objective. Any given reference may be included in one or several objectives, depending on its content. An asterisk in front of the first author's name denotes that such reference was not available as a PDF file. The term "et al." follows the first author's name in studies involving more than two authors.

4. River flow objectives: San Joaquin River at Airport Way Bridge, Vernalis, February - April 14 and May 16 - June.

Arthur, J.F. et al. 1996. Summary of federal and state water project environmental impacts in the San Francisco Bay-Delta estuary, California. In: pages 445-495. J.T. Hollibaugh (ed.) The San Francisco Bay: The ecosystem. Further investigations into the natural history of San Francisco Bay and Delta with reference to the influence of man. Friesen Printers, Altona, Manitoba.

This review summarizes the early and post Federal and State water project development and the major changes in physical, chemical, and biological constituents that have occurred as a result of direct water transfer throughout the Delta (fresh-brackish water portion of the San Francisco Bay Delta estuary. Transfer of increasing amounts of Sacramento River water across the Delta channels to the Federal and State water project export pumps in the South Delta over the last 45 years has resulted in several major environmental impacts. The increase in fresh water in many delta channels during the summer and fall comes from water released from reservoirs to reduce salinity intrusion into the Delta and protect water quality. Most of the negative project-related impacts result from transferring large quantities of water across the Delta in existing channels. The ever increasing demand for project export water has resulted in net flow reversals during most months of the year in the Central and Southern Delta. Flow reversals has resulted in: the recycling of large quantities of salt from the San Joaquin Valley back into the Valley, scouring of Delta channels; increase in trihalomethane (THM) precursors from Delta sources in export water designated for municipal use; flushing of Delta aquatic habitat resulting from decreased residence times, and entrainment of plankton and various life stages of fish in the project intakes.

*** Bennett, W. A. and P.B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary. In pages 519-542. J.T. Hollibaugh (ed.) The San Francisco Bay: The ecosystem. Further investigations into the natural history of San Francisco Bay and Delta with reference to the influence of man. Friesen Printers, Altona, Manitoba.**

Fish populations have declined markedly in the Sacramento-San Joaquin estuary. Evidence of factors contributing to the declining abundance of fishes is reviewed in the context of six pathways by which alteration of freshwater outflow to the estuary affects the survival of larval and juvenile fishes. Specific pathways include: 1) transport and entrainment, 2) retention in and/or advection from preferred habitats, 3) success and effects of invading species, 4) primary production and food web dynamics, 5) dilution and/or flushing of toxic compounds, and 6) the quantity and quality of shallow-water spawning/rearing habitat. Clearly, ameliorating the effects of various factors (e.g., reducing entrainment, toxic runoff, and improving shallow water habitat) will improve conditions for fish. The current lack of life history information and on several of the most affected species and the need to prevent extinctions suggests that the most pragmatic and promising solution is to ensure adequate outflow to the estuary. The simultaneous declines of so many species with different habitat requirements and life history strategies is an indication of broad problems with the estuarine environment, especially in the Delta.

2003 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2004. San Joaquin River Group Authority. Prepared for the California Water Resources Control Board in compliance with D-1641.

Vernalis flows are referenced to 123 times in the document; Table 2 and 4, and Figure 6-4 through 6-7.

Brandes, P.L, and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In R.L. Brown (ed.) Contributions to the Biology of Central Valley Salmonids. California Department of Fish and Game. Fish Bulletin 179(2):39-136.

All four races of juvenile Central Valley Chinook salmon migrate through and many rear in the Sacramento-San Joaquin Delta and Estuary. Delta residence and migration is considered important in determining adult production, as it is generally believed that density dependent effects are minimal after this life stage. Populations of winter run and spring run are presently listed as endangered and threatened species, while the remaining populations in the Central Valley are candidate species. Actions in the Delta to improve survival are likely important in the recovery of these depressed populations. The tidally influenced freshwater Delta also is an important area for water management in California, as it is where the Central Valley and State Water Project pump large volumes of water to southern California, the San Joaquin Valley and the Bay area. To document the effect of these various water management activities in the Delta on juvenile salmon, monitoring and special studies have been conducted since the early 1970s to the present. Changes in abundance in the Delta and estuary appear related to flow; high flows increase the use of the Delta and San Francisco Bay by fry. Relative survival of fry appears greater in the upper Sacramento River than in the Delta or bay, especially in the wetter years. Survival appears lower in the Central Delta relative to that in the North Delta in drier years for both fry and smolts. Fall-run smolt and late-fall-run yearling survival studies have found that diversion into the Central Delta via the Delta Cross Channel or Georgiana Slough reduces survival through the Delta. Experiments in the San Joaquin Delta have shown that survival appears greater for smolts that migrate down the mainstem San Joaquin River rather than through upper Old River. A temporary barrier in upper Old River was tested and found to improve survival for smolts originating in the San Joaquin basin. These specific experiments have identified management actions that could improve juvenile salmon survival through the Delta. In addition, indices of annual survival provide a way to compare survival through the Delta and could be used to assess restoration and management actions. This work demonstrates How long-term scientific studies can be applied to address management and restoration issues.

Brandes, P., E. et al. 2003. The Use of the Environmental Water Account for the Protection of Anadromous Salmonids in the Sacramento/San Joaquin Delta in 2002-2003. October 2003. Prepared for CALFED Bay-Delta Program.

Vernalis flows are referenced to 6 times in the document. The following quote is an example (page 6):

"The Management Agencies requested an export reduction at the State Water Project and Central Valley Project facilities consistent with the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Pursuant to the VAMP study plan, and after an evaluation to determine the base flow, the target flow at Vernalis was set at 3,200 cfs with exports at the CVP and SWP established at a combined 1,500 cfs between April 15 and May 15, 2003. The purpose of the VAMP is to evaluate the relative effects of exports, inflow and the Head of Old River (HORB) on juvenile San Joaquin basin Chinook salmon survival and assist in providing protection for both anadromous and estuarine species. An increase in the survival of juvenile salmon and steelhead emigrating from the Sacramento River basin and East-side tributaries to the Delta may also occur due to improved Delta hydrodynamic conditions created by the VAMP."

Brown, L.R. 2000. Fish communities and their associations with environmental variables, lower San Joaquin River drainage, California. Environmental Biology of Fishes 57: 251-269.

Twenty sites in the lower San Joaquin River drainage, California, were sampled from 1993 to 1995 to characterize fish communities and their associations with measures of water quality and habitat quality. The feasibility of developing an Index of Biotic Integrity was assessed by evaluating four fish community metrics, including percentages of native fish, omnivorous fish, fish intolerant of environmental degradation, and fish with external anomalies. Of the thirty-one taxa of fish captured during the study, only 10 taxa were native to the drainage. Multivariate analyses of percentage data identified four site groups characterized by different groups of species. The distributions of fish species were related to specific conductance, gradient, and mean depth; however, specific conductance acted as a surrogate variable for a large group of correlated variables. Two of the fish community metrics – percentage of introduced fish and percentage of intolerant fish – appeared to be responsive to environmental quality but the responses of the other two metrics – percentage of omnivorous fish and percentage of fish with anomalies – were less direct. The conclusion of the study is that fish communities are responsive to environmental conditions, including conditions associated with human-caused disturbances, particularly agriculture and water development. The results suggest that changes in water management and water quality could result in changes in species distributions. Balancing the costs and benefits of such changes poses a considerable challenge to resource managers.

The following is a quote from page 267:

"Differences in stream discharge among years is the most likely reason that species communities in 1995 were so different from those in the other years. Stream discharge in the lower San Joaquin drainage was much higher in water year 1995 (October 1 of previous year to September 30) compared to 1993 and 1994 (Mullen et al.6, Anderson et al.7, Hayes et al.8). Annual mean daily stream discharges ($m^3 s^{-1}$) in water years 1993 to 1995 were 66.6, 47.7, and 246.5, respectively, at the San Joaquin River near Vernalis (SJ1), 14.2, 8.4, and 42.6, respectively, at the Merced River at River Road (MR1), and 13.9, 10.4, and 93.5, respectively, at the Tuolumne River in Modesto (TR2). The exception was the Stanislaus River near Ripon (SR2), where stream discharge was relatively unchanged with values of 13.2, 12.7, and 16.5$m^3 s^{-1}$ in 1993, 1994, and 1995, respectively. Stream discharge at the time of sampling followed the same pattern."

DWR. 2004. Management of the California State Water Project. California Department of Water Resources. Bulletin 132-03. December 2004.

Vernalis flows are referenced to 18 times in the document. The following quote is an example (page 42):

"D-1641 also includes a minimum San Joaquin River base and pulse flows from the Winter-Run Salmon Biological Opinion that are dependent upon water year type. These flows are measured at Vernalis on the San Joaquin River. Dry year base flows are set at 2,280 cfs from February to April 14 and from May 16 through June 30, if the X2 objective is required to be at or west of the Chipps Island location. The baseflow objective is relaxed to 1,420 cfs when X2 is required to be east of Chipps Island. The X2 objective was required to be met at Chipps Island during February through May. During June, X2 was located east of Chipps Island, allowing the relaxed Vernalis flow minimum of 1,420 cfs for June. The ernalis flow objective was not met during February, March, and the first half of April. The Bureau informed SWRCB that water monies were not available to meet the objective. SWRCB decided that the Bureau dedicate a similar quantity of water to fishery purposes later in the year."

DWR 1998. California Water Plan Update 1998. Executive Summary. November 1998. California Department of Water Resources. Bulletin 160-98.

Vernalis flows are referenced to 17 times in the document. The following quotes are examples from page 2-15:

"(5) Watershed Alternative–Monthly average flow requirements are established for major watersheds based on Delta outflow and Vernalis flow objectives and the watersheds' average unimpaired flow. The parties responsible for providing the required flows are water users with storage in foothill reservoirs that control downstream flow to the Delta, and water users with upstream reservoirs that have a cumulative capacity of at least 100 taf who use water primarily for consumptive uses.

(6) Recirculation Alternative–USBR is required to make releases from the Delta-Mendota Canal to meet the Vernalis flow objectives.

(7) San Joaquin Basin Negotiated Agreement–San Joaquin Basin water right holders' responsibility to meet the plan objectives is based on an agreement titled "Letter of Intent among

Export Interests and San Joaquin River Interests to Resolve San Joaquin River Issues Related to Protection of Bay-Delta Environmental Resources."
(8) San Joaquin Basin Negotiated Agreement–Vernalis flow objectives are replaced by target flows contained in the agreement.

Dege, M. and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. American Fisheries Society Symposium 39:49–65.

Data on spring and summertime larval and juvenile fish distribution and abundance was analyzed in the upper San Francisco Estuary (SFE), California between 1995 and 2001. The upper SFE includes the tidal freshwater areas of the Sacramento–San Joaquin Delta downstream to the euryhaline environment of San Pablo Bay. The sampling period included years with a variety of outflow conditions. Fifty taxa were collected using a larval tow net. Two common native species, delta smelt *Hypomesus transpacificus* and longfin smelt *Spirinchus thaleichthys*, and four common alien taxa, striped bass *Morone saxatilis*, threadfin shad *Dorosoma petenense*, gobies of the genus *Tridentiger*, and yellowfin goby *Acanthogobius flavimanus*, were selected for detailed analysis. Outflow conditions had a strong influence on the geographic distribution of most of the species, but distribution with respect to the 2 psu isohaline (X2) was not affected. The distribution patterns of delta smelt, longfin smelt, and striped bass were consistent with larvae moving from upstream freshwater spawning areas to downstream estuarine rearing areas. There were no obvious relationships of outflow with annual abundance indices. Our results support the idea of using X2 as an organizing principle in understanding the ecology of larval fishes in the upper SFE. Additional years of sampling will likely lead to additional insights into the early life history of upper SFE fishes.

Estuarine Ecology Team. 1997. An assessment of the likely mechanisms underlying the "Fish-X2" relationships. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 52.

The effect of X2 on delta smelt entrainment losses are very well documented. In low outflow years, delta smelt may exhibit a higher probability of entrainment mortality of larvae, juveniles and adults at SWP, CVP, PG&E and agricultural diversions. Other less well documented, yet presumably important effects of X2 on delta smelt, include: 1) increase spawning habitat. The amount of flooded vegetation increases with increasing outflow, 2) increased co-occurrence of young delta smelt with food organisms. There is a significant relationship between delta smelt year-class strength and the amount of time during spring X2 is located in Siusun Bay. Other factors may be operating in some years as well, 3) more suitable habitat for larvae and juveniles may occur when X2 is located downstream in Siusun Bay, which supplies substantially more shallow water habitat than the river channels upstream, 4) reduced probability of encounter with predators. Annual delta smelt year classes exhibit a significant negative association with the abundance of the non-native predator inland silverside in years when X2 is located upstream during spring, 5) entrapment zone (EZ) residence time. Overall, food for larval and juvenile delta smelt is higher near the upstream end of the EZ. When X2 is positioned in Siusun Bay, a higher proportion of the larval population occurs in the EZ, 6) delta smelt may also reside longer in Siusun Bay if they are transported there earlier by higher flows and 7) higher production of food. The abundance of many food organisms for delta smelt larvae and juveniles is affected by mean X2 during spring. Thus, overall growth and condition of delta smelt may be better in higher outflow years.

Mesick, C. 2001. The effects of the San Joaquin River flows and Delta export rates during October on the number of adult San Joaquin Chinook salmon that Stray. In: R.L. Brown (ed.) Contributions to the Biology of Central Valley Salmonids. California Department of Fish and Game. Fish Bulletin 179(2): 139-162.

This report describes a two-part investigation of the effects of fall make-up pumping on straying of adult San Joaquin Chinook salmon. The first part is a reevaluation of 1964 to 1967 data collected by Hallock and others (1970) on the migratory behavior of tagged and untagged adult San Joaquin salmon in the Delta. The second part is an evaluation of the recovery of adult salmon that were released in the San Joaquin basin as coded-wire tagged juveniles reared at the Merced River Fish Facility. First, adult salmon are found migrating throughout the San Joaquin Delta near Prisoners Point primarily during October, the period when they are probably most susceptible to low flows and high exports. Second, the fish migrate slowly and do not arrive in San Joaquin tributaries until about four weeks after they pass Prisoners Point, even when flows, exports, and dissolved oxygen concentrations near Stockton are suitable for migration and third, migration rates of adult salmon are substantially higher when Vernalis flows exceed about 3,000 cfs and total exports are less than 100% of Vernalis flows. CWT recovery data suggest that: 1) straying rates of salmon increased as the percentage of San Joaquin flow exported by the CVP and SWP pumping facilities increased and 2) the critical period is between 1 and 21 October. Pulse flows from the San Joaquin tributaries, or a reduction of Delta exports that result in no more than a 300% export rate of San Joaquin flows at Vernalis for eight to 12 days in mid-October, are sufficient to keep straying rates below 3%. When more than 300% of Vernalis flow is exported over a ten-day period in mid-October, adult San Joaquin Chinook salmon stray to the Sacramento and eastside basins. Further tests are needed to support the conclusions derived from existing data.

Moyle, P.B. et al. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society. 121:67-77.

The **delta smelt** *Hypomesus transpacificus* is endemic to the upper Sacramento-San Joaquin estuary. It is closely associated with the freshwater-saltwater mixing zone except when it spawns in fresh water. The **delta smelt** feeds on zooplankton, principally copepods. Its dominant prey was the native copepod *Eurytemora affinis* in 1972-1974 but the exotic copepod *Pseudodiaptomus forbesi* in 1988. Because the **delta smelt** has a 1-year life cycle and low fecundity, it is particularly sensitive to changes in estuarine conditions. Tow-net and midwater trawl samples showed wide year-to-year fluctuations in population densities. Surveys of different areas showed declines in different years between 1980 and 1983. After 1983, however, all populations remained at very low densities throughout most of the range. The recent decline of **delta smelt** coincides with an increase in the diversion of inflowing water during a period of extended drought. These conditions have restricted the mixing zone to a relatively small area of deep river channels and, presumably, have increased the entrainment of **delta smelt** into water diversions.

Nobriga, M., et al. 2001. Spring 2000 Delta smelt salvage and delta hydrodynamics and an introduction to the Delta smelt decision tree. Interagency Ecological Program. Newsletter Spring 2001 14(2):42-46.

San Joaquin River flows during winter and early spring 2000 were similar to other years hypothesized by Nobriga et al. (2000) to attract spawning delta smelt into the Central Delta. Delta smelt salvage quickly exceeded red light levels following the VAMP in 2000 as it has in most recent years. This lends additional support to the hypothesis that the VAMP results in suitable larval rearing conditions within the Central and South Delta as suggested by high subsequent salvage when CVP and SWP exports ramp up after the VAMP. Because delta smelt begins to be counted in salvage statistics when fish reach sizes of about 25 mm, it is conceivable that more fish were entrained as larvae in years prior to VAMP and thus, would not have survived to be reported in salvage statistics.

Sacramento Fish and Wildlife Office. 2004. 5-year review. *Hypomesus transpacificus* (delta smelt) . Notice: Federal Register 68(148):45270-45271 on August 1, 2003.

The current U.S. Fish and Wildlife Service (Service) Recovery Plan (1996) for delta smelt assigned a recovery potential of 2C. A listed species is assigned a recovery priority number from 1 (highest) to 18 (lowest) according to the degree of threats, recovery potential and taxonomic distinctness. In addition, a species' rank may be elevated by adding a C designation to its numerical rank to indicate that there is some degree of conflict between the species' conservation efforts and economic development associated with its recovery. Recovery priority numbers are based on criteria published the Federal Register Notice (48 FR 43098; September 21, 1983). At the time of listing, Delta smelt was under a high degree of threat from the severe 1987-1992 California drought. The species persisted in small numbers and rebounded to pre-decline levels in 1993, suggesting that its recovery potential is fairly high. The subsequent decline in 1994, a critical water year, to a then all-time low annual abundance index of 102 (Fall Midwater Trawl Survey (FMWT)), however, illustrates the high degree of threat that neutralizes gains in abundance that result from good water years. More recent abundance indices have varied, but overall, the trend is still negative.

USFWS. 1995. Biological Opinion for Delta Smelt. March 6, 1995. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office. Sacramento, CA.

The following is a quote from Attachment B:

"Implementation -Measures - San Joaquin River System

1. Not later than three years following adoption of this Plan, the SWRCB shall assign responsibility for the following flows, together with other measures in the watershed sufficient to meet the narrative criteria, in the San Joaquin River at Vernalis among the water right holders in the watershed. During this three-year period, the Bureau of Reclamation shall provide these flows, in accordance with the biological opinion for Delta smelt. These flows are interim flows and will be reevaluated as to timing and magnitude (up or down) within the next 3 years.

	Feb-June Flows (cfs)*	April-May pulse flows (cfs)"
C	71 0-1140	3110-3540
D	1420-2280	4020-4880
BN	1420-2280	4620-5480
AN	2130-3420	5730-7020
W	2130-3420	7330-8620 ”

USFWS. 1995A. Working paper on restoration needs: Habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volumes 1-3. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the anadromous Fish Restoration Program. Stockton, CA.

Volumes 1 and 3 summarize the production goals, limiting factors, flows and other restoration actions that AFRP technical teams found necessary to double production of the anadromous fish stocks. Volume 2 identifies historical and existing conditions for anadromous fish and identifies roles of state and federal agencies in managing anadromous fish.

USFWS. 2005. Operational Criteria and Plan, Biological Opinion for Delta Smelt. February 16, 2005. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office. Sacramento, CA.

In-stream flow requirements for the Vernalis from February to June are discussed. Table 5 (p. 59) lists water year class and flows at Vernalis for the February-June period. The VAMP is pulse flow period is discussed with regards to flow objectives and export restrictions (p. 62-63).

The distribution of delta smelt may not always be regulated by X2 since food availability may influence their distribution (p.116). Further, “In addition to the degradation and loss of estuarine habitat, delta smelt have been increasingly subject to entrainment, upstream or reverse flows of waters in the Delta and San Joaquin river, and constriction of low salinity habitat to deep-water channels of the interior Delta (Moyle et al. 1992) (p.120). “For a large part of its annual life span, this species is associated with the freshwater edge of the mixing zone, where the salinity is approximately 2 ppt. (also described as X2) (Ganssle 1966, Moyle et al. 1992, Sweetnam and Stevens 1993). The relationship between the portion of the smelt population west of the Del;ta as sampled in the summer townet survey and the natural logarithm of Delta outflow from 1959 to 1988, indicates the summer townet index increased dramatically when outflow was between 34,000 and 48,000 cubic feet per second, placing X2 between Chipps and roe islands (DWR and Reclamation 1994).” (p.120).

The Summary of the Five Year Review state that “In summary, the threats of the destruction, modification, or curtailment of its habitat or range resulting from extreme outflow conditions, the operations of the State and Federal water projects, and other water diversions as described in the original listing remain.” (p.121)

Vogel, D.A. January 2004. Juvenile Chinook Salmon Radio-Telemetry Studies in the Northern and Central Sacramento - San Joaquin Delta; 2002 - 2003. Natural Resource Scientists, Inc. National Fish and wildlife Foundation.

Vernalis flows are referenced to 9 times in the document. The following quote is an examples (page 32):

"During the four-consecutive week study, a wide range of hydrodynamic/environmental conditions occurred in the Delta. The first and third fish releases occurred during a spring tide cycle and the second and fourth fish releases occurred during a neap tide cycle (Figure 22). During 2003, the Vernalis Adaptive management Plan experiments with increased San Joaquin River flow and reduced south Delta export levels occurred between April 15 and May 15. The first fish release occurred prior to VAMP and the last three fish releases occurred during the (about 40%) and lowest during the last three fish releases (range of about 3-7%) (Figure 23), a decline attributable to the sharp export curtailment for the VAMP experiments beginning on April 15 and significant precipitation runoff during late April and early May. Daily data on Delta flow and diversions are provided in Appendix H.

Water Quality Control Plan. San Francisco Bay/Sacramento - San Joaquin Delta Estuary. 95-1WR. May 1995. Water Resources Control Board, State of California.

Vernalis flows are referenced to10 times in the document.
Table 3, page 19 shows water quality objectives beneficial to fish and wildlife.

Water Right Decision 1641. March 15, 2000. State Water Resources Control Board, California Environmental Protection Agency. Page 184.

Vernalis flows are referenced to 19 times in the document. The following quote is an examples (page 152):

"6.3.2 The VAMP Experiment

The VAMP experiment is designed to assess the effect of export pumping at various specific river
flows, which range from 3,200 cfs to 7,000 cfs. (SJRGA 2, Appendix A, p. 3.) Under the VAMP experiment, the flows at Vernalis during the April-May pulse flow period could be lower than is required by the objectives in the 1995 Bay-Delta Plan, and the export pumping rates would be lower than the pumping rates allowed in the Plan. The parties to the SJRA have agreed, with certain limitations, to use the following pairs of operational constraints and export targets to conduct an experiment on the effects of Vernalis flows and export rates during a 31-day period between April 1 and May 31:"

5. San Joaquin River at Airport Way Bridge, Vernalis: 31 day Pulse Flow objectives for April 15 - May 15.

2003 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2004. San Joaquin River Group Authority. Prepared for the California Water Resources Control Board in compliance with D-1641.

Vernalis flows are referenced to 123 times in the document. The following quotes are examples:

"VAMP 2003 is the fourth year of full implementation of the program. Average Vernalis flow during the VAMP period was 3,235 cfs. SWP and CVP export rates averaged 1,446 cfs. The VAMP period was between April 15 and May 15, 2003."

"Actions associated with the Vernalis Adaptive Management Plan (VAMP) were implemented between April 15 and May 15, 2003 to protect juvenile Chinook salmon and evaluate the relationship between San Joaquin River flow and State Water Project (SWP) and federal Central Valley Project (CVP) water project exports on the survival of marked juvenile Chinook salmon migrating through the Sacramento-San Joaquin Delta."

***Bennett, W. A. and P.B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary. In pages 519-542. J.T. Hollibaugh (ed.) The San Francisco Bay: The ecosystem. Further investigations into the natural history of San Francisco Bay and Delta with reference to the influence of man. Friesen Printers, Altona, Manitoba.**

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Twenty sites in the lower San Joaquin River drainage, California, were sampled from 1993 to 1995 to characterize fish communities and their associations with measures of water quality and habitat quality. The feasibility of developing an Index of Biotic Integrity was assessed by evaluating four fish community metrics, including percentages of native fish, omnivorous fish, fish intolerant of environmental degradation, and fish with external anomalies. Of the thirty-one taxa of fish captured during the study, only 10 taxa were native to the drainage. Multivariate analyses of percentage data identified four site groups characterized by different groups of species. The distributions of fish species were related to specific conductance, gradient, and mean depth; however, specific conductance acted as a surrogate variable for a large group of correlated variables. Two of the fish community metrics – percentage of introduced fish and percentage of intolerant fish – appeared to be responsive to environmental quality but the responses of the other two metrics – percentage of omnivorous fish and percentage of fish with anomalies – were less direct. The conclusion of the study is that fish communities are responsive to environmental conditions, including conditions associated with human-caused disturbances, particularly agriculture and water development. The results suggest that changes in water management and water quality could result in changes in species distributions. Balancing the costs and benefits of such changes poses a considerable challenge to resource managers.

The following is a quote from page 267:

"Differences in stream discharge among years is the most likely reason that species communities in 1995 were so different from those in the other years. Stream discharge in the lower San Joaquin drainage was much higher in water year 1995 (October 1 of previous year to September 30) compared to 1993 and 1994 (Mullen et al.6, Anderson et al.7, Hayes et al.8). Annual mean daily stream discharges (m3 s−1) in water years 1993 to 1995 were 66.6, 47.7, and 246.5, respectively, at the San Joaquin River near Vernalis (SJ1), 14.2, 8.4, and 42.6, respectively, at the Merced River at River Road (MR1), and 13.9, 10.4, and 93.5, respectively, at the Tuolumne River in Modesto (TR2). The exception was the Stanislaus River near Ripon (SR2), where stream discharge was relatively unchanged with values of 13.2, 12.7, and 16.5m3 s−1 in 1993, 1994, and 1995, respectively. Stream discharge at the time of sampling followed the same pattern."

DWR 2004. Management of the California State Water Project. California Department of Water Resources. Bulletin 132-03. December 2004.

Vernalis flows are referenced to 18 times in the document. The following quote is examples:

"In recent years the Department coordinated with the Bureau of Reclamation to increase flows in the San Joaquin River from mid-April through mid-May (pulse flow period) to benefit fall-run Chinook salmon emigrating from the San Joaquin River Basin. This plan, known as the Vernalis Adaptive Management Plan, is a 12-year federal/State research component associated with the San Joaquin River Agreement. VAMP calls for intensive fisheries sampling in the lower San Joaquin River."

The following quote is an example from page 42:

"During dry years, D-1641 requires the San Joaquin River spring pulse flow for April 15 to May 15 to be at a mean of 4,020 cfs at Vernalis. This spring pulse flow requirement varies based on the location of X2 during April. However, the CALFED Operations Group may vary the actual timing and duration of the pulse/attraction flow, based on real-time monitoring data. The Vernalis Adaptive Management Plan, part of the San Joaquin River Agreement approved in D-1641, contains SWRCB-approved alternate spring pulse flow and export limits, which the Bureau and the Department typically use in lieu of D-1641 limits. A pulse attraction flow of up to 2,000 cfs is also required during October."

DWR. 1998. Executive Summary. November 1998. California Department of Water Resources. Bulletin 160-98.

Vernalis flows are referenced to 17 times in the document. The following quotes are examples from page 2-15:

"(5) Watershed Alternative–Monthly average flow requirements are established for major watersheds based on Delta outflow and Vernalis flow objectives and the watersheds' average unimpaired flow. The parties responsible for providing the required flows are water users with storage in foothill reservoirs that control downstream flow to the Delta, and water users with upstream reservoirs that have a cumulative capacity of at least 100 taf who use water primarily for consumptive uses.

(6) Recirculation Alternative–USBR is required to make releases from the Delta-Mendota Canal to meet the Vernalis flow objectives.

(7) San Joaquin Basin Negotiated Agreement–San Joaquin Basin water right holders' responsibility to meet the plan objectives is based on an agreement titled "Letter of Intent among Export Interests and San Joaquin River Interests to Resolve San Joaquin River Issues Related to Protection of Bay-Delta Environmental Resources."

(8) San Joaquin Basin Negotiated Agreement–Vernalis flow objectives are replaced by target flows contained in the agreement."

Dege, M. and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. American Fisheries Society Symposium 39:49–65.

Data on spring and summertime larval and juvenile fish distribution and abundance was analyzed in the upper San Francisco Estuary (SFE), California between 1995 and 2001. The upper SFE includes the tidal freshwater areas of the Sacramento–San Joaquin Delta downstream to the euryhaline environment of San Pablo Bay. The sampling period included years with a variety of outflow conditions. Fifty taxa were collected using a larval tow net. Two common native species, delta smelt *Hypomesus transpacificus* and longfin smelt *Spirinchus thaleichthys*, and four common alien taxa, striped bass *Morone saxatilis*, threadfin shad *Dorosoma petenense*, gobies of the genus *Tridentiger*, and yellowfin goby *Acanthogobius flavimanus*, were selected for detailed analysis. Outflow conditions had a strong influence on the geographic distribution of most of the species, but distribution with respect to the 2 psu isohaline (X2) was not affected. The distribution patterns of delta smelt, longfin smelt, and striped bass were consistent with larvae moving from upstream freshwater spawning areas to downstream estuarine rearing areas. There were no obvious relationships of outflow with annual abundance indices. Our results support the idea of using X2 as an organizing principle in understanding the ecology of larval fishes in the upper SFE. Additional years of sampling will likely lead to additional insights into the early life history of upper SFE fishes.

Estuarine Ecology Team. 1997. An assessment of the likely mechanisms underlying the "Fish-X2" relationships. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 52.

The effect of X2 on delta smelt entrainment losses are very well documented. In low outflow years, delta smelt may exhibit a higher probability of entrainment mortality of larvae, juveniles and adults at SWP, CVP, PG&E and agricultural diversions. Other less well documented, yet presumably important effects of X2 on delta smelt, include: 1) increase spawning habitat. The amount of flooded vegetation increases with increasing outflow, 2) increased co-occurrence of young delta smelt with food organisms. There is a significant relationship between delta smelt year-class strength and the amount of time during spring X2 is located in Siusun Bay. Other factors may be operating in some years as well, 3) more suitable habitat for larvae and juveniles may occur when X2 is located downstream in Siusun Bay, which supplies substantially more shallow water habitat than the river channels upstream, 4) reduced probability of encounter with predators. Annual delta smelt year classes exhibit a significant negative association with the abundance of the non-native predator inland silverside in years when X2 is located upstream during spring, 5) entrapment zone (EZ) residence time. Overall, food for larval and juvenile delta smelt is higher near the upstream end of the EZ. When X2 is positioned in Siusun Bay, a higher proportion of the larval population occurs in the EZ, 6) delta smelt may also reside longer in Siusun Bay if they are transported there earlier by higher flows and 7) higher production of food. The abundance of many food organisms for delta smelt larvae and juveniles is affected by mean X2 during spring. Thus, overall growth and condition of delta smelt may be better in higher outflow years.

***Mesick, C. 2001. The effects of the San Joaquin River flows and Delta export rates during October on the number of adult San Joaquin Chinook salmon that stray. In: R.L. Brown (ed.) Contributions to the Biology of Central Valley Salmonids. California Department of Fish and Game. Fish Bulletin 179(2): 139-162.**

This report describes a two-part investigation of the effects of fall make-up pumping on straying of adult San Joaquin Chinook salmon. The first part is a reevaluation of 1964 to 1967 data collected by Hallock and others (1970) on the migratory behavior of tagged and untagged adult San Joaquin salmon in the Delta. The second part is an evaluation of the recovery of adult salmon that were released in the San Joaquin basin as coded-wire tagged juveniles reared at the Merced River Fish Facility. First, adult salmon are found migrating throughout the San Joaquin Delta near Prisoners Point primarily during October, the period when they are probably most susceptible to low flows and high exports. Second, the fish migrate slowly and do not arrive in San Joaquin tributaries until about four weeks after they pass Prisoners Point, even when flows, exports, and dissolved oxygen concentrations near Stockton are suitable for migration and third, migration rates of adult salmon are substantially higher when Vernalis flows exceed about 3,000 cfs and total exports are less than 100% of Vernalis flows. CWT recovery data suggest that: 1) straying rates of salmon increased as the percentage of San Joaquin flow exported by the CVP and SWP pumping facilities increased and 2) the critical period is between 1 and 21 October. Pulse flows from the San Joaquin tributaries, or a reduction of Delta exports that result in no more than a 300% export rate of San Joaquin flows at Vernalis for eight to 12 days in mid-October, are sufficient to keep straying rates below 3%. When more than 300% of Vernalis flow is exported over a ten-day period in mid-October, adult San Joaquin Chinook salmon stray to the Sacramento and eastside basins. Further tests are needed to support the conclusions derived from existing data.

Moyle, P.B. and B. Herbold. 1989. Status of the delta smelt, *Hypomesus transpacificus*. Final Report to U.S. Fish and Wildlife Service. Department of Wildlife and Fisheries Biology, University of California, Davis: 1-19 + Appendix.

Delta smelt was once one of the commonest pelagic fish in the upper Sacramento-San Joaquin estuary. Since 1982 the population is at its lowest level ever recorded. Reasons for its decline are probably multiple and synergistic, including: 1) reduction of outflows resulting from increased water diversions in the Sacramento and San Joaquin rivers and tributaries, particularly in years of low runoff, 2) high outflows occurring in years of unusually wet years which put the entrapment zone in San Pablo and/or San Francisco bays, 3) entrainment losses to water diversions that result in large numbers of delta smelt pumped through the CVP and SWP plants and reduced population size, 4) changes in food organisms that could increase the potential of larval starvation, 5) toxic substances which could be detrimental but for which there is limited information and 6) loss of genetic integrity due to potential introgression and/or direct competition with the introduced the smelt wakasagi. Data analyses suggested that water flow sets an upper limit on recruitment of smelt each year. The cumulative number of days of reverse flows in the San Joaquin River during spring was always associated with low abundance of delta smelt in Siusun Bay in the fall. Higher outflows favored the development of higher biomasses at all trophic levels in the late spring and led to larger adult populations of smelt in the fall.

Moyle, P.B. et al. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society. 121:67-77.

The **delta smelt** *Hypomesus transpacificus* is endemic to the upper Sacramento-San Joaquin estuary. It is closely associated with the freshwater-saltwater mixing zone except when it spawns in fresh water. The delta smelt feeds on zooplankton, principally copepods. Its dominant prey was the native copepod *Eurytemora affinis* in 1972-1974 but the exotic copepod *Pseudodiaptomus forbesi* in 1988. Because the delta smelt has a 1-year life cycle and low fecundity, it is particularly sensitive to changes in estuarine conditions. Tow-net and midwater trawl samples showed wide year-to-year fluctuations in population densities. Surveys of different areas showed declines in different years between 1980 and 1983. After 1983, however, all populations remained at very low densities throughout most of the range. The recent decline of delta smelt coincides with an increase in the diversion of inflowing water during a period of extended drought. These conditions have restricted the mixing zone to a relatively small area of deep river channels and, presumably, have increased the entrainment of delta smelt into water diversions.

Nobriga, M. et al. 2001. Spring 2000 Delta smelt salvage and delta hydrodynamics and an introduction to the Delta smelt decision tree. Interagency Ecological Program. Newsletter Spring 2001 14(2):42-46.

San Joaquin River flows during winter and early spring 2000 were similar to other years hypothesized by Nobriga et al. (2000) to attract spawning delta smelt into the Central Delta. Delta smelt salvage quickly exceeded red light levels following the VAMP in 2000 as it has in most recent years. This lends additional support to the hypothesis that the VAMP results in suitable larval rearing conditions within the Central and South Delta as suggested by high subsequent salvage when CVP and SWP exports ramp up after the VAMP. Because delta smelt begins to be counted in salvage statistics when fish reach sizes of about 25 mm, it is conceivable that more fish were entrained as larvae in years prior to VAMP and thus, would not have survived to be reported in salvage statistics.

Nobriga, M. et al. 2001. Spring 2000 Delta smelt salvage and delta hydrodynamics and an introduction to the Delta smelt decision tree. Interagency Ecological Program. Newsletter Spring 2001 14(2):42-46.

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Sacramento Fish and Wildlife Office. 2004. 5-year review. *Hypomesus transpacificus* (delta smelt). Notice: Federal Register 68(148):45270-45271 on August 1, 2003.

The current U.S. Fish and Wildlife Service (Service) Recovery Plan (1996) for delta smelt assigned a recovery potential of 2C. A listed species is assigned a recovery priority number from 1 (highest) to 18 (lowest) according to the degree of threats, recovery potential and taxonomic distinctness. In addition, a species' rank may be elevated by adding a C designation to its numerical rank to indicate that there is some degree of conflict between the species' conservation efforts and economic development associated with its recovery. Recovery priority numbers are based on criteria published the Federal Register Notice (48 FR 43098; September 21, 1983). At the time of listing, Delta smelt was under a high degree of threat from the severe 1987-1992 California drought. The species persisted in small numbers and rebounded to pre-decline levels in 1993, suggesting that its recovery potential is fairly high. The subsequent decline in 1994, a critical water year, to a then all-time low annual abundance index of 102 (Fall Midwater Trawl Survey (FMWT)), however, illustrates the high degree of threat that neutralizes gains in abundance that result from good water years. More recent abundance indices have varied, but overall, the trend is still negative.

USFWS. 1995. Biological Opinion for Delta Smelt. March 6, 1995. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office. Sacramento, CA.

The following is a quote from page 19:

“(2) San Joaquin River pulse flow-- The operating criteria listed above specifies that during the April and May 30-day pulse flow period, combined CVP and SWP exports may be the greater of 1,500 cfs or 100 percent of the Vernalis flow. Reclamation will pursue acquisition of additional flow (acquired flow) to provide San Joaquin flows at Vernalis during the April and May 30-day pulse in excess of those exported by the CVP and SWP. Any such acquired flows will be identified as being in excess of those attributable to CVP releases, unregulated accretions or unstorable flows. Through the CALFED process and other associated discussions, Reclamation and DWR will encourage measures that will minimize the diversion of acquired flows during the 30-day pulse flow period. An Operations Plan shall be submitted to the Service by April 1 of each year describing Reclamation's and DWR's Delta operations and forecasted San Joaquin River flows during the April and May 30-day pulse flow. The objective of this Operations Plan is to provide a flow at Vernalis that exceeds CVP plus SWP export by an amount equal to 50 percent of the identified pulse flow associated with the most recently available forecasted San Joaquin 60/20/20 Index (at 90 percent of exceedance).* In an effort to accomplish this goal, Reclamation and DWR will also consider re-allocation within the

Principles for Agreement or other means to provide Vernalis flows or Delta exports consistent with this objective."

USFWS. 1995A. Working paper on restoration needs: Habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volumes 1, 2, 3. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the anadromous Fish Restoration Program. Stockton, CA.

Volumes 1 and 3 summarize the production goals, limiting factors, flows and other restoration actions that AFRP technical teams found necessary to double production of the anadromous fish stocks. Volume 2 identifies historical and existing conditions for anadromous fish and identifies roles of state and federal agencies in managing anadromous fish.

USFWS. 2001. Final Restoration Plan for the Anadromous Fish Restoration Program; A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California. January 9, 2001. Prepared for the U.S. Fish and Wildlife Service under the direction of the anadromous Fish Restoration Program. Stockton, CA.

A number of specific flow and non-flow actions and evaluations deemed necessary to achieve doubling of anadromous fishes in the Sacramento-San Joaquin watershed are summarized.

USFWS. 2005. Operational Criteria and Plan, Biological Opinion for Delta Smelt. February 16, 2005. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office. Sacramento, CA.

In-stream flow requirements for the Vernalis from February to June are discussed. Table 5 (p. 59) lists water year class and flows at Vernalis for the February-June period. The VAMP is pulse flow period is discussed with regards to flow objectives and export restrictions (p. 62-63).

The distribution of delta smelt may not always be regulated by X2 since food availability may influence their distribution (p.116). Further, "In addition to the degradation and loss of estuarine habitat, delta smelt have been increasingly subject to entrainment, upstream or reverse flows of waters in the Delta and San Joaquin river, and constriction of low salinity habitat to deep-water channels of the interior Delta (Moyle et al. 1992) (p.120). "For a large part of its annual life span, this species is associated with the freshwater edge of the mixing zone, where the salinity is approximately 2 ppt. (also described as X2) (Ganssle 1966, Moyle et al. 1992, Sweetnam and Stevens 1993). The relationship between the portion of the smelt population west of the Del;ta as sampled in the summer townet survey and the natural logarithm of Delta outflow from 1959 to 1988, indicates the summer townet index increased dramatically when outflow was between 34,000 and 48,000 cubic feet per second, placing X2 between Chipps and roe islands (DWR and Reclamation 1994)." (p.120).

The Summary of the Five Year Review state that "In summary, the threats of the destruction, modification, or curtailment of its habitat or range resulting from extreme outflow conditions, the operations of the State and Federal water projects, and other water diversions as described in the original listing remain." (p.121)

Water Quality Control Plan. San Francisco Bay/Sacramento - San Joaquin Delta Estuary. 95-1WR. May 1995. Water Resources Control Board, State of California.

Vernalis flows are referenced to10 times in the document.

Table 3, page 19 shows water quality objectives beneficial to fish and wildlife.

Water Right Decision 1641. March 15, 2000. State Water Resources Control Board, California Environmental Protection Agency.

Vernalis flows are referenced to 19 times in the document. The following quote is an examples (page 152):

"6.3.2 The VAMP Experiment

The VAMP experiment is designed to assess the effect of export pumping at various specific river

flows, which range from 3,200 cfs to 7,000 cfs. (SJRGA 2, Appendix A, p. 3.) Under the VAMP experiment, the flows at Vernalis during the April-May pulse flow period could be lower than is required by the objectives in the 1995 Bay-Delta Plan, and the export pumping rates would be lower than the pumping rates allowed in the Plan. The parties to the SJRA have agreed, with certain limitations, to use the following pairs of operational constraints and export targets to conduct an experiment on the effects of Vernalis flows and export rates during a 31-day period between April 1 and May 31:"