Literature Cited

Arthur, J. F., M. D. Ball, and S. Y. Baughman. 1996. Summary of federal and State water project impacts in the San Francisco Bay-Delta estuary, California. Pages 445-495 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Adib-Samii 2008. Personal communication via e-mail with Victoria Poage, USFWS, re: water temperature thresholds for collection of delta smelt in routine survey sampling, October 8, 2008

Alpine, A. E., and J. E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 37: 946-955.

Amweg, E.L., D.P. Weston, & N.M. Ureda. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. Environmental Toxicology and Chemistry 24:966–972.

Bailey, H. C., C. Alexander, C. DiGiorgio, M. Miller, S. I. Doroshov, and D. E. Hinton. 1994. The effect of agricultural discharge on striped bass (Morone saxatilis) in California's Sacramento-San Joaquin drainage. Ecotoxicology 3: 123-142.

Baskerville-Bridges, B., J.C. Lindberg and S.I. Doroshov. 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. Pages 219-228 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer and K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. (available at: http://www/science.calwater.ca.gov/pdf/workshops/POD/IEP_POD_2007_synthesis_report_031408.pdf)

Bennett, WA, Moyle, PB. 1996. Where have all the fishes gone? Interactive factors producing fish declines. Pages 519-541 in Hollibaugh, JT, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science. San Francisco, CA.

Bennett, WA, Kimmerer, WJ, Burau, JR. 2002. Plasticity in vertical migration by native and exotic fishes in a dynamic low-salinity zone. Limnology and Oceanography 47:1496-1507.

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

Bennett, WA, Hobbs, JA, Teh, S. 2008. Interplay of environmental forcing and growth-selective mortality in the poor year-class success of delta smelt in 2005. Final Report to the Interagency Ecological Program.

Brandes, P.L. and J.S. McClain. 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. Fish Bulletin 179, pp 39-137

Bouley, P. and W. J. Kimmerer 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series 324: 219-228.

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. Pages 497-518 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Brown, L.R. 2003. Will tidal wetland restoration enhance populations of native fishes? San Francisco and Watershed Science 1: http://repositories.cdlib.org/jmie/sfews/vol1/iss1/art2.

Brown, L. R., W. Kimmerer, and R. Brown. 2008. Managing water to protect fish: a review of California's Environmental Water Account, 2001-2005. Environmental Management DOI 10.1007/s00267-008-9213-4 http://www.springerlink.com/content/u4022223x2181287/fulltext.pdf

Brown, R.L. and W.J. Kimmerer. 2001. Environmental and institutional background for CALFED's Environmental Water Account. CALFED Bay-Delta Program, Sacramento, California

Brown, R.L. & W. Kimmerer. 2002. Delta smelt and CALFED's Environmental Water Account: A summary of the 2002 delta smelt workshop. Prepared for the CALFED Science Program, October 2002.

Brown, LR, Michniuk, D. 2007. Littoral fish assemblages of the alien-dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. Estuaries and Coasts 30:186-200.

Bryant, ME, Arnold, JD. 2007. Diets of age-0 striped bass in the San Francisco Estuary, 1973-2002. California Fish and Game 93:1-22.

California Department of Fish and Game. 2008a. ttp://www.delta.dfg.ca.gov/data/20mm/

California Department of Fish and Game. 2008b. Spring Kodiak Trawl Survey. http://www.delta.dfg.ca.gov/data/skt/

California Department of Fish and Game. 2008c. Summer Tow Net Survey. http://www.delta.dfg.ca.gov/data/townet/

Castillo, G., Morinaka, J., Baskerville-Bridges, B., Lindberg, J., Fujimura, R., Dubois, J., Tigan, G., Poage, V. 2008. Pilot Mark-Recapture Study to Estimate Delta Smelt Pre-screen Loss and Salvage Efficiency. 2008 CALFED Science Conference Presentation

Cook and Buffaloe 1998. – Determining the effect of earlier entrainment has been limited because previous studies either (1) did not quantify the volumes of water diverted (Hallock and Van Woert 1959, Pickard et al. 1982) or (2) did not sample at times when, or locations where, delta smelt were abundant

Culberson, S.D., C.B. Harrison. C. Enright and M.L. Nobriga. 2004. Sensitivity of larval fish transport to location, timing, and behavior using a particle tracking model in Suisun Marsh, California. Pages 257-267 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA

Davis, J.A., D. Yee, J.N. Collins, S.E. Schwarzbach, & S.N. Luoma. 2003. Potential for Increased Mercury Accumulation in the Estuary Food Web. San Francisco Estuary and Watershed Science. Vol. 1.

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. Am. Fish. Soc. Symposium 39: 49-65

Dettinger, MD. 2005. From climate-change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science 3:http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4.

Dugdale, RC, Wilkerson, FP, Hogue, VE, Marchi, A. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal, and Shelf Science 73:17-29.

Durand J. San Francisco State University, oral presentation at 2006 CALFED Science Conference

DWR Delta Overview. http://baydeltaoffice.water.ca.gov/sdbtbp/deltaoverview/delta_overview.pdf

DWR and Reclamation (California Department of Water Resources and U.S. Bureau of Reclamation). 1994. Biological Assessment — Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail. Prepared for U.S. Fish and Wildlife Service, Sacramento, CA. 230 p.

DWR. 1994. Temporary Barriers Project Fishery, Water Quality, and Vegetation Monitoring, 1993. Submitted to U.S. Army Corps of Engineers for permit requirements. 169 pp. plus appendixes.

DWR. 2000a. Benchmark Studies Assumptions, (Draft), Sacramento, CA, Sept. 2000.

DWR 2007. Morrow Island Distribution System fish entrainment study. Interim data summary report, Division of Environmental Services, Sacramento, CA.

Edmunds, J.L., K.M. Kuivila, B.E. Cole, & J.E. Cloern. 1999. Do herbicides impair phytoplankton primary production in the Sacramento-San Joaquin River Delta? In: USGS Toxic Substances Hydrology Program Technical Meeting Proceedings, Charleston, SC, March 8-12, 1999.

Edwards, G.W., K. Urquhart , & T. Tillman. 1996. Adult salmon migration monitoring during the various operational phases of the Suisun Marsh Salinity Control Gates, September–November 1994. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 50. 27 p.

Enos, C, Sutherland, J, Nobriga, M. 2007. Results of a two year fish entrainment study at Morrow Island Distribution System in Suisun Marsh. Interagency Ecological Program Newsletter 20(1):10-19.

Feyrer, F, Herbold, B, Matern, SA, Moyle, PB. 2003. Dietary shifts in a stressed fish assemblage: consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67:277-288.

Feyrer, F, Nobriga, ML, Sommer, TR. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723-734.

Feyrer, F, Newman, K, Nobriga, ML, Sommer, TR. 2008. Modeling the effects of water management actions on suitable habitat and abundance of a critically imperiled estuarine fish (delta smelt *Hypomesus transpacificus*). Manuscript in preparation.

Foott, J. S., K. True, & R. Stone. 2006. Histological evaluation and viral survey of juvenile longfin smelt, (*Spirinchus thaleichthys*) and threadfin shad (*Dorosoma petenense*) collected in the Sacramento-San Joaquin River Delta, April-October 2006. California Nevada Fish Health Center

Giddings, J.M., L.W. Hall, Jr, & K.R. Solomon. 2000. Ecological risks of diazinon from agricultural use in the Sacramento - San Joaquin River Basins, California. Risk Analysis 20:545–572.

Grimaldo, LF, Sommer, T, Van Ark, N, Jones, G, Holland, E, Moyle, P, Smith, P, Herbold, B. Factors affecting fish entrainment into massive water diversions in a freshwater tidal estuary: can fish losses be managed? North American Journal of Fisheries Management: accepted manuscript

Grimaldo, L.F., A. R. Stewart, and W. Kimmerer. Dietary segregation of pelagic and littoral fish assemblages in a highly modified tidal freshwater estuary. In review Marine and Coastal Fisheries

Hallock, RJ, Van Woert, W. 1959. A survey of anadromous fish losses in irrigation diversions from the Sacramento and San Joaquin rivers. California Fish and Game 45: 227-521.

Hobbs, JA, Bennett, WA, Burton, J. 2006. Assessing nursery habitat quality for native smelts (Osmeridae) in the low-salinity zone of the San Francisco Estuary. Journal of Fish Biology 69: 907-922.

Hobbs, JA, Bennett, WA, Burton, J, Gras, M. 2007. Classification of larval and adult delta smelt to nursery areas by use of trace elemental fingerprinting. Transactions of the American Fisheries Society 136:518-527.

Horppila, *J., A.* Liljendahl-Nurminen and T. Malinen. 2004. Effects of clay turbidity and light on the predator–prey interaction between smelts and chaoborids. Can. J. Fish. Aquat. Sci. 61: 1862-1870

Herren, JR, Kawasaki, SS. 2001. Inventory of water diversions in four geographic areas in California's Central Valley. California Department of Fish and Game Fish Bulletin 179(vol.2):343-355.

Jassby, A. D., J. E. Cloern, and T. M. Powell. 1993. Organic carbon sources and sinks in San Francisco Bay: variability induced by river flow. Mar. Ecol. Prog. Ser. 95: 39-54.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecol. Appl. 5(1): 272-289

Jassby, AD, Cloern, JE, Cole, BE. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnology and Oceanography 47:698-712.

Jassby, A.D., A.B. Mueller-Solger and M. Vaysierres. 2005. Subregions of the

Sacramento-San Joaquin Delta: identification and use. Interagency Ecological Program Newsletter 18(2): 46-56

Kawakami, B.T., Denton, R.A., Gartrell, G. 2008. Investigation of the Basis for Increases in Delta Fall Salinity. CALFED Sceince Conference Poster Presentation.

Kimmerer, WJ, Orsi, JJ. 1996. Causes of long-term declines in zooplankton in the San Francisco Bay estuary since 1987. Pages 403-424 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Kimmerer, W.J. 2002. Physical, biological and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25: 1275-1290

Kimmerer, W. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological processes. San Francisco Estuary and Watershed Science [Internet] 2(1) http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1

Kimmerer, W. and M. Nobriga 2005. Development of bootstrapped confidence intervals for the IEP fish abundance indices. Interagency Ecological Program Newsletter 18(2): 68-75.

Kimmerer, W.J. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entraiment in water diversioins in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science [online serial] Vol. 6, Issue 2 (June 2008), Article 2 http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art2

Kimmerer, W.J. and M.L. Nobriga. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a particle tracking model. San Francisco Estuary and Watershed Science [online serial] Vol. 6, Issue 2 (February 2008), Article 4 http://repositories.cdlib.org/jmie/sfews/vol6/iss1/art4

Kimmerer, W.J. in prep Draft report on Tasl 4: Modeling. Report to the CALFED Ecosystem Restoration Program, Contract ERP-02-P19. Submitted June 12, 2008

Knutson, A.C. Jr and J.J. Orsi. 1983. Factors regulating abundance and distribution of the shrimp *Neomysis mercedis* in the Sacramento-San Joaquin Estuary. T. Am. Fish. Soc. 112: 476-485

Kuivila, K. M., and C. G. Foe 1995. Concentrations, transport, and biological effects of dormant spray pesticides in the San Francisco Estuary, California. Environmental Toxicology and Chemistry 14: 1141-1150.

Kuivila, KM, Moon, GE. 2004. Potential exposure of larval and juvenile delta smelt to dissolved pesticides in the Sacramento-San Joaquin Delta, California. American Fisheries Society Symposium 39:229-242.

Lehman, PW, Boyer, G, Hall, C, Waller, S, Gehrts, K. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. Hydrobiologia 541:87-99.

Lehman, PW, Boyer, G, Satchwell, M, Waller, S. 2008. The influence of environmental conditions on the seasonal variation of *Microcystis* cell density and microcystins concentration in San Francisco Estuary. Hydrobiologia 600:187-204.

Lehman, P. W., T. Sommer and L. Rivard, 2008. The influence of floodplain habitat on the quantity of riverine phytoplankton carbon produced during the flood season in San Francisco Estuary. Aquatic Ecology 42: 363-378.

Liermann, M. and R. Hilborn. 2001. Depensation, evidence, models and implications. Fish and Fisheries 2:33-58.

Lindberg, Joan C., B. Baskerville-Bridges, and S.I. Doroshov. 2003. "Two Reproductive Concerns Tested in Captive Delta Smelt, *Hypomesus transpacificus*, 2002: I. Effect of substrate and water velocity on spawning behavior.

Linville, R.G., S.N. Luoma, L. Cutter, & G.A. Cutter. 2002. Increased selenium threat as a result of invasion of the exotic bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. Aquatic Toxicology 57: 51-64.

Lopez , C. B., Cloern, J.E., Schraga, T.S., Little, A.J., Lucas, L.V., Thompson, J.K., and Burau, J.R., 2006, Ecological values of shallow-water habitats: implications for restoration of disturbed ecosystems, Ecosystems 9: 422-440.

Lott, J. 1998. Feeding habits of juvenile and adult delta smelt from the Sacramento-San Joaquin River Estuary. Interagency Ecological Program Newsletter 11(1):14-19 (available at http://iep.water.ca.gov/report/newsletter/)

Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. Moyle. 2007. Envisioning Futures for the Sacramento-San Joaquin Delta. San Francisco, CA: Public Policy Institute of California.

Mager RC. 1996. Gametogenesis, Reproduction and Artificial Propogation of Delta Smelt, *Hypomesus transpacificus.* [Dissertation] Davis: University of California, Davis. 115 pages.

Mager, R.C., S.I. Doroshov, J.P. Van Eenennaam and R.L. Brown. 2004. Early life stages of delta smelt. Pages 169-180 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA

Manly, B.F.J. and M. Chotkowski. 2006. Two new methods for regime change analyses.

Arch. Hydrobiol. 167(1-4): 593-607

Monson, N.E., J.E. Cloern and J.R. Burau. 2007. Effects of flow diversion on water and habitat quality: examples from California's highly manipulated Sacramento-San Joaquin

Moyle, P.B. 2002. Inland fishes of California. University of California Press, Berkeley and Los Angeles, California

Moyle, PB, Herbold, B, Stevens, DE, Miller LW. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67-77.

Moyle, P. B. 1976. Inland fishes of California. University of California Press. Berkeley, CA.

Moyle, PB, Herbold, B, Stevens, DE, Miller LW. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67-77.

Moyle, PB, Israel, JA. 2005. Untested assumptions: effectiveness of screening diversions for conservation of fish populations. Fisheries 30(5):20-28.

Miller, BJ. 2007. Declaration of William J. (B.J.) Miller, Ph.D. Regarding Interim Injunctive Relief, July 23, 2007, Proceedings of Natural Resources Defense Council, et al. v. Kempthorne, et al., Case No. 05 CV-01207 OWW (E.D. Cal.)

Mueller-Solger, A.B., Jassby, A.D., Mueller-Navarra, D.C. 2002. Nutritional quality of food resources for zooplankton (Daphnia) in a tidal freshwater system (Sacramento?San Joaquin River Delta), Limnol. Oceanogr. 47(5), 2002, 1468-1476.

Newman KB. 2008. Sample design-based methodology for estimating delta smelt abundance. San Francisco Estuary and Watershed Science 6(3): article 3. Available from: http://repositories.cdlib.org/jmie/sfews/vol6/iss3/art3

Nobriga, M, Hymanson, Z, Oltmann, R. 2000. Environmental factors influencing the distribution and salvage of young delta smelt: a comparison of factors occurring in 1996 and 1999. Interagency Ecological Program Newsletter 13(2):55-65. Available online at http://www.iep.ca.gov/report/newsletter/2000spring/IEPNewsletter_Spring2000.pdf

Nobriga, M. and M. Chotkowski 2000. Recent historical evidence of centrarchid increases and tule perch decrease in the Delta. Interagency Ecological Program Newsletter 13(1):23-27. Available online at http://www.iep.ca.gov/report/newsletter

Nobriga, M. L. and F. Feyrer (in press). Diet composition of San Francisco Estuary striped bass: does trophic adaptability have its limits? Environmental Biology of Fishes. In press.

Nobriga, ML. 2002. Larval delta smelt diet composition and feeding incidence: environmental and ontogenetic influences. California Fish and Game 88:149-164.

Nobriga, Matthew L, , Z Matica, and Z.P. Hymanson 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison among Open-Water Fishes. Pages 281-295 in F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, editors. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

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

Nobriga, M.L., & F. Feyrer. 2007. Shallow-water piscivore-prey dynamics in California's Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 5:http://repositories.cdlib.org/jmie/sfews/vol5/iss2/art4.

Nobriga, M. and B. Herbold. 2008. Conceptual model for delta smelt (*Hypomesus transpacificus*) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP)

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

Odum, W. E. 1988. Comparative ecology of tidal freshwater and salt marshes. Ann. Rev. Ecol. Syst. 19:147-176.

Ostrach, D. 2008. Multiple stressors and their effects on the striped bass population in the San Francisco estuary. Presented at Interagency Ecological Program 2008 Annual Workshop, Pacific Grove, CA, February 26-29, 2008.

Radtke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon, in Ecological studies of the Sacramento-San Joaquin Delta, Part II. In: S.L. Turner & D.W. Kelley (Eds.), Ecological Studies of the Sacramento–San Joaquin Estuary, pp. 115-129. California Department of Fish and Game Fish Bulletin 136.

Reclamation 2008. OCAP Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project.

Rose, KA. 2000. Why are quantitative relationships between environmental quality and fish populations so elusive? Ecological Applications 10:367-385.

Rose, KA., J.H. Cowan, K.O. Winemiller, R.A. Myers, and R. Hilborn. 2001. Compensatory density-dependence in fish populations: importance, controversy, understanding, and prognosis. Fish and Fisheries 2: 293-327.

Ruhl, C.A., P.E. Smith, J.J. Simi and J.R. Burau. 2006. The pelagic organism decline and long-term trends in Sacramento-San Joaquin Delta hydrodynamics. Presentation at the 4th Biennial 2006 CALFED Science Conference, October 23-25, 2006, Sacramento, California

Saiki, MK, Jennings, MR, Wiedmeyer, RH. 1992. Toxicity of agricultural subsurface drainwater from the San Joaquin River, California, to juvenile Chinook salmon and striped bass. Transactions of the American Fisheries Society 121:78-93.

Saiki, M.K. 1998. An ecological assessment of the Grassland Bypass Project on fishes inhabiting the Grassland Water District, California. Final report submitted to U.S. Fish and Wildlife Service, Sacramento, CA. 72 pp.

Slater Steven unpublished data California Department of Fish and Game

Sommer, T. R., R. Baxter, and B. Herbold. 1997. Resilience of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 126: 961-976.

Spaar, S. 1994. Delta agricultural diversion evaluation1992 pilot study. California Department of Water Resources, Interagency Ecological Program Technical Report 3, Sacramento, California

Sobczak, W. V., J. E. Cloern, A. D. Jassby, and A. B. Muller-Solger. 2002. Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources. Proceedings of the National Academy of Sciences 99, no. 12: 8101-8105.

Sommer, T.R., W.C. Harrell, A. Mueller-Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14:247-261.

Sommer, T, Armor, C, Baxter, R, Breuer, R, Brown, L, Chotkowski, M, Culberson, S, Feyrer, F, Gingras, M, Herbold, B, Kimmerer, W, Mueller-Solger, A, Nobriga, M, Souza, K. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32(6):270-277.

Stevens, DE, Miller, LW. 1983. Effects of river flow on abundance of young Chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin river system. North American Journal of Fisheries Management 3:425-437.

Sullivan et al., unpublished information

Swanson, C. and J.J. Cech Jr. 1995. Environmental tolerances and requirements of the delta smelt, *Hypomesus transpacificus*. Final Report. California Department of Water Resources Contracts B-59499 and B-58959. Davis, California. July 20, 1995

Swanson, C, Young, PS, Cech, JJ, Jr. 1998. Swimming performance of delta smelt: maximum performance, and behavioral and kinematic limitations on swimming at submaximal velocities. Journal of Experimental Biology 201:333-345.

Swanson, C., T. Reid, P.S. Young and J. Cech Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123: 384-390

Sweetnam, DA. 1999. Status of delta smelt in the Sacramento-San Joaquin Estuary. California Fish and Game 85:22-27.

Thetmeyer. H. and U. Kils. 1995. To see and not be seen: the visibility of predator and prey with respect to feeding behaviour. Mar. Ecol. Prog. Ser. 126: 1-8

Tillman, T., G.W. Edwards, K. Urquhart. 1996. Adult salmon migration monitoring during the various operational phases of the Suisun Marsh Salinity Control Gates in Montezuma Slough, August–October 1993. Stockton (CA): California Department of Fish and Game, Bay-Delta and Special Water Projects Division. 35 p.

Trenham, P.C., H.B. Shaffer and P.B. Moyle. 1998. Biochemical identification and assessment of population subdivision in morphometrically similar native and invading smelt species (*Hypomesus*) in the Sacramento-San Joaquin Estuary, California. T. Am. Fish. Soc. 127: 417-424

Turner, J. L. and H. K. Chadwick 1972. Distribution and abundance of young-of-the-year striped bass, Morone saxatilis, in relation to river flow in the Sacramento-San Joaquin estuary. Transactions of the American Fisheries Society 101: 442-452.

Turner, JL, Kelley, DW (editors). 1966. Ecological studies of the Sacramento-San Joaquin Delta, part II, fishes of the Delta. California Department of Fish and Game Fish Bulletin 136.

Utne-Palm, A.C. and J.E. Stiansen. Effect of larval ontogeny, turbulence and light on prey attack rate and swimming activity in herring larvae. J. Exper. Mar. Biol. Ecol. 268(2): 147-170

U.S. Fish and Wildlife Service. 1996. Sacramento-San Joaquin Delta Native Fishes Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology [online]1(2):1. Available from the Internet. URL: http://www.consecol.org/vol1/iss2/art1/

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: a guide to the early life stages. Interagency Ecological Studies Program Technical Report 9. Sacramento

Wang, J.C.S. 1991. Early life stages and early life history of the delta smelt, *Hypomesus transpacificus*, in the Sacramento-San Joaquin Estuary, with comparison of early life stages of the longfin smelt, *Spirinchus thaleichthys*. Interagency Ecological Studies Program Technical Report 28, August 1991

Wang, JCS. 2007. Spawning, early life stages, and early life histories of the Osmerids found in the Sacramento-San Joaquin Delta of California. Tracy Fish Facilities Studies California Volume 38. U.S. Bureau of Reclamation, Mid-Pacific Region.

Werner, I., L.A. Deanovic, V. Conner, V. de Vlaming, H.C. Bailey and D.E. Hinton. 2000. Insecticide-caused toxicity to *Ceriodaphnia dubia* (Cladocera) in the Sacramento-San Joaquin River Delta, California, USA. Environ. Tox. Chem. 19(1): 215-227

Werner, I, Deanovic, L, Markiewicz, D, Stillway, M, Offer, N, Connon, R, Brander, S. 2008. Pelagic organism decline (POD): Acute and chronic invertebrate and fish toxicity testing in the Sacramento-San Joaquin Delta, 2006-2007. Final report to the Interagency Ecological Program, April 30, 2008.

Weston, D.P, R.W. Holmes, J. You, & M.J. Lydy. 2005. Aquatic toxicity due to residential use of pyrethroid insecticides. Environmental Science and Technology 39: 9778-9784.

Weston, D.P., J. You, & M.J. Lydy. 2004. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's Central Valley. Environmental Science and Technology 38: 2752-2759.

Whitehead, A., K.M. Kuivila, J.L. Orlando, S. Kotelevtsev, & S.L. Anderson. 2004. Genotoxicity in native fish associated with agricultural runoff events. Environmental Toxicology and Chemistry: 23:2868–2877

Wilkerson, FP, Dugdale, RC, Hogue, VE, Marchi, A. 2006. Phytoplankton blooms and nitrogen productivity in San Francisco Bay. Estuaries and Coasts 29:401-416.

Winemiller, KO, Rose, KA. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49:2196-2218.

Personal Communications

Adib-Samii, J. DFG pers comm

Ali Ger. UC Davis, pers. comm

Baxter, Randy. DFG, pers comm

Bennet, Bill. UC Davis, pers comm

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Lehman, Peggy. DWR, pers comm

Schoelhammer, David. UC Davis, pers comm

Slater, Steve. DFG, pers comm

Attachment A-Delta Smelt Risk Assessment Matrix

Triggers	December	January	February	March	April	May	June	July
Life Stage	Adults	Adults	Adults	Adults and larvae	Adults and larvae	Larvae and juveniles	Larvae and juveniles	Juveniles
Previous Year's Fall Midwater Trawl Recovery Index (1)	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74
Risk of Entrainment (2)				X2 upstream of Chipps Island and temps are ≥ 12°	X2 upstream of Chipps Island and temps are between 12° and 18°C	X2 upstream of Chipps Island and mean delta-wide temps <18°C and south delta temps below 28°C	X2 upstream of Chipps Island and temps are below 28°C	X2 upstream of Chipps Island and temps are below 28°C
Duration of Spawning period (number of days temperatures are between 12 and 18°C) (3)					39 days or less by April 15	50 days or less by May 1		
Spawning Stage as determined by spring Kodiak trawl and/or salvage (4)			Presence of Adults at spawning stage ≥ 4	Adult spawning stage ≥ 4	Adult spawning stage ≥ 4			
smelt distribution (5)	See footnote #5	See footnote #5	See footnote #5	See footnote #5 or negative 20mm centroid or low juvenile abundance	Negative 20mm centroid or low juvenile abundance	Negative 20mm centroid or low juvenile abundance	Negative 20mm/summer townet centroid or low juvenile abundance	Negative 20mm/summer townet centroid or low juvenile abundance
Salvage Trigger (6)	Adult concern level calculation	Adult concern level calculation	Adult concern level calculation	Adult concern level calculation		If salvage is above zero	If salvage is above zero	

Delta Smelt Risk Assessment Matrix (DSRAM) **May 2008**

Tools for Change (7)	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**
Export reduction at one or both facilities	X	X	X	X	X	X	X	X
Change in barrier operations						X	X	X
Change in San Joaquin River flows				X	X	X	X	X
Change position of cross channel gates						X	X	

Delta Smelt Risk Assessment Matrix Footnotes

1 The Recovery index is calculated from a subset of the September and October Fall Midwater Trawl sampling (http://www.delta.dfg.ca.gov/). The number in the matrix, 74, is the median value for the 1980-2002 Recovery Index (Figure 1)

2 The temperature range of 12 to 18 °C is the range in which most successful delta smelt spawning occurs. This has been analyzed by using observed cohorts entering the 20-mm Survey length frequency graphs (1996-02). Cohorts were defined by having a noticeable peak or signal and occurring over three or more surveys during the rearing season. Temperature data from DWR's CDEC web site was compiled using three stations representing the South Delta (Mossdale), confluence (Antioch), and North Delta (Rio Vista). Spawning dates for each cohort was back-calculated by applying an average daily growth rate (wild fish) of 0.45 mm/day (Bennett, DFG pers. comm.) and egg incubation period of 8-14 days (Baskerville-Bridges, Lindberg pers. comm.)(Mager et al. 2004) from the median value of the analyzed cohort. Each spawning event was then plotted against temperature over time (Figure 2). While spawning does occur outside of the 12-18 °C range, larval survival is most likely reduced when temperatures are either below (DFG pers. comm.) or above this range (Baskerville-Bridges & DFG pers. comm.).

Critical thermal maxima for delta smelt was reached at 25.4 °C in the laboratory (Swanson et al., 2000); however, in 2007 delta smelt were observed in the delta and in salvage at temperatures up to about 28 °C.

Websites for the temperature data: http://cdec.water.ca.gov/cgi-progs/queryF?MSD
http://cdec.water.ca.gov/cgi-progs/queryF?ANH
http://cdec.water.ca.gov/cgi-progs/queryF?RIV

Mager RC, Doroshov SI, Van Eenennaam JP, and Brown RL. 2004. Early Life Stages of Delta Smelt. American Fisheries Society Symposium 39:169-180.

Swanson C, Reid T, Young PS, and Cech JJ. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced Wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123:384-390.

3 Figure 3: The working hypothesis for delta smelt is that spawning only occurs when temperatures are suitable during the winter and spring. In years with few days having suitable spawning temperatures, the spawning "window" is limited, so the species produces fewer cohorts of young smelt. Few cohorts increase the risk that mortality sources such as entrainment may have population level effects.

The figures below were used to help define years when there were relatively days with suitable temperatures. For April 15 and May 1, the figures show the cumulative spawning days for each year during 1984-2002. The cumulative spawning days for each year were calculated based on the number of days that the mean water temperature for three Delta stations (Antioch; Mossdale and Rio Vista) was in the 12 - 18 °C range starting on February 1. The results are plotted in terms of the ranks to identify the lower quartile. In other words, years in the lower quartile represent examples of years with relatively few spawning days.

4 The adult spawning stage is determined by the Spring Kodiak Trawl and/or fish salvaged at the pumping facilities (http://www.delta.dfg.ca.gov/). A stage greater than or equal to 4 indicates female delta smelt are ripe and ready to spawn or have already spawned (Mager 1996).

Mager RC. 1996. Gametogenesis, Reproduction and Artificial Propogation of Delta Smelt, *Hypomesus transpacificus.* [Dissertation] Davis: University of California, Davis. 115 pages. Published.

5 The spring kodiak trawl will be used to help generally determine the distribution of adult smelt. However, since the spring kodiak trawl is not intended to be a survey for abundance or distributions, no definitive trigger for concern can be determined at this time.

Juveniles (March-July) – distribution of juvenile delta smelt where the centroid is located upstream (negative) or downstream (positive) of the Sacramento-San Joaquin River confluence (Figure 4). The 20-mm Survey (or Summer Townet Survey) centroid is calculated by multiplying the observed delta smelt station CPUE (fish/10,000 m3) by a distance parameter in km from the confluence. The summed result (summed over a survey) is divided by the survey CPUE which gives the survey centroid position (Figure 5)

Low juvenile abundance will also be a trigger. Abundance (total cumulative count) will be monitored throughout the sampling season with low values based upon median values of historic cumulative 20-mm Survey catch (1995-2003). Each survey within a season has a median value associated with it and when catch is equal to or below that value, concern is high (Table 1).

6 Salvage trigger: the salvage trigger for December through March is determined by calculating the ratio of adult salvage to the fall MWT index. This ratio will increase as fish are salvaged during the winter months. If the ratio exceeds the median of what was observed during December-March 1980-2002, then the trigger was met (see Figure 6 for more explanation of the calculation)

During May and June, if delta smelt salvage at the salvage facilities is greater than zero, then the working group will meet. This is because May and June are the peak of smelt salvage and salvage densities cannot be predicted. Therefore, during these two months, the SWG will meet proactively to protect these fish by looking at relevant information such as salvage, Delta temperatures, Delta hydrology and smelt distributions.

7 The tools for change are actions that the working group can recommend to the DAT and WOMT group to help protect delta smelt. Exports may be reduced at one or both of the South Delta export facilities and a proposed duration of the reduction would be recommended by the working group. Export reductions and changes in San Joaquin River flows may be covered by (b)(2) or EWA assets. Details of past fish actions can be found at the CALFED Ops website: http://wwwoco.water.ca.gov/calfedops/index.html; >Operations [year]

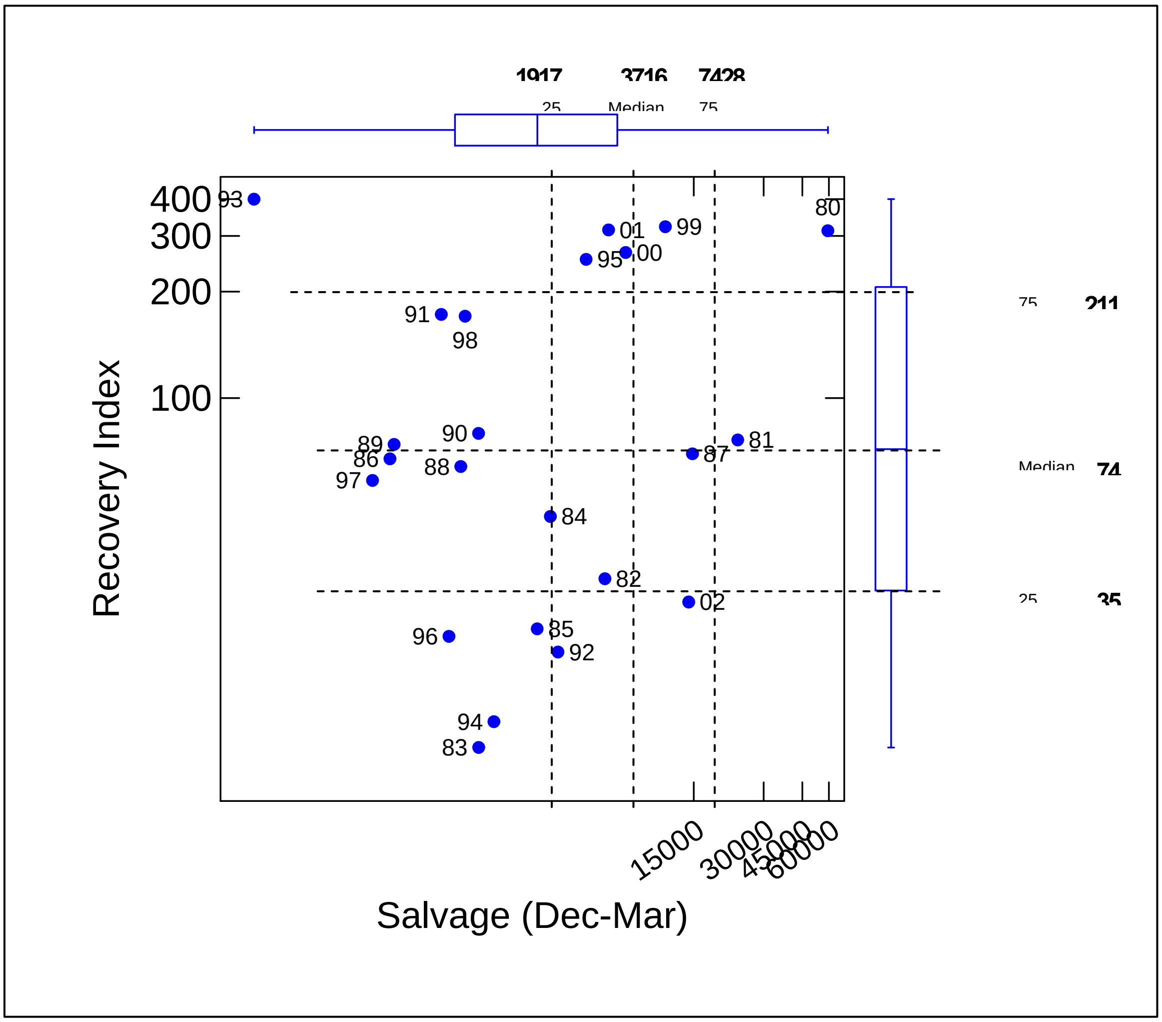


Figure 1 1980-2002 Recovery Index

Figure 1 points are labeled with the year representing the recovery index.
The winter salvage is for this analysis starts in December of the recovery index year and carries through March of the following year.

Figure 2 shows the successful delta smelt spawning periods (black bars) and start and end of spawning season (yellow bars) determined by the 20-mm Survey catch results (1996-2002). Temperature data (^{o}C) was compiled from CDEC using mean daily temperatures from the South Delta (Mossdale), North Delta (Rio Vista), and confluence (Antioch).

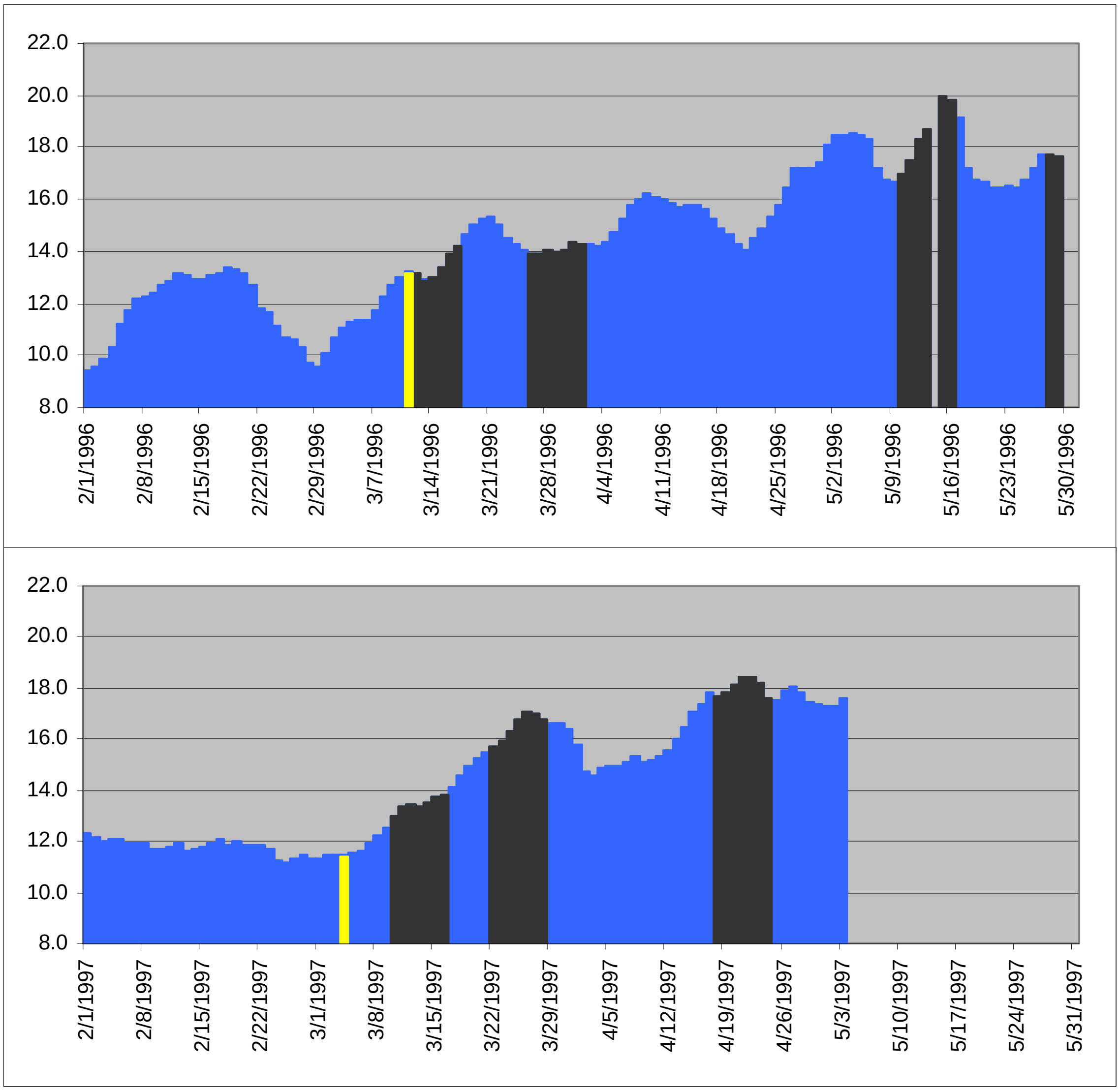
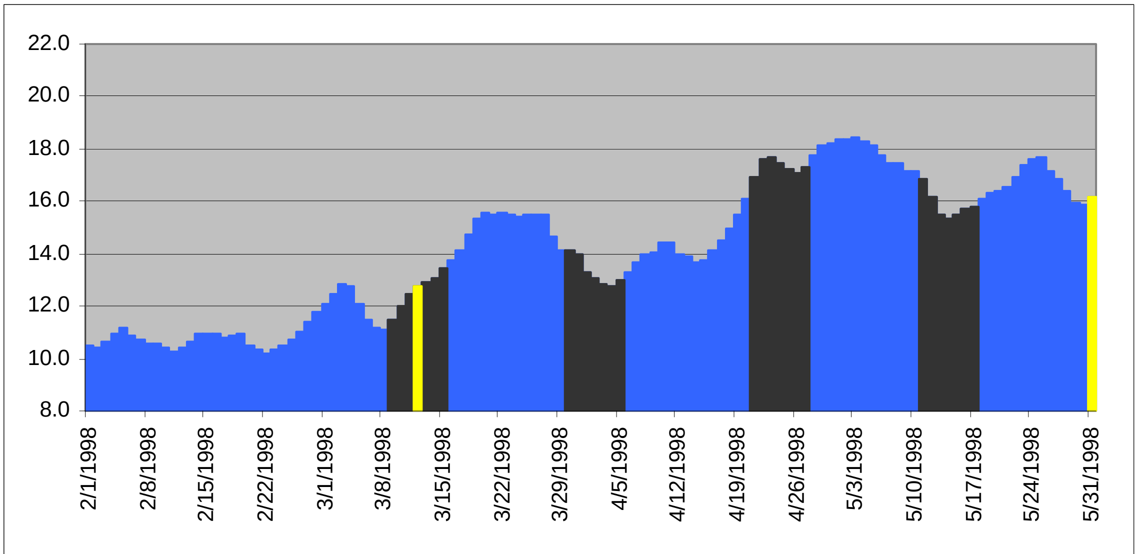


Figure 2 Successful delta smelt spawning periods


22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
2/1/1998
2/8/1998
2/15/1998
2/22/1998
3/1/1998
3/8/1998
3/15/1998
3/22/1998
3/29/1998
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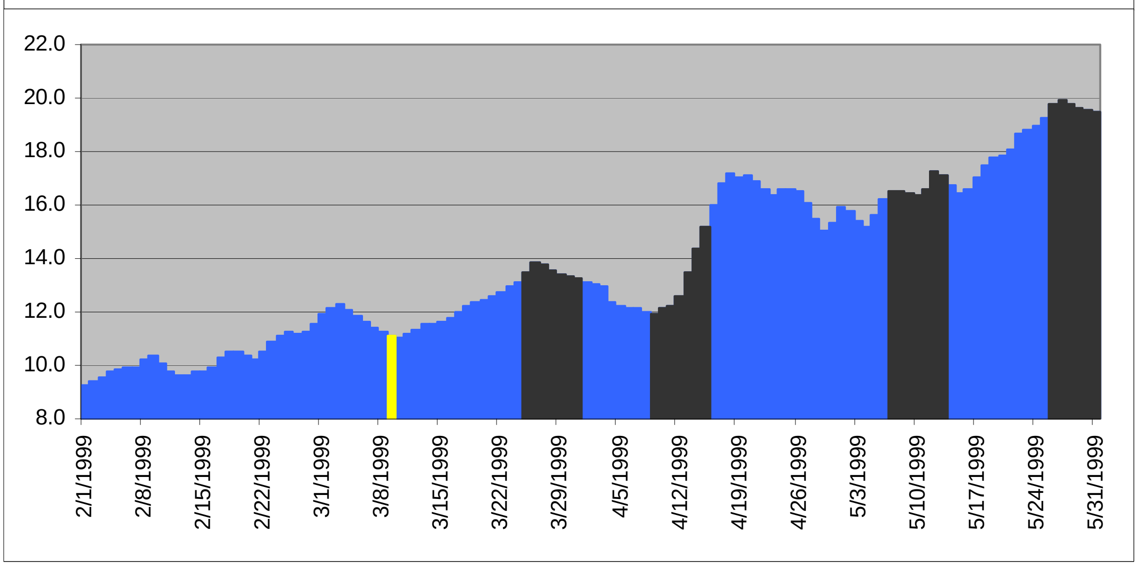
5/24/1998
5/31/1998


22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
2/1/1999
2/8/1999
2/15/1999
2/22/1999
3/1/1999
3/8/1999
3/15/1999
3/22/1999
3/29/1999
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5/24/1999
5/31/1999

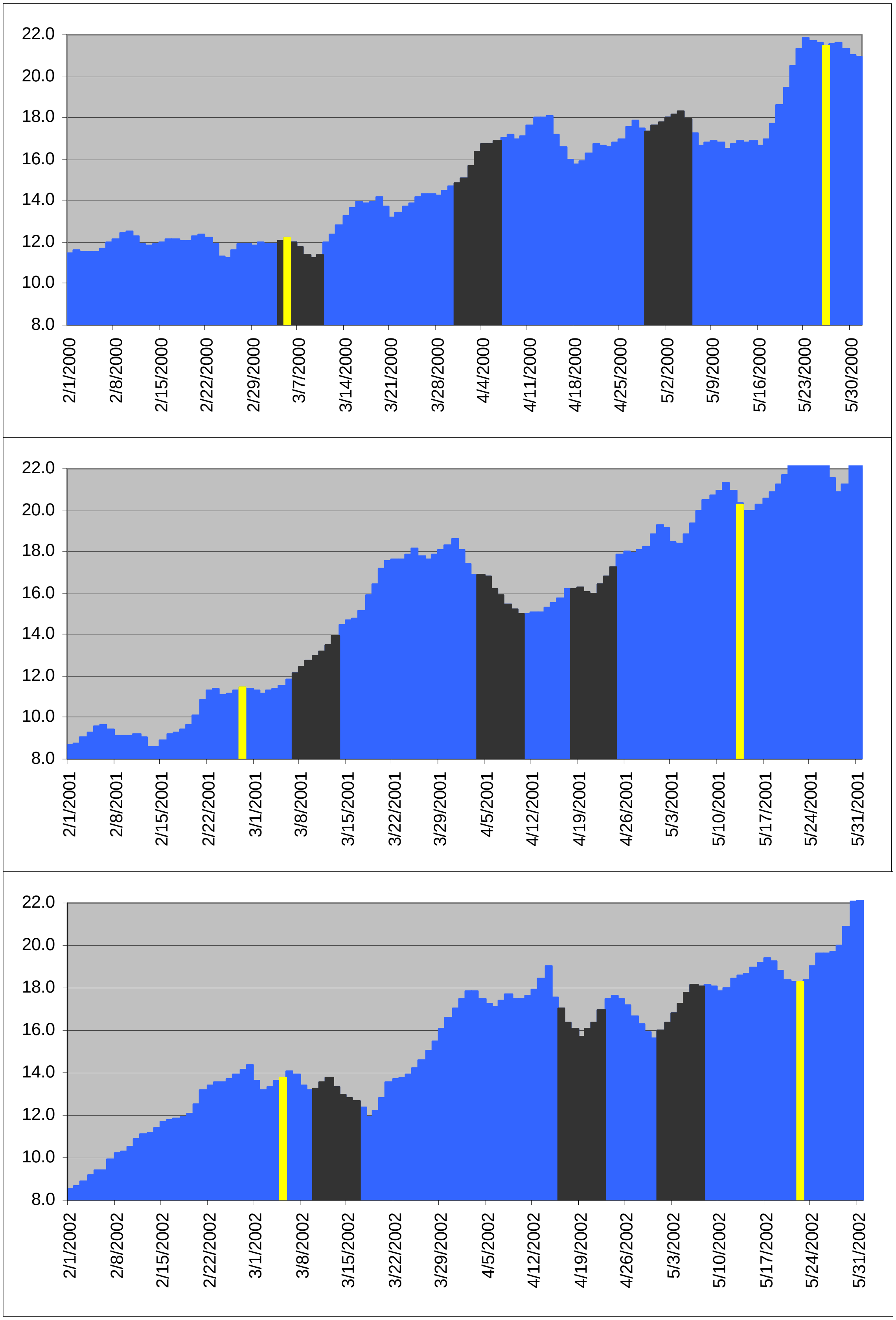


Figure 2 cont.

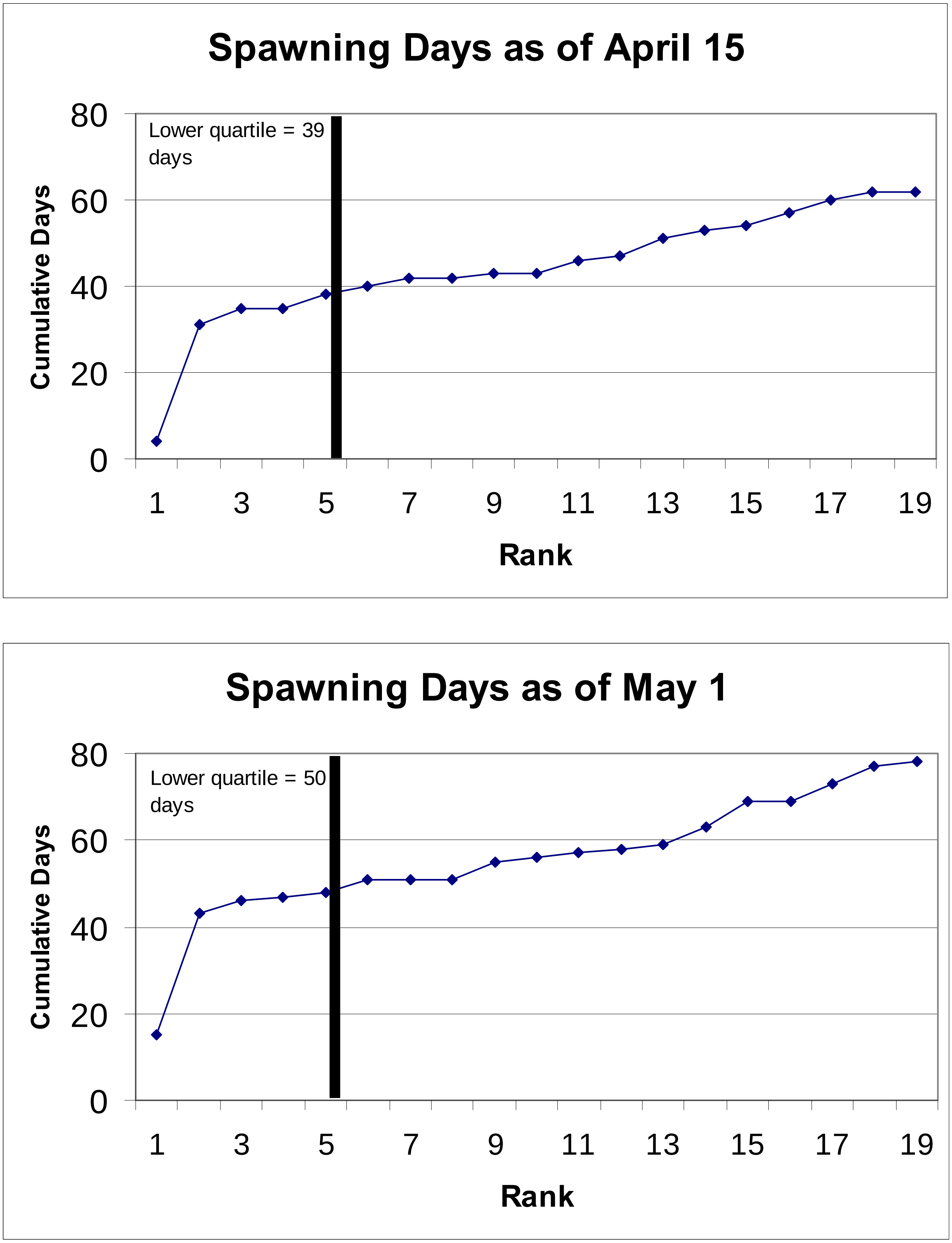


Figure 3 Delta smelt spawning days

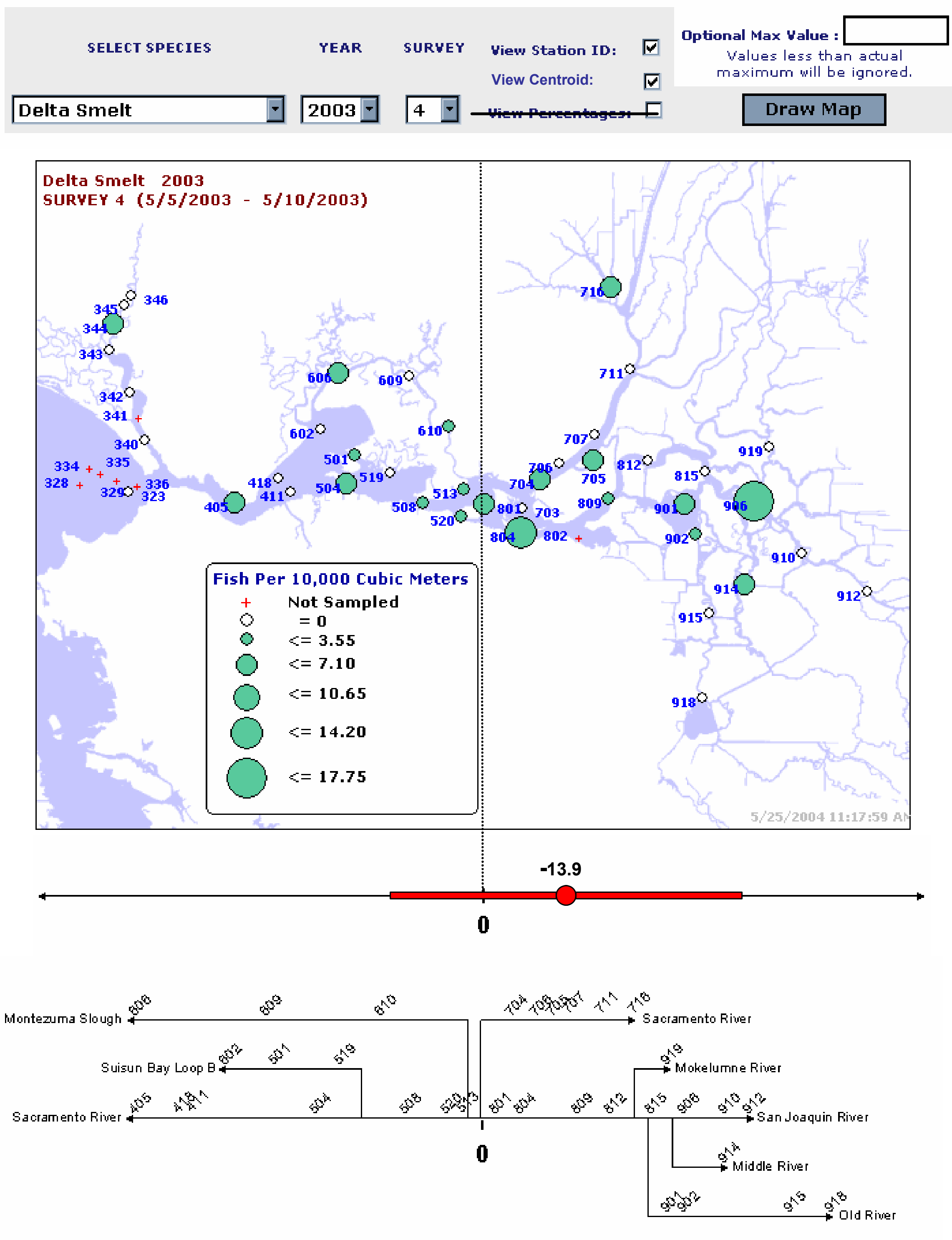


Figure 4 A 20-mm Survey delta smelt bubble plot map with calculated centroid position from the confluence of Sacramento-San Joaquin Rivers with one standard deviation.

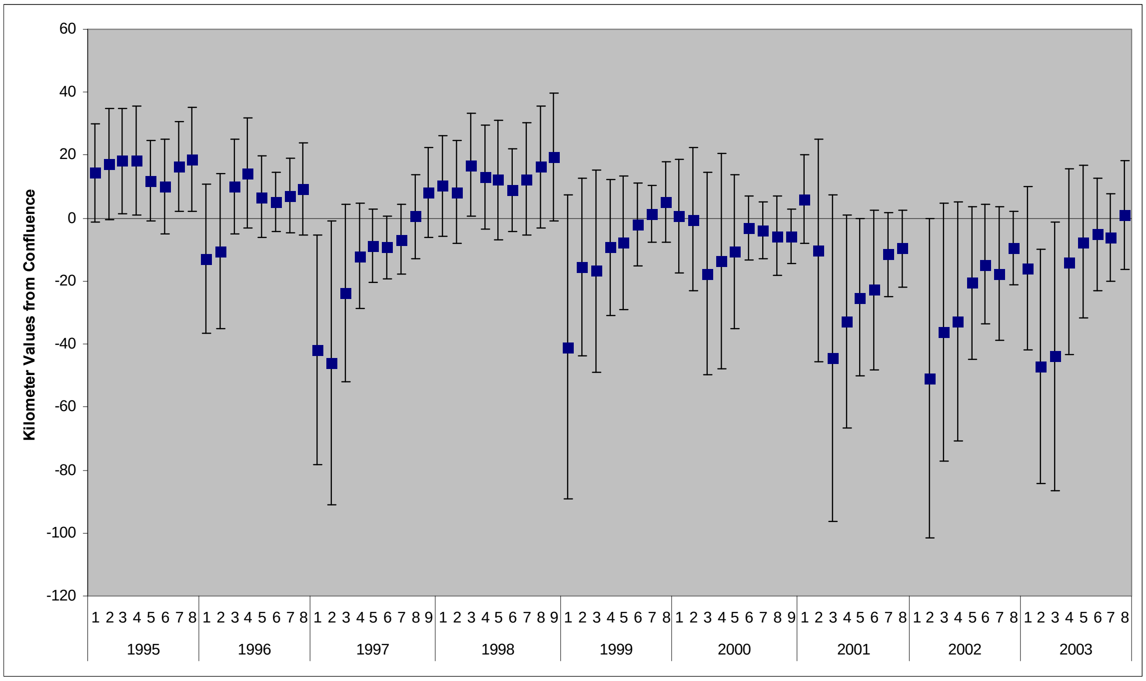


Figure 5 Historic juvenile centroid position (20-mm Survey) with one standard deviation.

Table 6 Lower quartile values of cumulative catch from the 20-mm Survey. When cumulative catch per survey during a season is at or below the calculated value, concern is high.

	survey 1	survey 2	survey 3	survey 4	survey 5	survey 6	survey 7	survey 8
lower quartile	12	40	144	188	346	500	924	1019

In Figure 7**,** the objective is to quantify a level of concern for adult delta smelt during the winter, that is based upon not only the number of fish salvaged but also accounts for the overall abundance of smelt. Whatever quantifier we select should reflect that when the abundance is low and salvage is high concern is high and conversely, when abundance is high and salvage is low that concern is low.

Below is a Quantile plot of the ratio of winter salvage to MWT index (ln (winter salvage/MWT index)). Winter salvage is defined as the total salvage from December through March. In the figure below, the size of the bubbles is proportional to the log of the fall midwater trawl just to give some indication of relative abundance. The resulting quartiles of the ratio are as follows:

25th percentile =: 2.950; 50th percentile = 3.575; 75th percentile = 5.029.

If we were to use this approach to calculate winter concern levels and use the median value, then all years above the 1999 point in the graph would have been years of concern. In other words, these are the years in which we may have recommended some protection. Comparing it to the protection afforded adult delta smelt in the winter by the 1995 biological opinion ("red light" was, or would have been reached in the following winters of 1980, 1981, 1982, 1984 and 1999) .

If the median was selected as the measure of concern it would be calculated by:

concern level = anti ln(3.575)* MWT recovery index

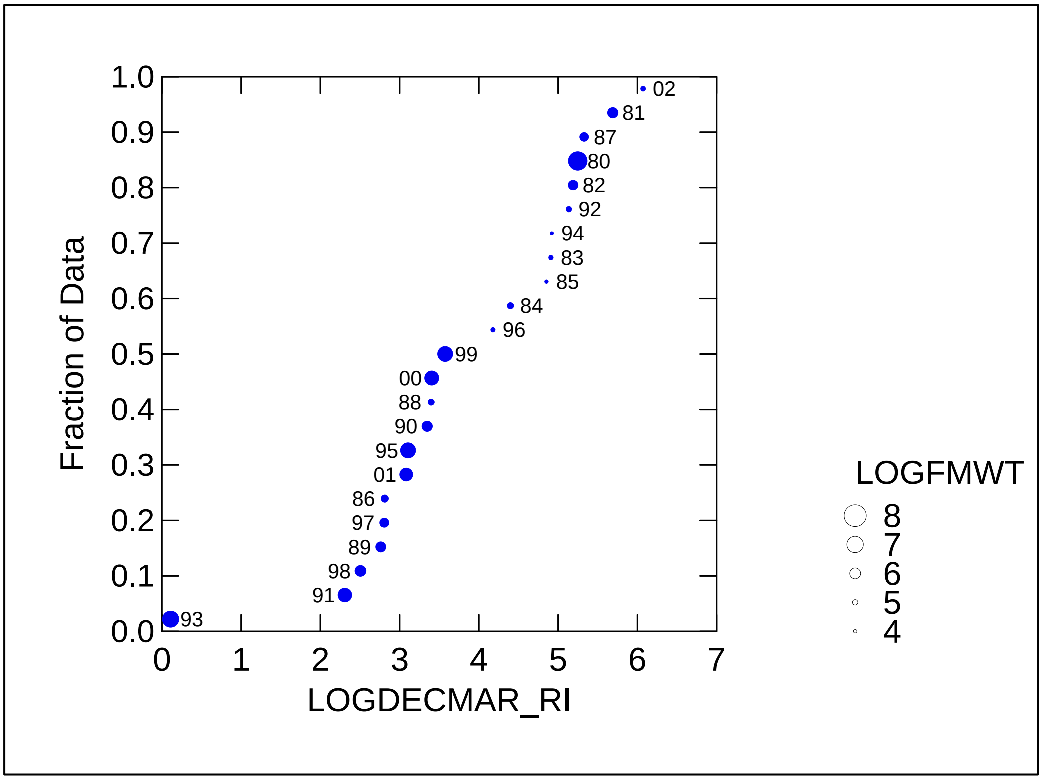


Figure 7 Quantile plot of the ratio of winter salvage to MWT recovery index

The goal for the DSRAM is to avoid the upper quartile of the above graph, in general, to avoid high salvage events when the MWT recovery index is low. Actions would be taken prior to salvage events and ideally, high salvage events would not occur.

Attachment B, Supplemental Information related to the Reasonable and Prudent Alternative

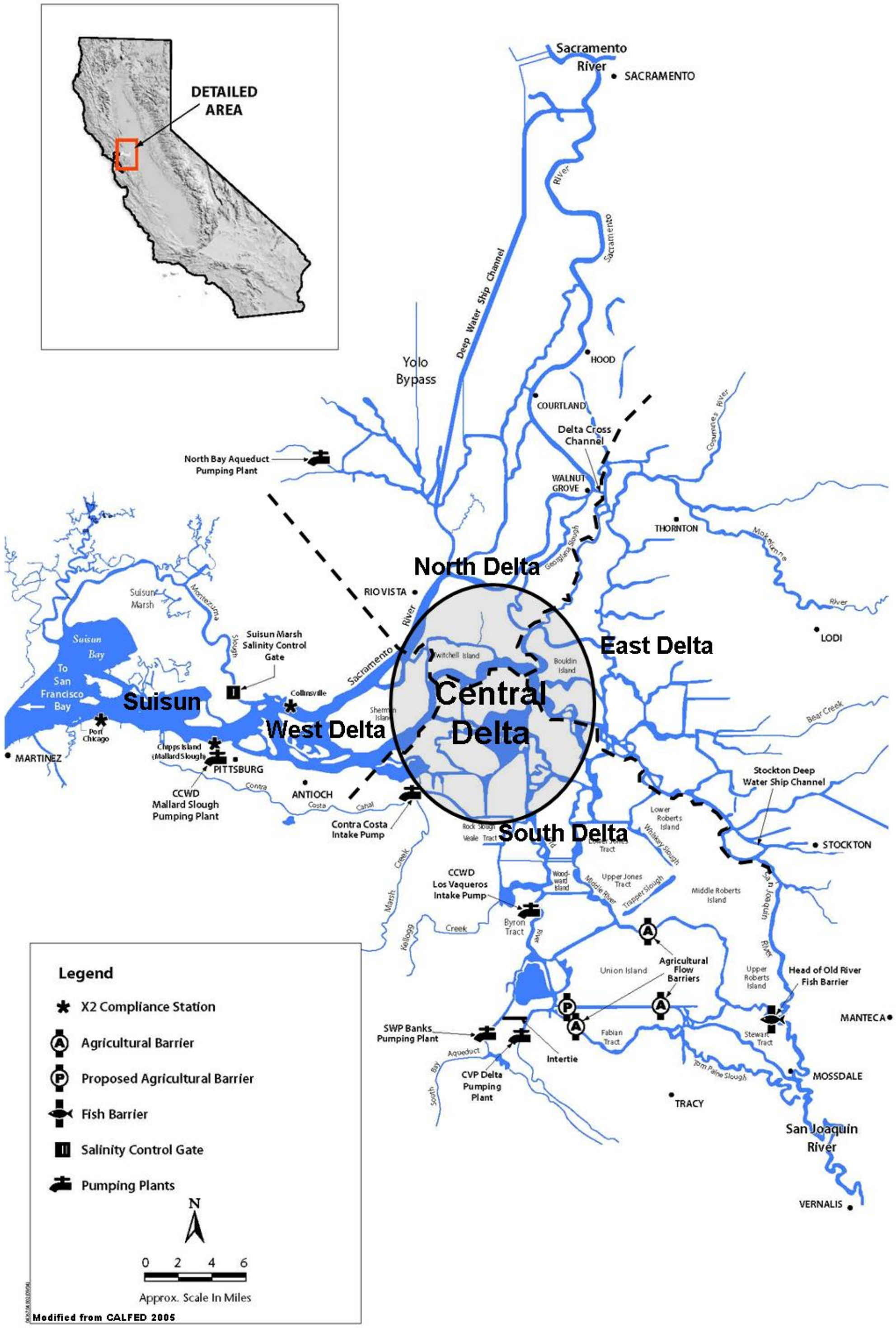
There are three major factors related to operations of the CVP/SWP affecting delta smelt population resilience and long-term viability. It is also recognized that the hydrologic changes from the CVP/SWP result in ecological conditions that influence delta smelt interactions with other stressors within the Delta. The following actions were developed to counter these adverse effects based upon the Baseline and Effects section of the biological opinion.

These three factors are: 1) direct mortality associated with entrainment of pre-spawning adult delta smelt by CVP/SWP operations; 2) direct mortality of larval and early juvenile delta smelt associated with entrainment by CVP/SWP operations; and, 3) indirect mortality and reduced fitness through reductions to and degradation of Delta habitats by CVP/SWP operations, with the fall as a particular concern. The actions below address these factors and will ameliorate the adverse effects that are brought about from the hydrologic modifications that influence delta smelt interactions with other stressors in the Delta.

The metric for monitoring direct mortality of delta smelt is salvage at Banks and Jones during pumping operations. However, this metric alone cannot be used to trigger operational changes in CVP/SWP to prevent entrainment. This is because the combination of tidal cycles, hydrologic and meteorological events, and CVP/SWP operations can draw delta smelt into the South and Central Delta (see Map 1) where they are more susceptible to entrainment by the facilities prior to any observed delta smelt salvage. This necessitates an anticipatory strategy in order to sufficiently protect delta smelt from entrainment.

As discussed in the Baseline and Effects Sections of the biological opinion, there are other impacts to delta smelt through reduction and degradation of habitat. These effects are functional year-round, through mechanisms defined and discussed in those sections. Indirect mortality and reduced fitness of juvenile delta smelt due to degraded environmental quality (habitat suitability) in the fall impacts delta smelt. The mechanism of this impact is habitat constriction, entrainment of primary and secondary productivity leading to food-web deprivation for prey species, decreased dilution flows resulting in increased exposure to lethal and sublethal concentrations of contaminants. Additionally it results in reduced habitat variability that is expected to help control invasive species such as *Corbula* or *Microcystis* that either compete with, or directly impact survival of delta smelt. The operational criteria to restore habitat quality for rearing juveniles in the estuary are related to increasing delta outflows during fall months (September through November) of above-normal and wet WYs to improve habitat variability.

Actions 1 and 2 will reduce the direct mortality of pre-spawning adult delta smelt (Adult Entrainment). Action 3 will reduce the direct mortality of larval and juvenile delta smelt (Larval/Early Juvenile Entrainment). Action 4 will restore habitat quality for rearing juveniles in the estuary that are directly related to increasing Delta outflows during fall months (September through November) of above-normal and wet WYs to restore habitat



Map 1: Delta Regions

suitability. Action 5 describes the installation and operations of the spring temporary Head of Old River Barrier (HORB) and the temporary agricultural barriers to reduce juvenile entrainment. The detailed elements of these prescriptions, including rationale and justification, appear in subsequent sections of this document, by Action.

Delta Smelt Evaluation Team

To develop the initial actions, the Service re-evaluated the Interim Remedies for delta smelt protection as proposed in the Service's declarations of July 3, 2007 and August 3, 2007 (Cay Collette Goude 2007), and implemented in the Federal District Court's Interim Remedies Order. The Service used the CALLite operations model to evaluate different operational scenarios. Different operational parameters were run to evaluate their influence upon predicted entrainment. These parameters included export-inflow (EI) ratios, QWest, X2, and OMR flows, among others.

During these sessions, two clear patterns became evident. First, shifting operations to reduce exports during any one given month resulted in a shift in operations to increase exports in other months. Second, holding one particular parameter steady did not prevent other parameters from adapting to meet similar water supply objectives. For example, modeling Qwest to some static number still allowed considerable variability in negative OMR flows, due to the contribution of other intervening variables to Qwest, including operation of the DCC and Sacramento and San Joaquin River flows. For these reasons, the most logical operational criterion for protecting delta smelt from entrainment is controlling the magnitude of flows in the South and Central Delta towards the export facilities. This is reflected quantitatively as net negative OMR flows during the time periods when delta smelt are present and subject to entrainment.

In July 2008, the Service convened a team of experts comprising members of the Adaptive Management Planning Team (AMPT) of the ERP, technical staff from the Department of Fish and Game and the Service, and an expert hydrodynamicist to conduct evaluations of Interim Remedy actions using the evaluation process and conceptual models developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) in light of the current project description.

To the extent practicable, the DRERIP evaluation tools were used in formulating potential actions to ameliorate the anticipated effects of the proposed action. The DRERIP tools include peer reviewed ecosystem and species conceptual models for the Delta drafted by teams of experts. These models represent a compilation of the current state of scientific knowledge regarding specific ecosystems and fish species, including delta smelt.

The full DRERIP evaluation process was not applied to the potential actions for delta smelt, but elements of the process were considered and followed during the initial phases of actions development and evaluation. The nature of the task before the evaluation team finally necessitated direct involvement of technical experts in providing up-to-date quantitative analysis and detailed evaluation exceeding the level of detail inherent in the current DRERIP conceptual models.

Role of Adaptive Process and Monitoring

As discussed in the Baseline and Effects Sections of this biological opinion, we recognize that there are multiple factors affecting delta smelt population dynamics and that not all are directly influenced by operations of the CVP/SWP. With respect to direct mortality from entrainment, the prescriptions and triggers presented in actions 1, 2, and 3 are based on historical data. Net daily OMR flows serve as a key indicator of overall Delta hydrodynamics and changing OMR flows will change a key underlying driver of future salvage. Based on the low numbers of delta smelt and therefore the difficulties in delta smelt monitoring and the uncertainty in relying on historical data, the use of an adaptive process with regulatory sideboards is essential.

It is very important that the control mechanisms used to implement the actions be functionally protective when delta smelt densities are low. Delta smelt densities are likely to remain low for the foreseeable future. When delta smelt occur at low densities, it becomes difficult to reliably infer distribution and flux towards Banks and Jones based on IEP monitoring data. In circumstances where it is difficult to reliably infer these parameters, automated control mechanisms that assume reliable distribution information are likely to fail.

The real-time monitoring of final flow prescriptions within these actions are necessary parts of the final actions. Such a strategy utilizes weekly review of the sampling data and real-time salvage data at the CVP/SWP. It utilizes the most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity, and thereby adapts to current conditions. This would provide protection to delta smelt and reduce operational constraints when the risk of delta smelt entrainment is low based on distribution and data analysis. Such a strategy would provide necessary protections while utilizing the minimum possible regulatory constraints on the project.

ACTION 1: ADULT MIGRATION AND ENTRAINMENT (FIRST FLUSH)

Objective: A fixed duration action to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period.

Action: Limit exports so that the average daily OMR flow[6] is no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25 percent).

Timing:

Part A: <u>December 1 to December 20</u> – Based upon an examination of turbidity data from Prisoner's Point, Holland Cut, and Victoria Canal and salvage data from CVP/SWP (see below), and other parameters important to the protection of delta smelt including, but not limited to, preceding conditions of X2, FMWT, and river flows; the SWG may recommend a start date to the Service. The Service will make the final determination.

Part B: <u>After December 20</u> – The action will begin if the 3 day average turbidity at Prisoner's Point, Holland Cut, and Victoria Canal exceeds 12 NTU. However the SWG can recommend a delayed start or interruption based on other conditions such as Delta inflow that may affect vulnerability to entrainment.

Triggers (Part B):

<u>*Turbidity*</u>**:** 3-day average of 12 NTU or greater @ <u>*all three*</u> stations (Prisoner's Point, Holland Cut, Victoria Canal)

OR

<u>*Salvage*</u>**:** Three days of delta smelt salvage after December 20 at either facility or cumulative daily salvage count that is above a risk threshold based upon the "daily salvage index" approach reflected in a daily salvage index value ≥0.5 (daily delta smelt salvage > one-half prior year FMWT index value).

The window for triggering Action 1 concludes when either offramp condition described below is met. These offramp conditions may occur without Action 1 ever being

[6] OMR Flows for this and all relevant actions will be measured at the Old River at Bacon Island and Middle River at Middle River stations, as has been established already by the Interim Order.

triggered. If this occurs, then Action 3 is triggered[7], unless the Service concludes on the basis of the totality of available information that Action 2 should be implemented instead.

Off-ramps:

Temperature: Water temperature reaches 12°C based on a three station daily mean at Mossdale, Antioch, and Rio Vista

OR

Biological: Onset of spawning (presence of spent females in SKT or at Banks or Jones).

[7] The offramp criteria for Actions 1 and 2 to protect adults from entrainment are identical to the initiation triggers for Action 3 to protect larval/juveniles from entrainment

Background

Adult delta smelt entrainment is characterized by a pulse of pre-spawning migrants entering the Central and South Delta following a "first flush" flow event in winter. This event generally involves a coincident increase in turbidity; which, along with the flows, is a cue for delta smelt migration. The interaction of these migratory cues: flow, turbidity, temperature, and season, leads to migration patterns that are difficult to predict yearly. However, historical salvage of delta smelt at Banks and Jones provides an index of entrainment that can be compared against key general predictors like flow and turbidity. Figures B-1 and B-2 below graphically depict the relationship of these variables against daily smelt salvage at Banks and Jones during two example WYs. Once the initial pulse of pre-spawning migration passes, it is believed that spawning adults moderate their movements to maintain their geographical range to a smaller area (when conditions stay favorable) and to the extent that delta smelt can control their location based on extant flow variables.

Entrainment effects upon delta smelt populations can be substantial (Kimmerer 2008). In one historically common scenario, a tight coincidence between calendar timing, sudden influx of turbid (>12 NTU) fresh water into the Delta, and high Delta exports may lead to very high salvage spikes. These events are seen within the data as high amplitude peaks in the daily adult delta smelt salvage histogram. Such events occurred in WY's 1993 and 2003, as displayed in Figures B-3 and B-4, which plot turbidity and negative OMR on visually convenient scales against total salvage. If this scenario plays out in years where there are few delta smelt, it may be difficult to detect salvage spikes even if they represent substantial proportional entrainment events.

In a second scenario there are no large salvage spikes, but chronic entrainment over a sufficient duration adds up to a relatively large cumulative salvage. Alternatively, there may be multiple entrainment spikes in years where the timing of migratory cues is diffuse or occurs in episodes. This would appear graphically as a histogram with generally low-amplitude over the duration of the entrainment period. Examples of such entrainment years would include WY 2004 and 2005, as displayed in Figures B-5, and B-6.

Total entrainment depends on precipitation patterns, ambient air temperature, controlled and uncontrolled releases from waterways feeding the Delta, specific operation of facilities such as the DCC, and condition of that year's pre-spawning cohort based on current year habitat quality. All of these factors may affect the distribution of delta smelt adults as and after they migrate into the Delta—and it is the migration into the entrainment risk zone and the area of that zone based on operational conditions at the time that determines ultimate mortality. However, the list of variables known or believed to influence delta smelt distribution during this period is not complete, and there is substantial apparently stochastic variation in adult delta smelt habitat use.

Figure B-1: 1995 WY OMR, Turbidity, Salvage

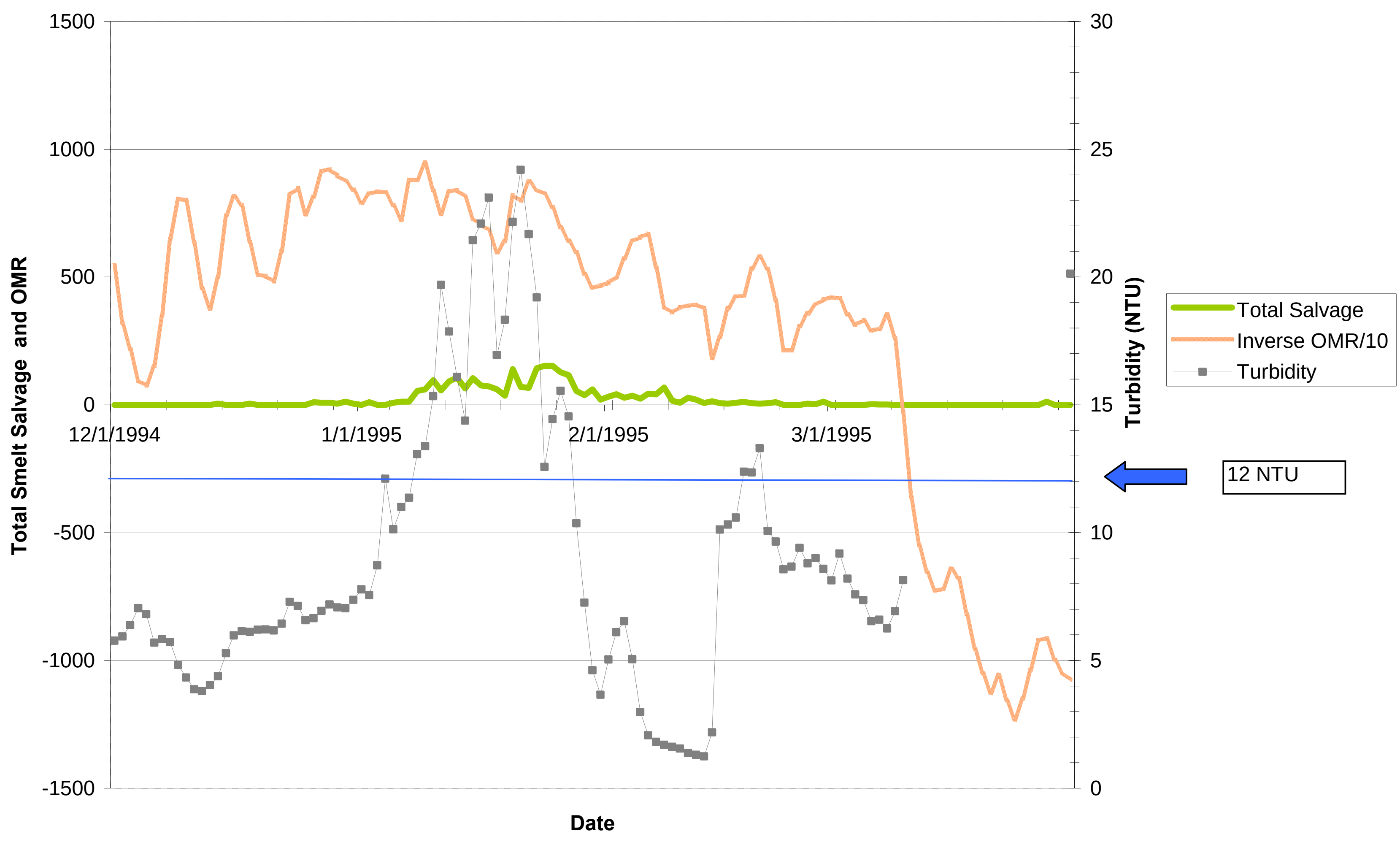


Figure B-2: 2002 WY OMR, Turbidity, Salvage

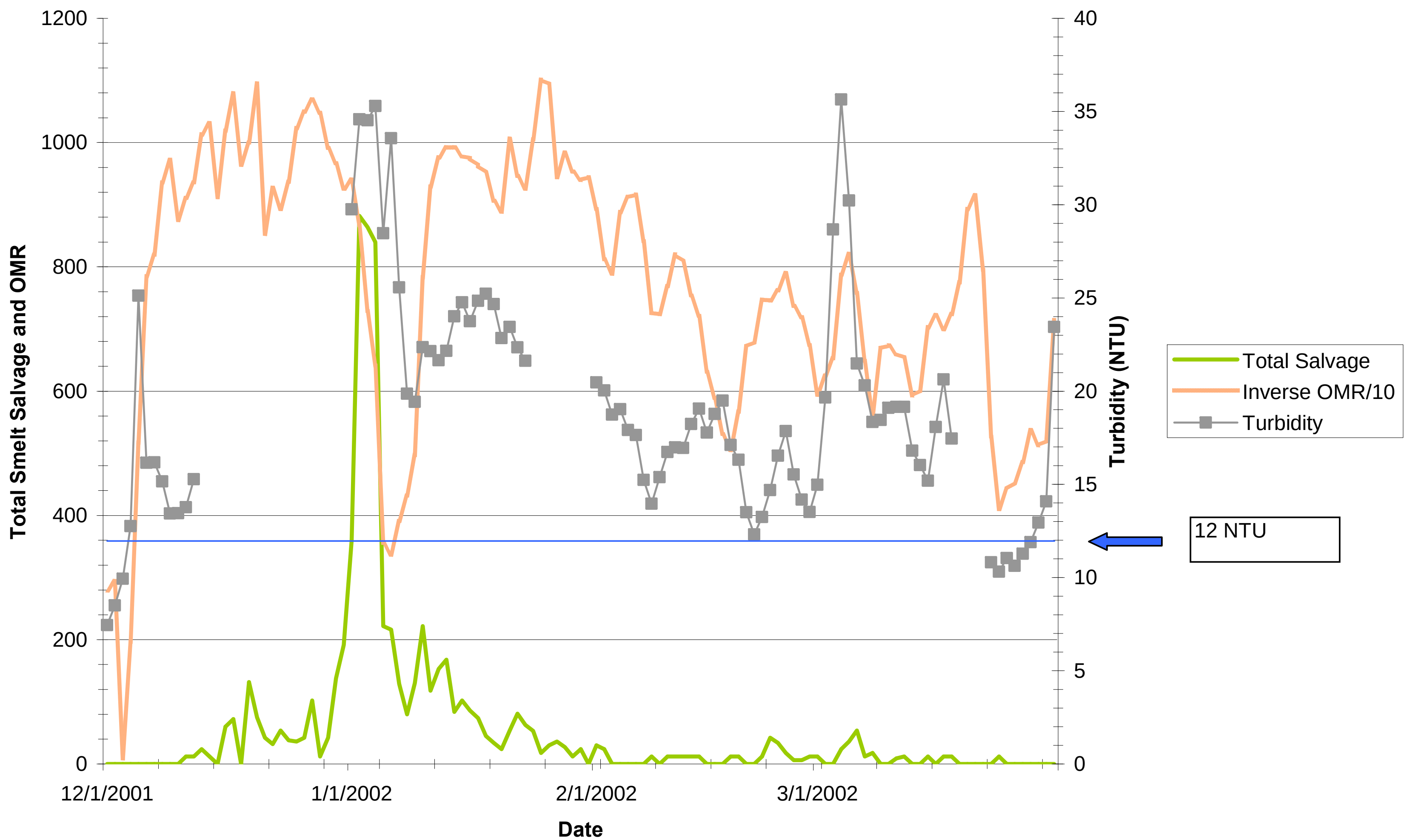


Figure B-3: 1993 WY OMR, Turbidity, Salvage

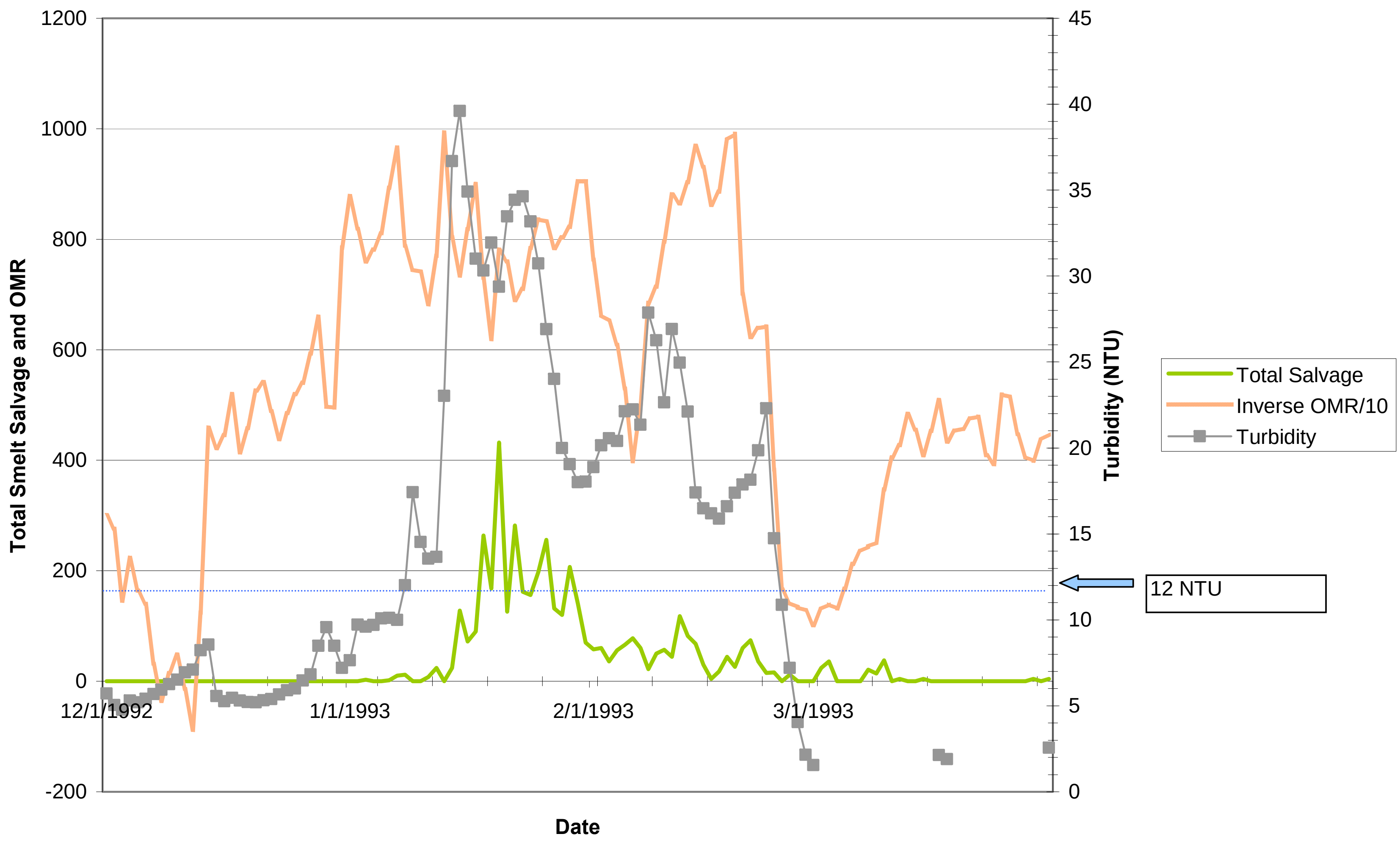


Figure B-4: 2003 WY OMR, Turbidity, Salvage

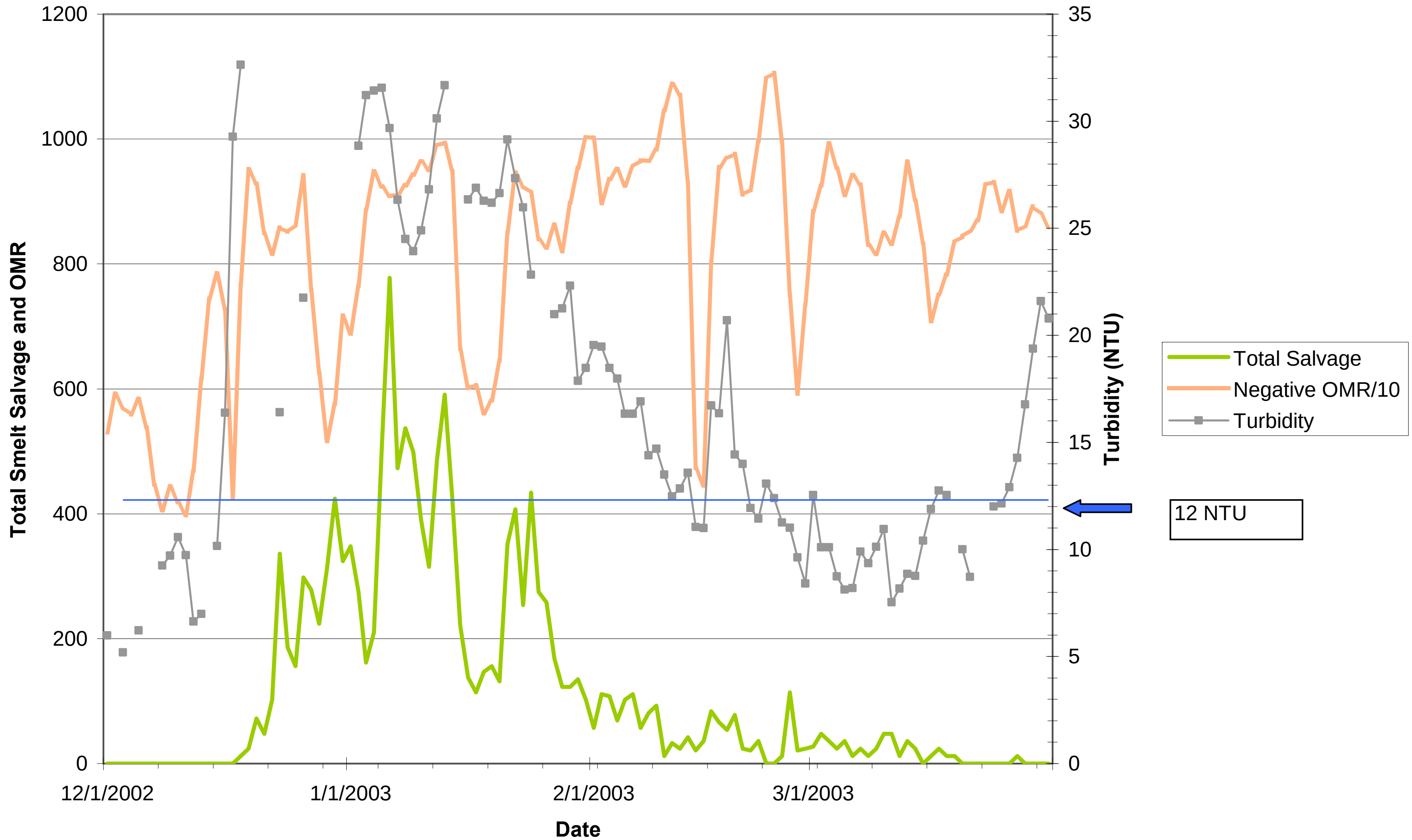


Figure B-5: 2004 WY OMR, Turbidity, Salvage

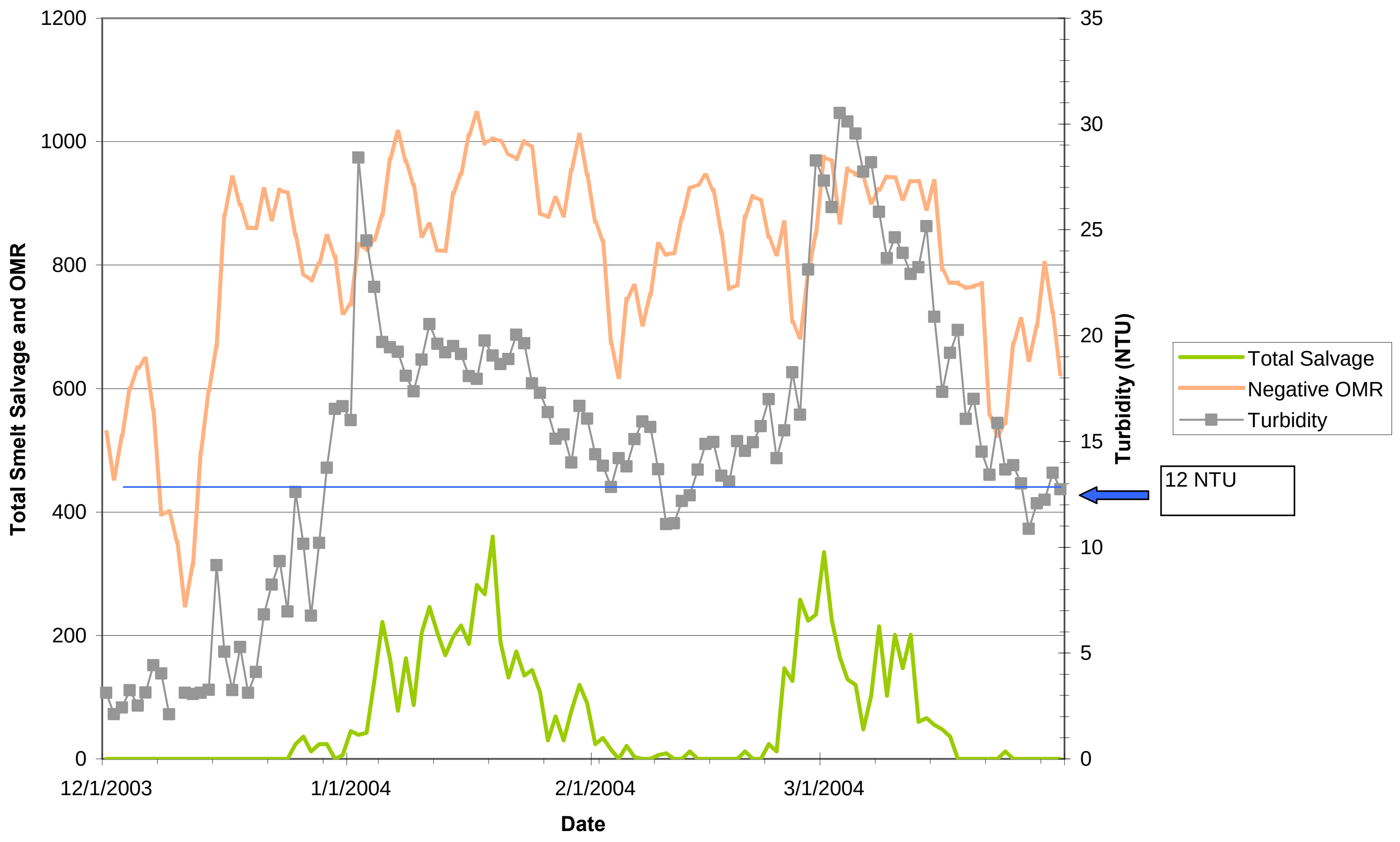
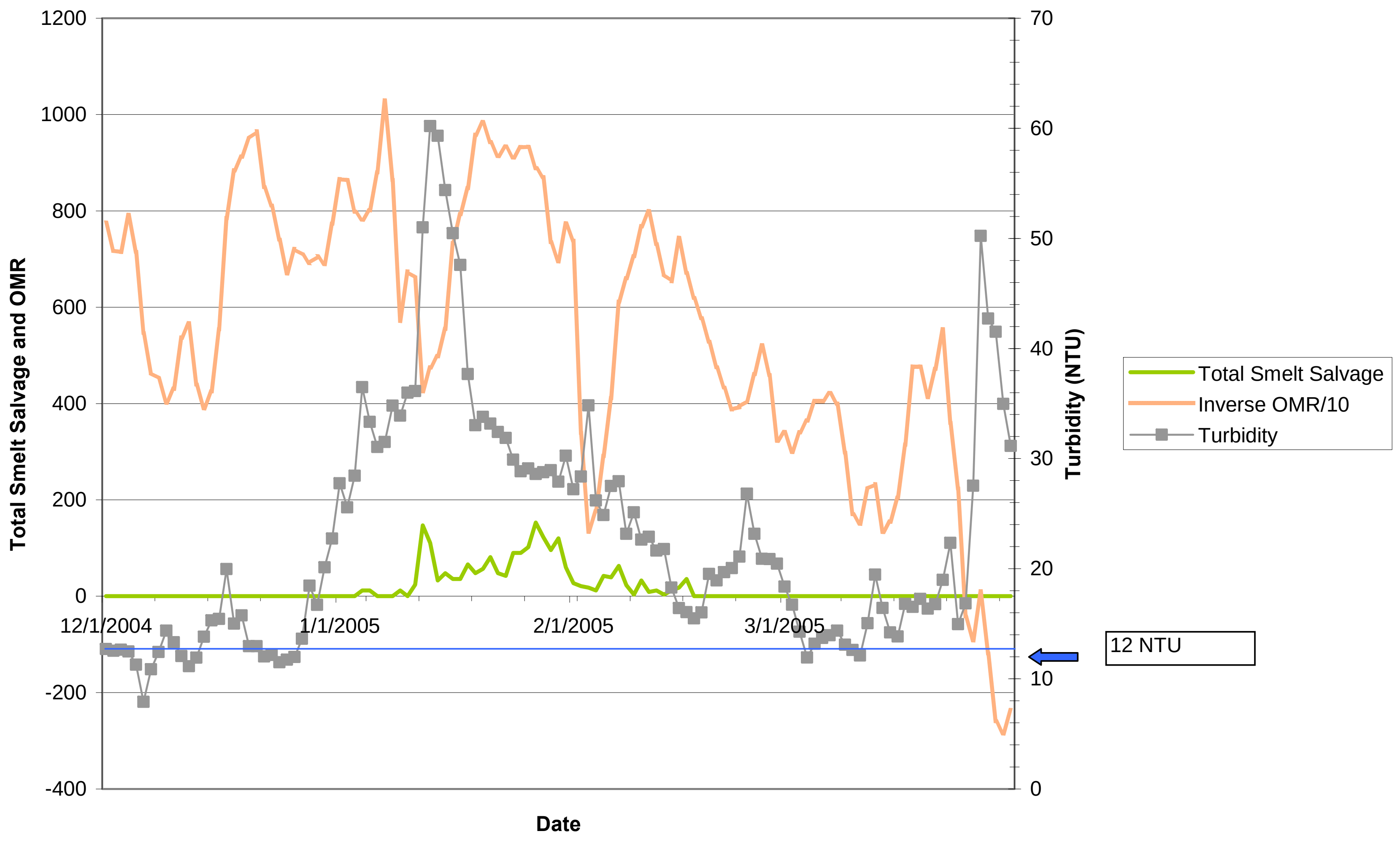


Figure B-6: 2005 WY OMR, Turbidity, Salvage



Up to fifty percent of the pre-spawning adult population has been entrained at the export facilities in recent years, depending on circumstances (Kimmerer 2008). Entrainment risk depends most importantly upon the distribution of delta smelt relative to the entrainment footprint of the CVP/SWP export facilities. Monitoring programs such as the FMWT and SKT provide a useful basis for estimating the abundance and distribution of delta smelt, despite having drawbacks (Newman 2008). The margin of error associated with abundance and distribution inferences increases at low abundances that have characterized the last several years. Abundances near the detection threshold of the sampling techniques makes it very difficult to draw reliable inferences about how many delta smelt there are, and where they are located.

To provide context to determine the magnitude of effect of pre-spawning adult direct mortality through entrainment within any given season (as measured by salvage), it is necessary to consider two important factors. First, although salvage is an index of entrainment, it is not a direct quantitative equivalent. The number of delta smelt that are actually counted at the salvage facilities represents a small percentage of the actual number entrained (See baseline section). Efficiency of sampling methodology is another consideration given the delicate tissues of the delta smelt, and this decreases inversely with fish size (adults are most accurately counted, while juvenile salvage efficiency is much lower, while <20mm smelt are mostly undetectable at the salvage facilities). Finally, although surviving individuals are held and released to the Delta, it is generally thought that they do not survive. Therefore salvage at the Banks and Jones facilities is not a good estimate of actual adult delta smelt mortality through entrainment (See baseline section).

The second factor to consider when relating salvage data to population-level significance is that the total number salvaged at the facilities does not necessarily indicate a negative impact upon the overall delta smelt population. The Salvage Index normalizes salvage to the population size based upon the previous FMWT Index:

Salvage Index = Number of Delta Smelt Salvaged ÷ Prior Year FMWT Index

Summaries of delta smelt salvage are presented by WY in Table B-2. Figures B-7 through B-11 display salvage data normalized to prior-year FMWT for the POD years (WY2002-WY2006). These plots have consistent units on the y-axis, reflecting the Salvage Index. The area under the salvage histogram reflects the total number of smelt salvaged, and this is a metric that can be related to total demographic impacts through entrainment. Review of salvage histograms within Figures B-7 through B-11 gives a sense of the magnitude of entrainment effects for all detectable lifestages of smelt through the water year.

Table B-2: Total Adult Delta Smelt Salvage by Year, including summary statistics

Year	Total Salvage	Prior Year FMWT	Cumulative Salvage Index	Peak Daily Salvage "Amplitude"	Salvage distribution	12 NTU "Trigger Date"	NTU trigger to peak salvage (days)	Total # salvaged before trigger	propn of total season salvage prior to trigger date
1993	4425	156	28.4	2.77	unimodal	10-Jan	12	27	0.0061
1994	398	1078	0.37	0.08	unimodal	4-Jan	52	100	0.25
1995	2600	102	25.5	1.49	unimodal	9-Jan	16	150	0.058
1996*	5634	899	6.27	0.52	unimodal	14-Feb	36	0	0.00
1997	1816	127	14.3	1.12	unimodal	20-Dec	80	12	0.007
1998	1027	303	3.39	0.38	bimodal	20-Dec	10 & 94	75	0.073
1999	2074	420	4.94	0.40	unimodal	14-Jan	36	20	0.0096
2000	11493	864	13.34	0.72	unimodal	23-Jan	28	482	0.042
2001	7991	756	10.6	0.49	unimodal	13-Jan	29	255	0.032
2002	6865	603	11.4	1.46	unimodal	20-Dec	14	324	0.047
2003	14323	139	103	5.60	unimodal	20-Dec	17	108	0.0075
2004	8148	210	38.8	1.71	bimodal	31-Dec	19	126	0.015
2005	2018	74	27.3	2.07	unimodal	20-Dec	39	0	0.00

* 3 NTU sensor malfunctions most of year; date evaluated as Dec 20 using total inflow > 25,000 cfs

Review of salvage data across years for which monitoring data are available indicate some patterns which led to the development of Interim Remedies Action 1; the same logic has been used to develop the present Action 1. First, salvage data during winter generally follows a unimodal distribution, with a defined salvage peak, and short duration. Occasionally, climatic conditions and operational criteria interact to produce bimodal or diffuse salvage distributions, however these year types are the exception, as summarized in Table B-2. Peak salvage usually occurs during the month of January, however this pattern does not hold during all year types, and some years even exhibit low overall adult salvage (wet WY of 1997 and 1998, or dry years with no winter first flush as in WY 1994).

Historic delta smelt salvage data and the current population status suggest a protective strategy for this period that focuses upon prevention of the attraction and subsequent entrainment of pre-spawning adults during the onset of upstream migration. While salvage itself is a useful indicator of distribution after the fact, it has serious drawbacks as a management tool when used on its own, because a large entrainment event may be inevitable by the time an increase in salvage is detected.

Figure B-7: 2002 WY Salvage Index

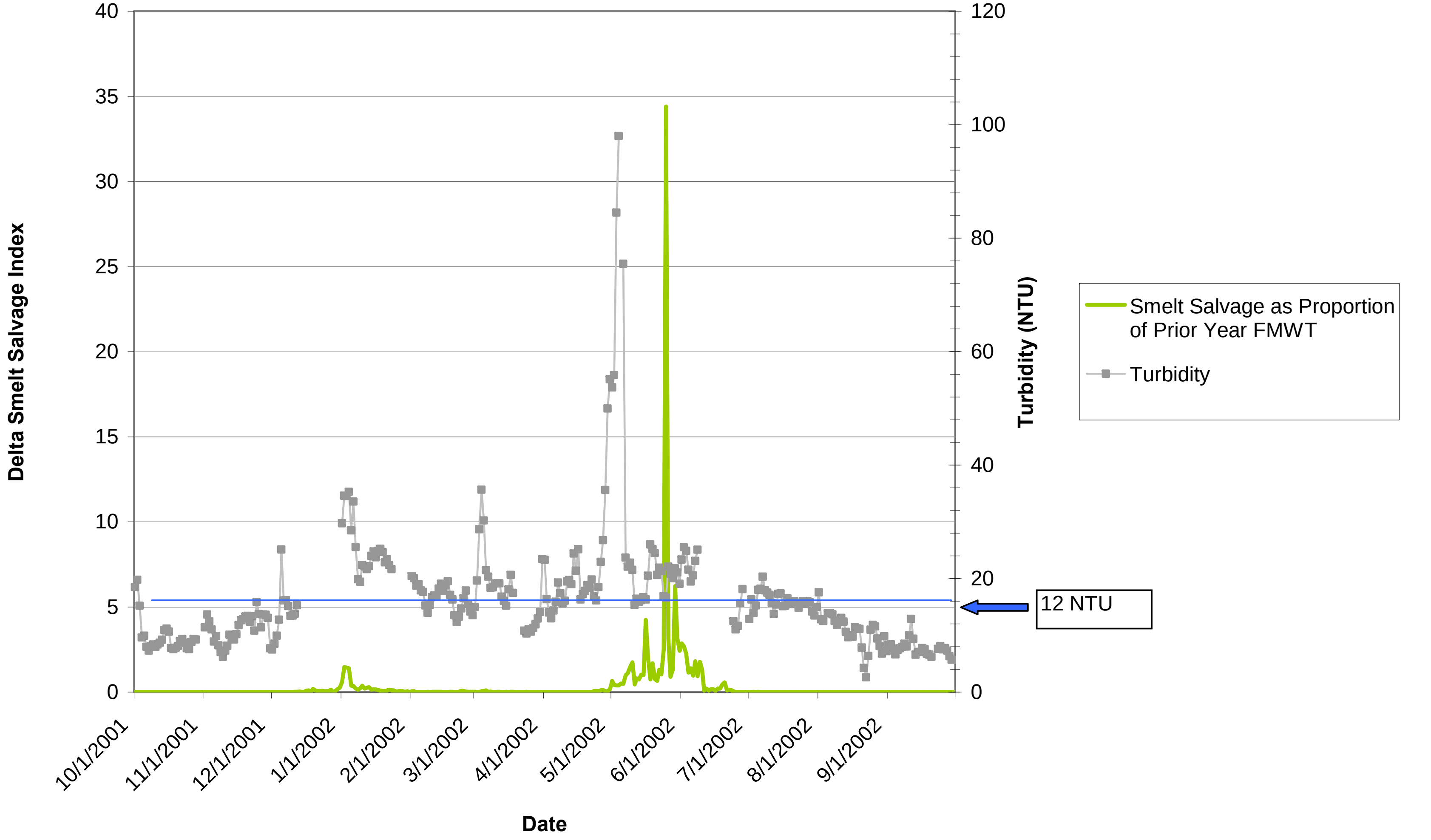


Figure B-8: 2003 WY Salvage Index

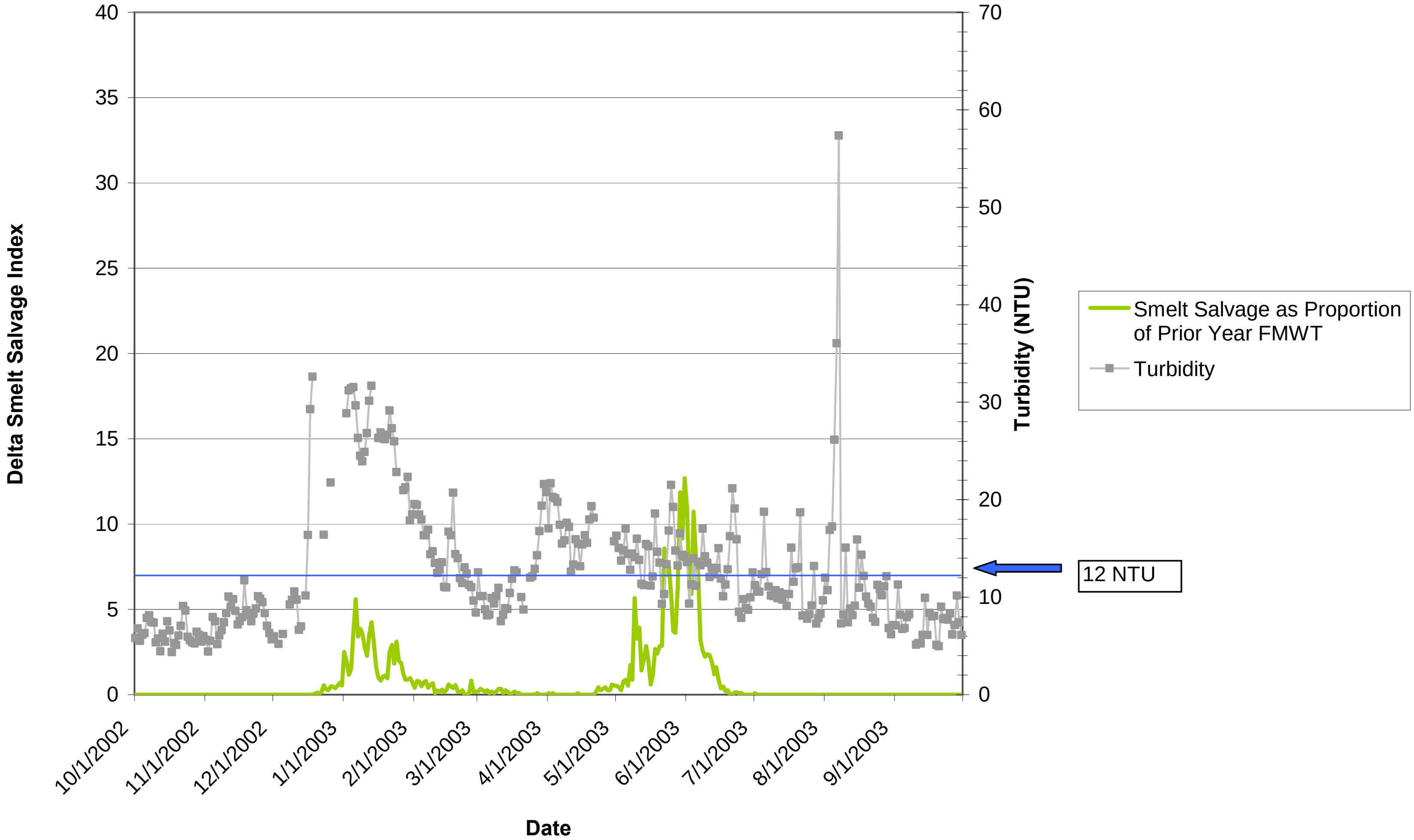


Figure B-9: 2004 WY Salvage Index

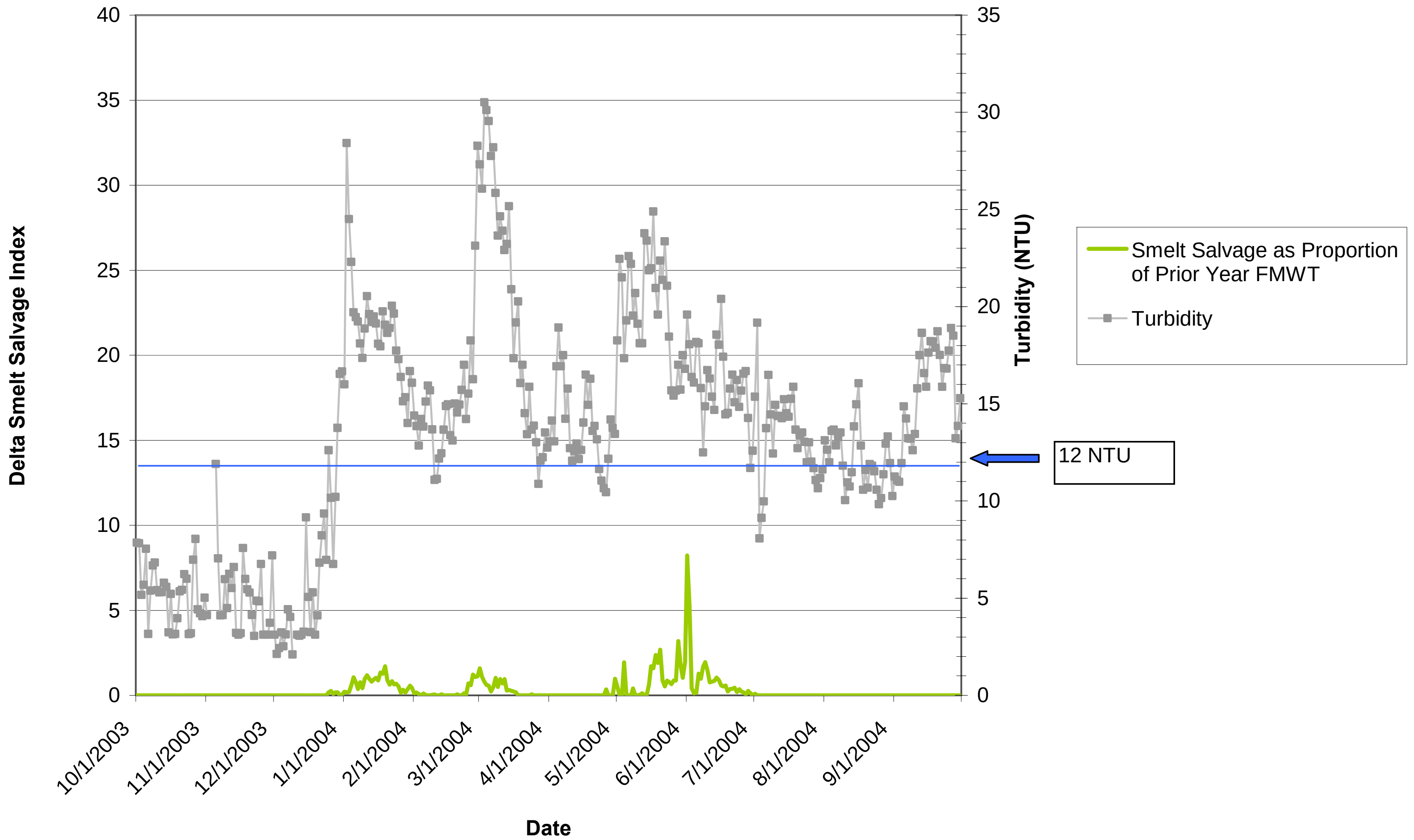


Figure B-10: 2005 WY Salvage Index

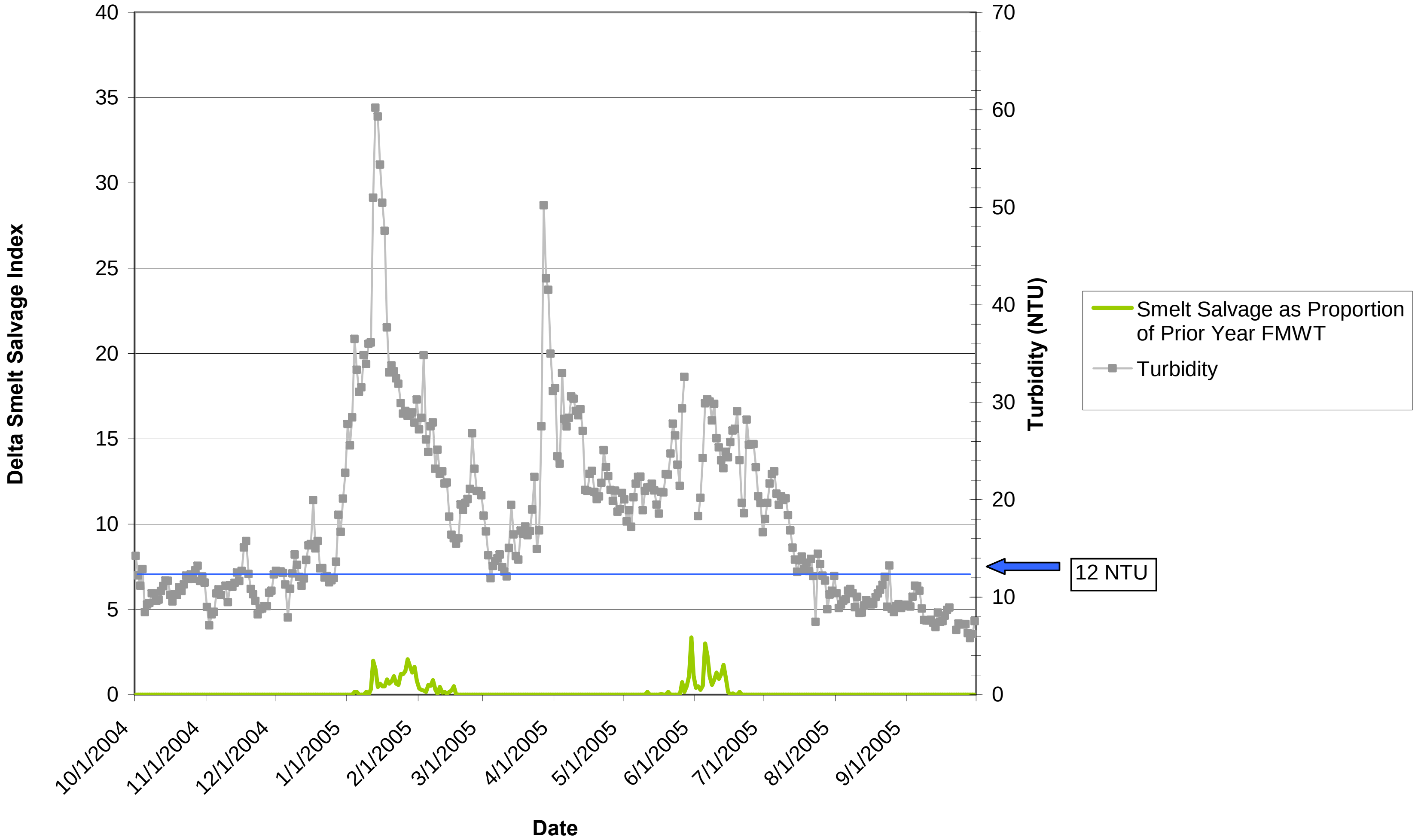
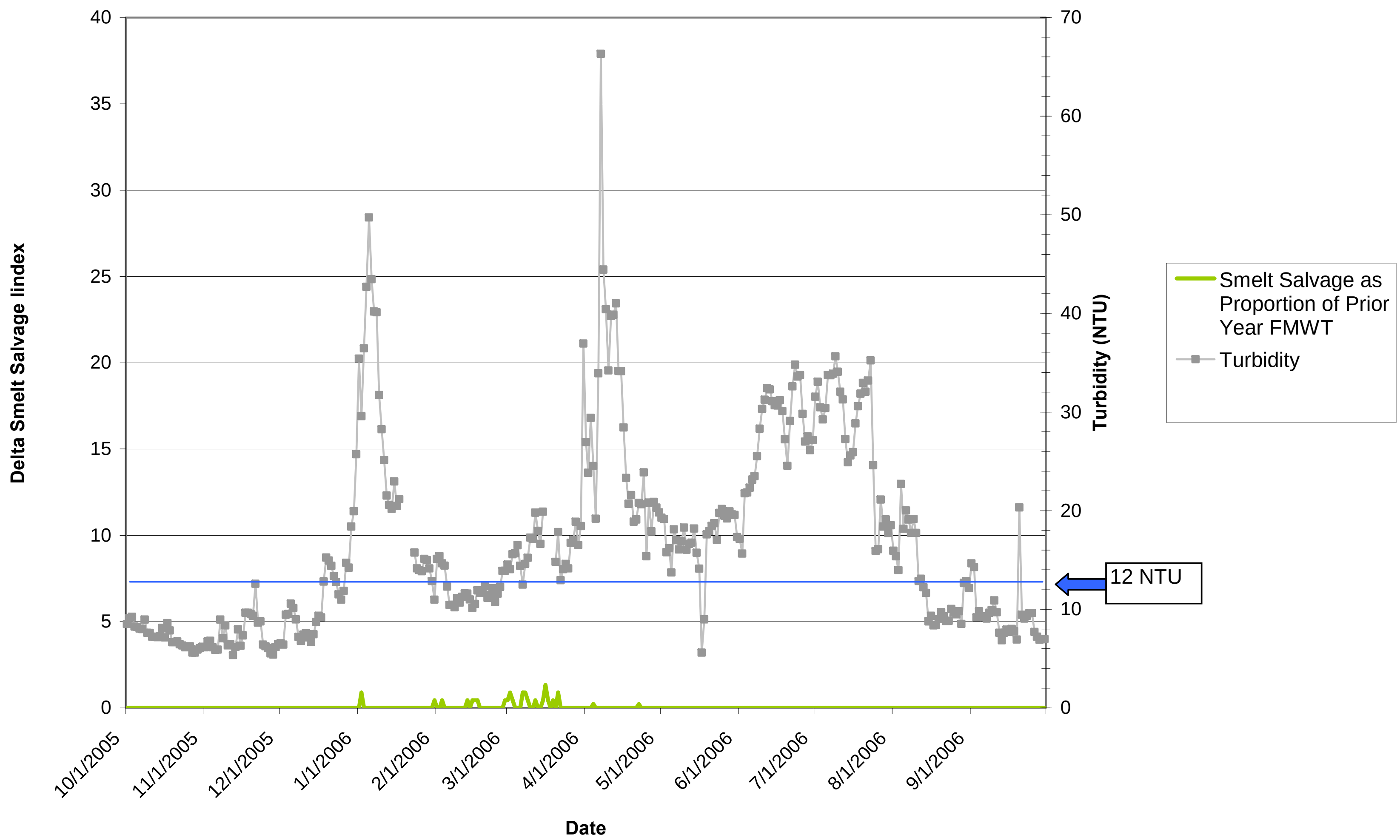


Figure B-11: 2006 WY Salvage Index



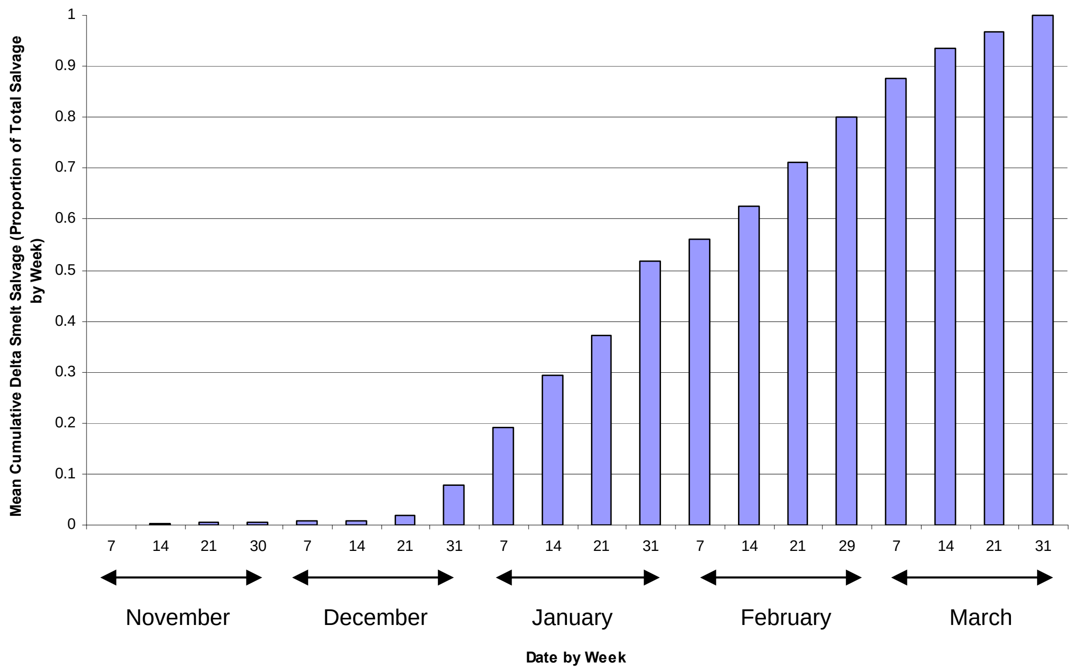
Justification for Timing of Action 1

Action 1, Part A covers the period (December 1 to December 20) when first flush salvage events were historically uncommon (Figure B-12). During this period the SWG will review conditions from week to week and may recommend to the Service that Action 1 be triggered. Part B of Action 1 (December 20 to March) covers a period when first flush salvage events have been historically more common. Part B will be triggered when turbidity increases above 12 NTU. The Service can bypass implementation of the trigger if the SWG concludes that the trigger was met by conditions (i.e., wind-induced turbidity) not likely to initiate smelt migration.

The timing of first flush salvage events is variable in any given WY. Thus, initiation of Action 1 is based on conditions (i.e., turbidity) rather than a specific month. Action 1 is therefore designed to provide flexibility and maximum protection for delta smelt. On average, about 1 percent of cumulative adult delta smelt entrainment occurs by December 21 (Figure B-12). By December 31, cumulative salvage has historically reached 3.2 percent.

Action 1 will be shifted from December 25 (as described in the Interim Remedies) to December 20 because it better reflects the period when protection will be needed. As previously mentioned, the Service will decide to initiate Action 1 before December 20 if the conditions warrant evidence smelt are migrating upstream (i.e., salvage, trawl data). Beginning in December, the SWG will review physical and biological parameters historically associated with smelt migration (i.e., precipitation, operations, turbidity, and salvage data) to make ongoing recommendations to the Service about the need to implement Action 1 at any time.

Figure B-12: Cumulative Proportional Salvage for WY 1993 to 2006 by Week



Duration of Action 1

The Interim Remedies Action 1 has been revised from ten to 14 days to incorporate coverage between spring and neap tidal cycles that may influence migration rate into the interior Delta.

Justification for the Salvage Guideline Action 1

In many years, delta smelt have been salvaged prior to when turbidity elevates above 12 NTU (Table B-2). In the case that salvage begins prior to the trigger, the decision to implement Action 1 will be based on the following: 1) magnitude of salvage scaled to the population size (Table B-2), and 2) the amplitude which represents daily salvage divided by the prior year FMWT.

The 4th column in Table B-2 lists the cumulative seasonal salvage of adult delta smelt divided by the prior year FMWT Index (the Cumulative Salvage Index). This value ranged from a minimum of 0.37 in WY 1994 to a maximum of 103 during WY 2003. The combination of peak (amplitude in the histogram or maximum daily salvage), and Cumulative Salvage Index is a general index of the magnitude of adult entrainment in a given WY.

The median value for the Cumulative Salvage Index for the years presented would be 13.3. The mean value for all years within the range presented in Table B-2 is 22.1. For peak daily salvage, the Salvage Index mean for the WY 1993 through 2005 is 1.45. The median amplitude value is 1.1. Taking these data into account, a Cumulative (seasonal) Salvage Index exceeding 7.25 appears to be indicative of an unacceptable risk threshold based on the current low numbers of delta smelt. A peak Daily Salvage Index of 1.0 is suggested as an index of daily smelt salvage at levels or maintained at existing levels that ongoing or anticipated salvage could rapidly reach unacceptable losses if exports are to increase. These values are carried forward into the prescriptions as pre-emptive triggers, and as releases from Action prescriptions to carry forward through Actions 1 and 2.

Justification for the Turbidity Criterion as a Trigger in Action 1 (Part B)

Onset of Action 1 during Part B

Turbidity associated with freshets of water is a reasonable indicator of when smelt begin to migrate upstream and become vulnerable to salvage. Though this historical trend is based on the turbidity sensor located outside the Clifton Court Forebay, there is no expectation that the relationship between increased flow and turbidity would differ from recently installed sensors identified in the Interim Remedies: Prisoners Point, Holland Cut, and Victoria Canal. It appears that the Holland Cut sensor is sensitive to localized wind conditions at times. On December 25-27, 2007, a three-day rise in turbidity at the Holland Cut monitoring station triggered Action 1. It was unlikely that a wind-associated turbidity event initiated smelt migration. Rather than rely on one of these stations to trigger Action 1 (Interim Remedies), Action 1 will be triggered when turbidities elevate over 12 NTU at all three stations. The use of three stations would better reflect a Delta-wide change in turbidity than one station which may be prone to localized conditions.

Timing and the Protectiveness of the 12 NTU criterion

If the 12 NTU threshold had been used in previous years, Action 1 would have likely provided early protection (i.e., less salvage) during most years. The degree to which it would have minimized the number of smelt entering the South Delta is unknown.

Justification for Flow Prescriptions in Action 1

Understanding the relationship between OMR flows and delta smelt salvage allows a determination of what flows will result in salvage. The OMR-Salvage analysis herein was initiated using the relationship between December to March OMR flow and salvage provided by P. Smith and provided as Figure B-13, below. Visual review of the relationship expressed in Figure B-13 indicates what appears to be a “break” in the dataset at approximately -5,000 OMR; however, the curvilinear fit to the data suggest that the break is not real and that the slope of the curve had already begun to increase by the time that OMR flows reached -5,000 cfs.

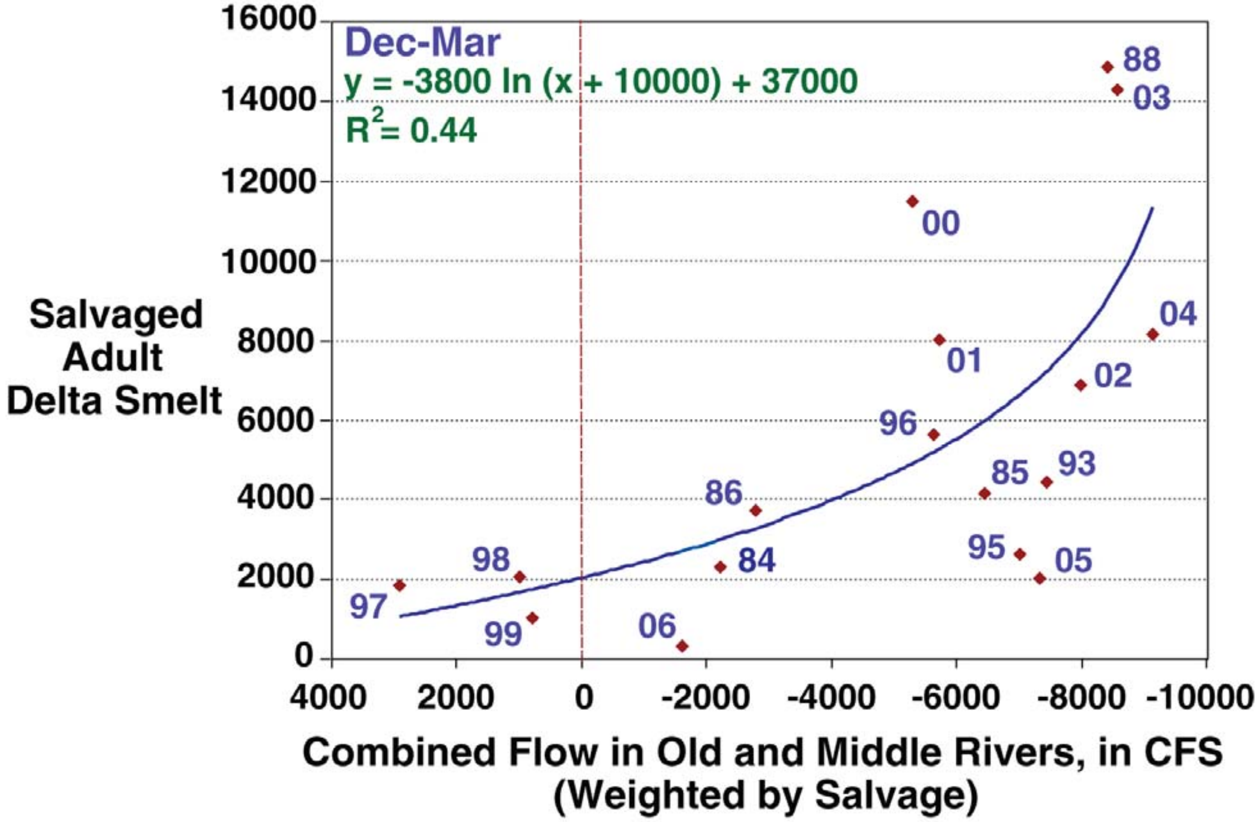


Figure B-13. OMR-Salvage relationship for adult delta smelt. (source, P. Smith). Data from this figure were the raw data used in the piecewise polynomial regression analysis.

Further, a nonlinear regression was performed on the dataset, and the resulting pseudo-R^2 value was 0.44—suggesting that although the curvilinear fit is a reasonable description of the data, other functional relationships also may be appropriate for describing the data. Fitting a different function to the data could also determine the location where salvage increased, i.e. identify the "break point" in the relationship between salvage and OMR flows. Consequently, an analysis was performed to determine if the apparent break at -5,000 cfs OMR was real. A piecewise polynomial regression, sometimes referred to as a multiphase model, was used to establish the change (break) point in the dataset.

A piecewise polynomial regression analysis with a linear-linear fit was performed using data from 1985 to 2006. The linear-linear fit was selected because it was the analysis that required the fewest parameters to be estimated relative to the amount of variation in the salvage data. Piecewise polynomial regressions were performed using Number Cruncher Statistical Systems (© Hintz, J., NCSS and PASS, Number Cruncher Statistical Systems, Kaysville UT).

The piecewise polynomial regression analysis resulted in a change point of -1162, i.e. at -1162 cfs OMR, the slope changed from 0 to positive (Figure B-14). These results indicate that there is a relatively constant amount of salvage at all flows more positive than -1162 cfs but that at flows more negative than -1162, salvage increases. The pseudo-R^2 value was 0.42, a value similar to that obtained by P. Smith in the original analysis.

To verify that there was no natural break at any other point, the analysis was performed using a linear-linear-linear fit (fitting two change points). The linear-linear-linear fit resulted in two change points, -1,500 cfs OMR and -2,930 cfs OMR. The -1,500 cfs value is again the location in the dataset at which the slope changes from 0 to positive. The pseudo-R^2 value is 0.42 indicating that this relationship is not a better description of the data. Because of the additional parameters estimated for the model, it was determined that the linear-linear-linear fit was not the best function to fit the data, and it was rejected. No formal AIC analysis was performed because of the obvious outcome.

A major assumption of this analysis is that as the population of Delta smelt declined, the number of fish at risk of entrainment remained constant. If the number of fish in the vicinity of the pumps declined, fewer fish would be entrained and more negative OMR flows would result in lower salvage. This situation would result in an overestimate, i.e. the change point would be more positive. In fact, if the residuals are examined for the relationship in Figure B-13 above, the salvage for the POD years 2002, 2004, 2005, and 2006 are all below the line. 2003 is above the line although the line is not extended to the points at the top of the figure, and these data points occur when the curve becomes almost vertical. The negative residuals could be a result of a smaller population size available for entrainment and salvage. This could be verified by normalizing the salvage data by the estimated population size based on the FMWT data.

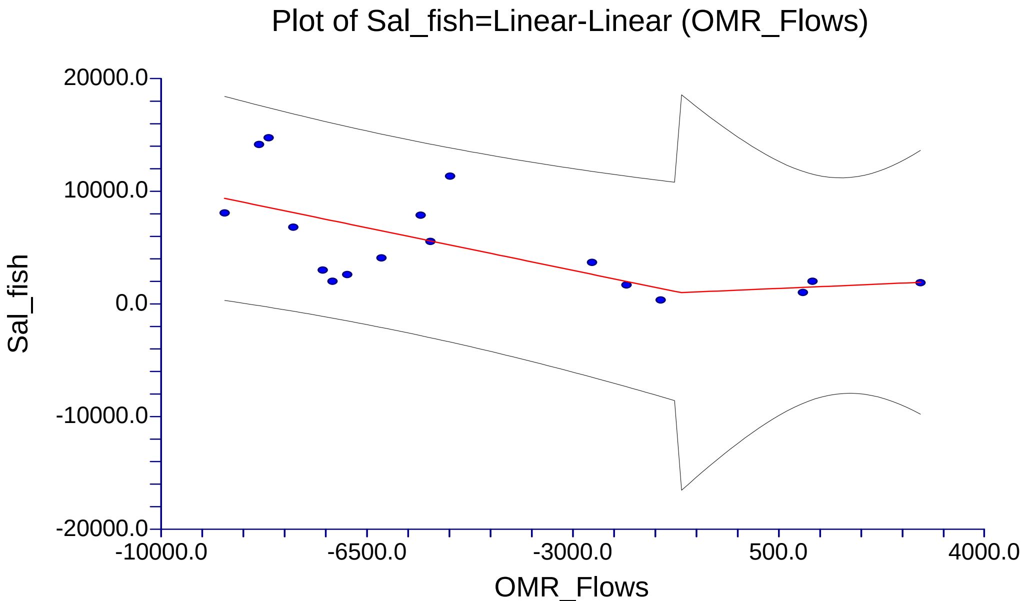


Figure B-14. Piecewise polynomial regression of OMR flows and salvage. The change point is the location at which the two regression lines meet; -1,162 cfs OMR.

The original values of OMR and salvage could have been measured with error due to a number of causes, consequently the values used in the original piecewise polynomial analysis could be slightly different than the "true" values of salvage and OMR flow. Consequently, a second analysis was undertaken to examine the effect of adding stochastic variation to the OMR and salvage values in the piecewise polynomial regression analysis. The correlation between OMR and salvage in the original dataset was -0.61 indicating that the more negative the OMR, the greater the salvage. Consequently, it was necessary to maintain the original covariance structure of the data when adding the error terms and performing the regressions. The original covariance structure of the OMR–salvage data was maintained by adding a random error term to both parameters. The random error term was added to OMR and a correlated error term was added to salvage. The expected value of the correlated errors was -0.61.

The error terms were selected from a normal distribution with a mean of 1.0 and a standard deviation of 0.25 which provided reasonable variability in the original data. Operationally this process generated a normal distribution of OMR and salvage values in which the mean of the distributions were the original data points. Additional analyses were performed with standard deviations of 0.075, 0.025, and 0.125. Smaller standard deviations in the error term resulted in estimates of the change point nearer to the original estimate of -1,162 cfs. This is to be expected as the narrower the distribution of error terms, the more likely the randomly selected values would be close to the mean of the distribution. The process was repeated one hundred times, each time a new dataset was generated and a new piecewise polynomial regression was performed. The software package @Risk (© Palisade Decision Tools) was used to perform the Monte Carlo simulations. Latin hypercube sampling was used to insure that the distributions of OMR and salvage values were sampled from across their full distributions. The parameter of interest in the simulations was the change point, the value of the OMR flow at which the amount of salvage began to increase. Incorporating uncertainty into the analysis moved the change point to -1,800 cfs OMR, indicating that at flows above -1683, the baseline level of salvage occurred but with flows more negative than -1683, salvage increased.

Justification for Release from Prescriptions of Action 1

Temperature

The Interim Remedies prescribed regulatory release from Action 1 once mean water temperatures at Rio Vista, Antioch, and Mossdale Stations reaches 12^{O}C. This metric is used as a surrogate to indicate time when spawning is likely to have begun based on physiological preferences.

Biological Conditions

The Interim Remedies prescribed regulatory release from Action 1 once spent females are detected in the SKT or at the salvage facilities.

Changing the Timing of the Action

If the SWG recommends a delayed start or interruption to Action 1 based on variations in conditions which may affect vulnerability to entrainment (e.g., no observed salvage and a rapid reduction in turbidity after the first week of Action 1), the Service will weigh such information and make a final determination on protective OMR flow requirements.

ACTION 2: ADULT MIGRATION AND ENTRAINMENT

Objective: An action implemented using an adaptive process to tailor protection to changing environmental conditions after Action 1. As in Action 1, the intent is to protect pre-spawning adults from entrainment and, to the extent possible, from adverse hydrodynamic conditions.

Action: The range of net daily OMR flows will be no more negative than -1,250 to -5,000 cfs. Depending on extant conditions (and the general guidelines below) specific OMR flows within this range are recommended by the SWG from the onset of Action 2 through its termination (see Adaptive Process in Introduction). The SWG would provide weekly recommendations based upon review of the sampling data, from real-time salvage data at the CVP and SWP, and utilizing most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity. The Service will make the final determination.

Timing: Beginning immediately after Action 1. Before this date (in time for operators to implement the flow requirement) the SWG will recommend specific requirement OMR flows based on salvage and on physical and biological data on an ongoing basis. If Action 1 is not implemented, the SWG may recommend a start date for the implementation of Action 2 to protect adult delta smelt.

Suspension of Action:

Flow: OMR flow requirements do not apply whenever a three day flow average is greater than or equal to 90,000 cfs in Sacramento River at Rio Vista and 10,000 cfs in San Joaquin River at Vernalis. Once such flows have abated, the OMR flow requirements of the Action are again in place.

Off-ramps:

Temperature: Water temperature reaches 12°C based on a three station daily average (Rio Vista, Antioch, Mossdale)

OR

Biological: Onset of spawning (presence of spent females in SKT or at either facility)

Adaptive Process Required Parameters:

Two scenarios span the range of circumstances likely to exist during Action 2. First, the low-entrainment risk scenario. There may be a low risk of adult entrainment because (a) there has been no discernable migration of adults into the South and Central Delta (b) the upstream migration has already occurred but turbidity is low and there is no or little evidence of ongoing adult entrainment. In this scenario, higher negative OMR flow rates as high as -5,000 cfs may be ventured as long as entrainment risk factors and salvage permit.

The second scenario, the high-entrainment risk scenario, is one in which either (a) there is evidence that upstream adult migration is currently occurring, or (b) upstream migration has already occurred and there are adult fish in the South and Central Delta and turbidity is high, increasing the risk of entrainment, or (c) there is evidence of ongoing entrainment, regardless of other risk factors. In this case, OMR flow will be set to reduce entrainment and/or the risk of entrainment as the totality of circumstances warrant.

Generally, if the available distributional information suggests that most of the delta smelt are in the North or North/Central Delta, then OMR flow can be chosen to minimize Central Delta entrainment. However, if the distributional information suggests there are delta smelt in the Central or South Delta, then OMR flow will have to be set lower to reduce entrainment of delta smelt.

The following two paragraphs describe how these action guidelines would be implemented at the start of Action 2 and at other times during Action 2.

1. OMR flow setting at initiation of Action 2

a) If salvage is zero during the final 7 days of Action 1, and three-station mean turbidity is below 15 NTU, then increase negative OMR flow to no more negative than -5,000 cfs on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable required OMR flow[8]; *UNLESS*

b) If salvage is less in the most recent three days than in the preceding three days of Action 1, and the maximum Daily Salvage Index is ≤1 during the prior 7 days, then limit exports to achieve OMR flows no

[8] Both the 14-day and the 5-day running averages will be computed using the "tidally filtered" daily average OMR flows reported by USGS.

more negative than -3,500 cfs on a 14-day running average for 7 days (or until 4 consecutive days of zero salvage or any 5 of 7 days with zero salvage), with a 5-day running average within 25 percent of the applicable required OMR flow; *OR*

c) If salvage is greater or equal in the last three days than in the preceding three days of Action 1, and maximum Daily Salvage Index ≥1 during any of those days, then continue OMR flow at no more negative than -2,000 cfs on a 14-day running average for an additional 7 days (or until 4 succeeding days of zero salvage or any 5 of 7 days zero salvage), with a simultaneous 5-day running average within 25 percent of the applicable requirement OMR; *OR*

d) If circumstances existing at the initiation of Action 2 are, in the judgment of the Service, markedly different from those anticipated in (a) through (c) above, then the OMR flow requirement in (c) will be applied and the SWG will review available data and recommend an initial flow rate to the Service.

2. OMR flow setting after initiation of Action 2

a) The SWG will review all available information and request updated entrainment simulations and/or other information, as needed, on a weekly basis to decide whether the current OMR flow requirement is appropriate or should be changed.

b) Unless OMR flow is grossly positive regardless of water project operations, due to high Delta inflows, then important variables that affect the risk of adult entrainment during Action 2 include (1) salvage or other actual entrainment indicators, (2) turbidity, (3) available monitoring results, hydrologic variables other than export pumping rates that affect OMR flow, (4) apparent population size from the preceding FMWT survey, and (5) particle tracking or other model-based entrainment risk information.

c) As described above, the risk of entrainment is generally higher when there is evidence of ongoing entrainment or turbidity is high, and these two variables are the most likely triggers of decisions to raise or lower OMR flow requirements.

d) Based on historical experience, OMR flow requirements between the limits of -2,000 cfs and -5,000 cfs are likely to be adequate in most years. The exception is years in which there appears, for whatever reasons, to be a substantial fraction of the adult spawning migrant population in the Central and/or South Delta. When this occurs, more stringent OMR limitation (possibly to no more negative than -1,250 cfs) may be required.

Background

Action 2 reflects the period when OMR prescriptions for pre-spawning adult delta smelt are still required to protect parental stock prior to reproduction, however such controls may generally be relaxed because the main pulse of fish migration has occurred and adults are holding more tightly to their selected spawning areas. Action 2 may also be needed to extend protections consistent with Action 1 in years of longer spawning migration periods or changing environmental conditions. Conditions are highly variable in any given year. Rather than provide a prescription that is protective under all circumstances, an adaptive process based on the guidelines outlined herein is warranted. This process can most efficiently and effectively provide protections utilizing analysis of all available data and seasonal conditions.

The OMR flow prescriptions set forth during Action 2 will be based upon analysis of population status in any given year, available monitoring data from the SKT, seasonal variables such as WY type, CVP and SWP reservoir storage levels, temperature, and observed salvage during Action 1. Of these, population status and real-time salvage data are expected to be the primary driving criterion.

Justification for Guidelines in Setting Prescriptions of Action 2

The SWG will apply the following criteria to set the flow prescriptions during Action 2, to be operational until the onset of Action 3.

Zero Salvage or Extended Salvage Index of Low Amplitude

a) If salvage is zero during the final 7 days of Action 1, then increase negative OMR to no more negative than -5,000 cfs on a 14-day running average, with a simultaneous 5-day running average within 25 percent of the applicable requirement OMR; *OR*

Decreasing Salvage or Salvage Index with Low Amplitude

b) If salvage is less in the last three days than in the preceding three days and the maximum daily salvage index is ≤1 during the prior 7 days, then limit exports to achieve OMR flows no more negative than -4,000 cfs on a 14-day running average for 7 more days with average OMR for the period within 25 percent of the requirement (or until 4 succeeding days of zero salvage or any 5 of 7 days zero salvage); *OR*

Rising Salvage or Salvage Index with High Amplitude

c) If salvage is greater or equal in the last three days than in the preceding three days, and maximum daily salvage index ≥1 during any of those days, then continue OMR flow at no more negative than -2000 cfs on a 14-day running average for an additional 7 days (or until 4 succeeding days of zero salvage or any

5 of 7 days zero salvage), with a simultaneous 5-day running average within 25 percent of the applicable OMR requirement.

Flow requirements will be monitored in real-time utilizing salvage data as a check on performance of the Service-recommended requirements, consistent with the objectives and numerical requirements established in the take statement (Attachment C).

Flow requirements defined within Action 2 follow the same protectiveness criterion established during Action 1, as adjusted to reflect real-time conditions and predicted entrainment risk relative to the anticipated distribution and abundance of year-class delta smelt; and reflecting their behavioral propensity to hold in their chosen spawning habitat. These are allowed to vary based upon assessment of available data as described in the adaptive process described in the Introductions to Actions section above.

Justification for Release from Prescriptions of Action 2

Flow

The Interim Remedies provided release from the prescription of Action 2 when the three day average Sacramento River flow at Freeport is greater than 80,000 cfs.
During WY 1982 and 1995, salvage was observed during periods when Sacramento River flows exceeded this criterion. During 1995, Sacramento River flows at Freeport exceeded 90,000 cfs while San Joaquin River flows approximated 5,000 cfs—salvage still occurred. This data suggests that adult delta smelt can still navigate the channels upstream at these flows. During 1997 and 1998, low salvage was observed while flows within both the Sacramento and San Joaquin rivers were high. For these reasons, it was determined that the offramp for prescriptions in Actions 1 and 2 should be Sacramento River flows at *Rio Vista* exceeding a three-day average of *90,000* cfs *and* San Joaquin River flows at Vernalis exceeding 10,000 cfs. Based on historic observations, it is predicted that salvage under these flow conditions will be minimal.

Temperature

The Interim Remedies prescribed regulatory release from Action 1 once mean water temperatures at Rio Vista, Antioch, and Mossdale Stations reaches 12^{O}C. This metric is used as a surrogate to indicate time when spawning is likely to have begun based on physiological preferences.

Biological Conditions

The Interim Remedies prescribed regulatory release from Action 1 once spent females are detected in the SKT or at the salvage facilities.

ACTION 3: ENTRAINMENT PROTECTION OF LARVAL SMELT

Objective: Minimize the number of larval delta smelt entrained at the facilities by managing the hydrodynamics in the Central Delta flow levels pumping rates spanning a time sufficient for protection of larval delta smelt, e.g., by using a VAMP-like action. Because protective OMR flow requirements vary over time (especially between years), the action is adaptive and flexible within appropriate constraints.

Action: Net daily OMR flow will be no more negative than -1,250 to -5,000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR.[9] Depending on extant conditions (and the general guidelines below) specific OMR flows within this range are recommended by the SWG from the onset of Action 3 through its termination (see adaptive process in Introduction).[10] The SWG would provide these recommendations based upon weekly review of sampling data, from real-time salvage data at the CVP/SWP, and expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity. The Service will make the final determination.

Timing: Initiate the action after reaching the triggers below, which are indicative of spawning activity and the probable presence of larval delta smelt in the South and Central Delta. Based upon daily salvage data, the SWG may recommend an earlier start to Action 3. The Service will make the final determination.

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[9] Both the 14-day and the 5-day running averages will be computed using the "tidally filtered" daily average OMR flows reported by USGS.

[10] During most conditions, it is expected that maximum negative OMR flows will range between -2000 and -3500. During certain years of higher or lower predicted entrainment risk, requirements as low as -1,250 or -5,000 will be recommended to the Service by the SWG.

Triggers:

Temperature: When temperature reaches 12°C based on a three station average at Mossdale, Antioch, and Rio Vista.

OR

Biological: Onset of spawning (presence of spent females in SKT or at either facility).

Offramps:

Temporal: June 30;

OR

Temperature: Water temperature reaches a daily average of 25°C for three consecutive days at Clifton Court Forebay.

Adaptive Process Required Parameters:

During the larval/juvenile entrainment risk period, the SWG will meet weekly to review available physical and biological data and develop a recommendation to the Service. The Service will determine the specific OMR requirement based upon the SWG recommendation and the strength of the accompanying scientific justification.

Two scenarios span the range of circumstances likely to exist during Action 3. First, the low-entrainment risk scenario. There may be a low risk of larval/juvenile entrainment because there has been no evidence of delta smelt in the South and Central Delta or larval delta smelt are not yet susceptible to entrainment. In this scenario, negative OMR flow rates as high as -5,000 cfs may occur as long as entrainment risk factors permit.

The second scenario, the high-entrainment risk scenario, is one in which either (a) there is evidence of delta smelt in the South and Central Delta from the SKT and/or 20mm survey, or (b) there is evidence of ongoing entrainment, regardless of other risk factors. In this case, OMR should be set to reduce entrainment and/or the risk of entrainment as the totality of circumstances warrant.

Usually, if the available distributional information suggests that most delta smelt are in the North or North/Central Delta, then OMR flow can be chosen to minimize Central Delta entrainment. However, if the distributional information suggests there are delta smelt in the Central or South Delta, then OMR flows will have to be set lower to reduce entrainment of these fish. If delta smelt abundance is low, distribution cannot be reliably inferred. Therefore, the adaptive process is extremely important. The SWG may recommend any specific OMR flow within the specified range above.

Action 3 is initiated when temperature reaches 12^{o}C based on a three station average at Mossdale, Antioch, and Rio Vista, or when spent females or larva are detected;

a) Once larvae are likely to become vulnerable to entrainment, set OMR flows to no more negative than -2,000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR;[11]

b) The SWG will use available physical and biological real-time monitoring data to decide whether a large fraction of the delta smelt population is in the Central Delta and therefore at risk of entrainment. If a large portion of the delta smelt population appears to be in the Central Delta, OMR flows would likely be set to no more negative than -1,250 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR; [6]

c) The SWG will use available physical and biological real-time monitoring data to decide whether the delta smelt population is at a lesser entrainment risk. In this circumstance, OMR flows would likely be set to no more negative than -3,500 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR;[6]

d) The SWG will use available physical and biological real-time monitoring data to decide whether the delta smelt population is at a low entrainment risk. In this circumstance, OMR flows to no more negative than -5,000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR;[6]

e) If circumstances existing at the initiation of Action 3 are, in the judgment of the Service, markedly different from those anticipated in (a) through (d) above, then the OMR flow prescription will be set to entrain no more than 1 percent of the particle entrainment at Station 815 (approximately no more than 10 percent of the cumulative population).

[11] Both the 14-day and the 5-day running averages will be computed using the "tidally filtered" daily average OMR flows reported by USGS.

Background

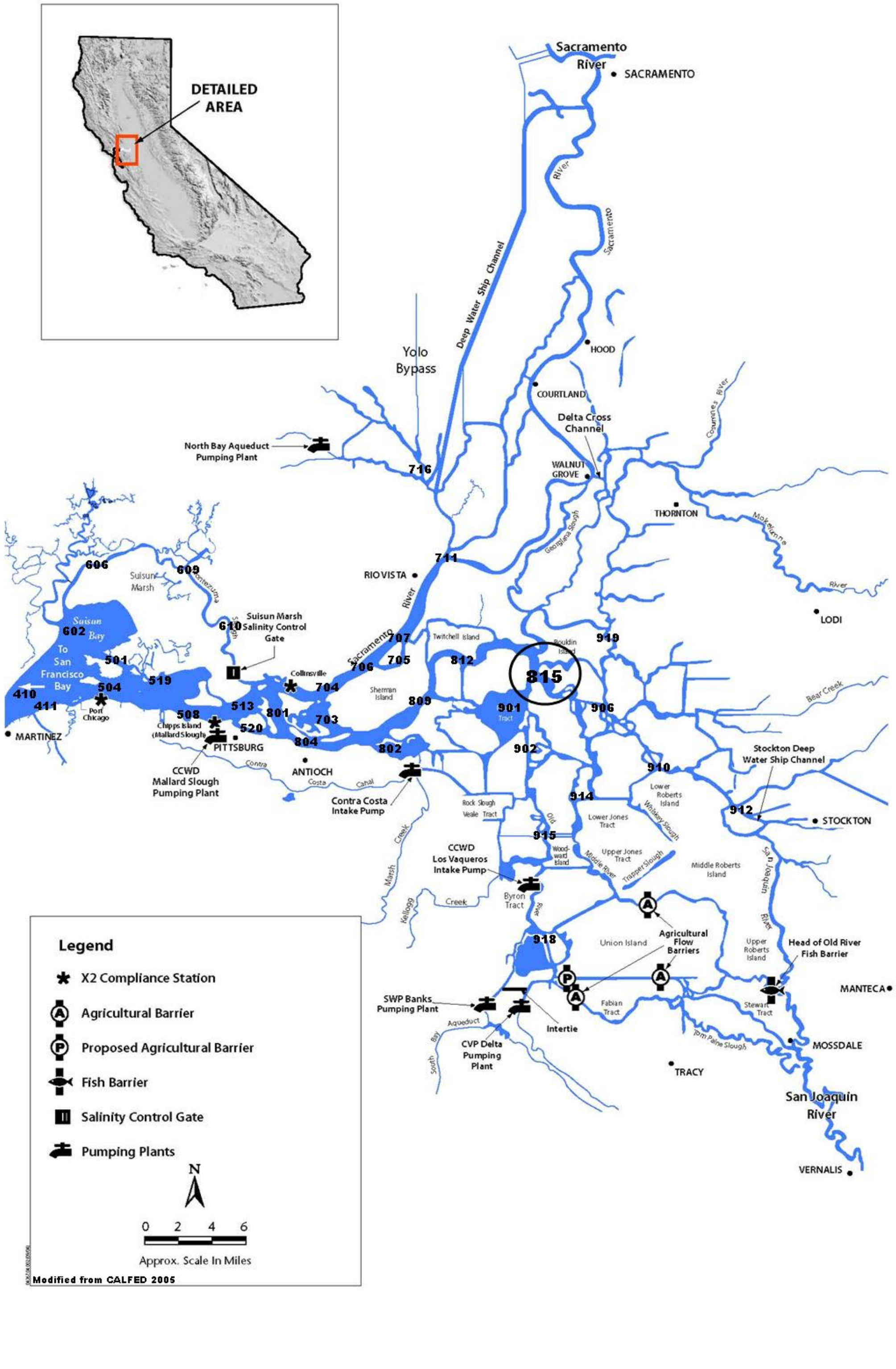
Action 3 is intended to minimize the entrainment of larval/juvenile delta smelt in the Central and South Delta. When the distribution of delta smelt is in the North or North/Central Delta, this will generally be accomplished by holding entrainment to ~1 percent of the individuals utilizing the Central and South Delta (south and east [upstream] of Station 815, see Map 2) across a 14-day particle modeling interval. Preserving larvae and juveniles that are in the Central Delta, or might be in the Central Delta in circumstances where it is difficult to ascertain the distribution of the fish, is critical to ensuring year-to-year stock-recruitment of the population and minimize the risk of localized disturbances that might adversely affect the North Delta.

In circumstances where it is known or suspected that the Central Delta or South Delta is a principal source of emerging larvae, as occurred in WY 2003, OMR restrictions might be calculated using reduction of 14-day Station 815 entrainment below 1 percent, or other methods as needed to ensure protection of the larval population in conditions of such severe vulnerability. The Action utilizes OMR restrictions to achieve the desired end, as OMR flow is a strong predictor of geographical variation in entrainment risk in the Central and North Delta. The OMR flows associated with the protectiveness criteria defined above have been derived from particle tracking modeling with the input assumptions defined below.

These protections are directly tied to presence of vulnerable larval and juvenile delta smelt within the zone of entrainment of Banks and Jones. Therefore, Action 3 must commence no later than the time when larvae are likely to become vulnerable to entrainment.

Data presented in the Effects section of this biological opinion support the conclusion that flow conditions during the VAMP (during the years in which they have been in effect) have been instrumental in protecting delta smelt progeny. Examination of the OMR flow records shows that the combination of increased San Joaquin River flows and reduced pumping during the VAMP generally resulted in OMR flows of approximately -2,000 cfs (Figure B-15).

Protection from entrainment for larval and juvenile delta smelt will be achieved using OMR prescriptions generally ranging between -2,000 to -3,500 cfs on a 14-day running average with a simultaneous 5-day average not more negative by more than 25 percent of the current OMR flow requirement. However, during certain years of unusual smelt distribution (while predicted or measured larval/juvenile delta smelt distribution are in close proximity to the zone of entrainment), maximum negative OMR flows may for a time be set as low as -1,250 cfs. Overall, the OMR flow may be set anywhere between -1,250 to -5,000 cfs on a 14-day running average with a simultaneous 5-day average (from actual daily OMR values) not more negative than the required OMR by more than 25 percent.



Map 2 Biological Monitoring Stations in the Delta

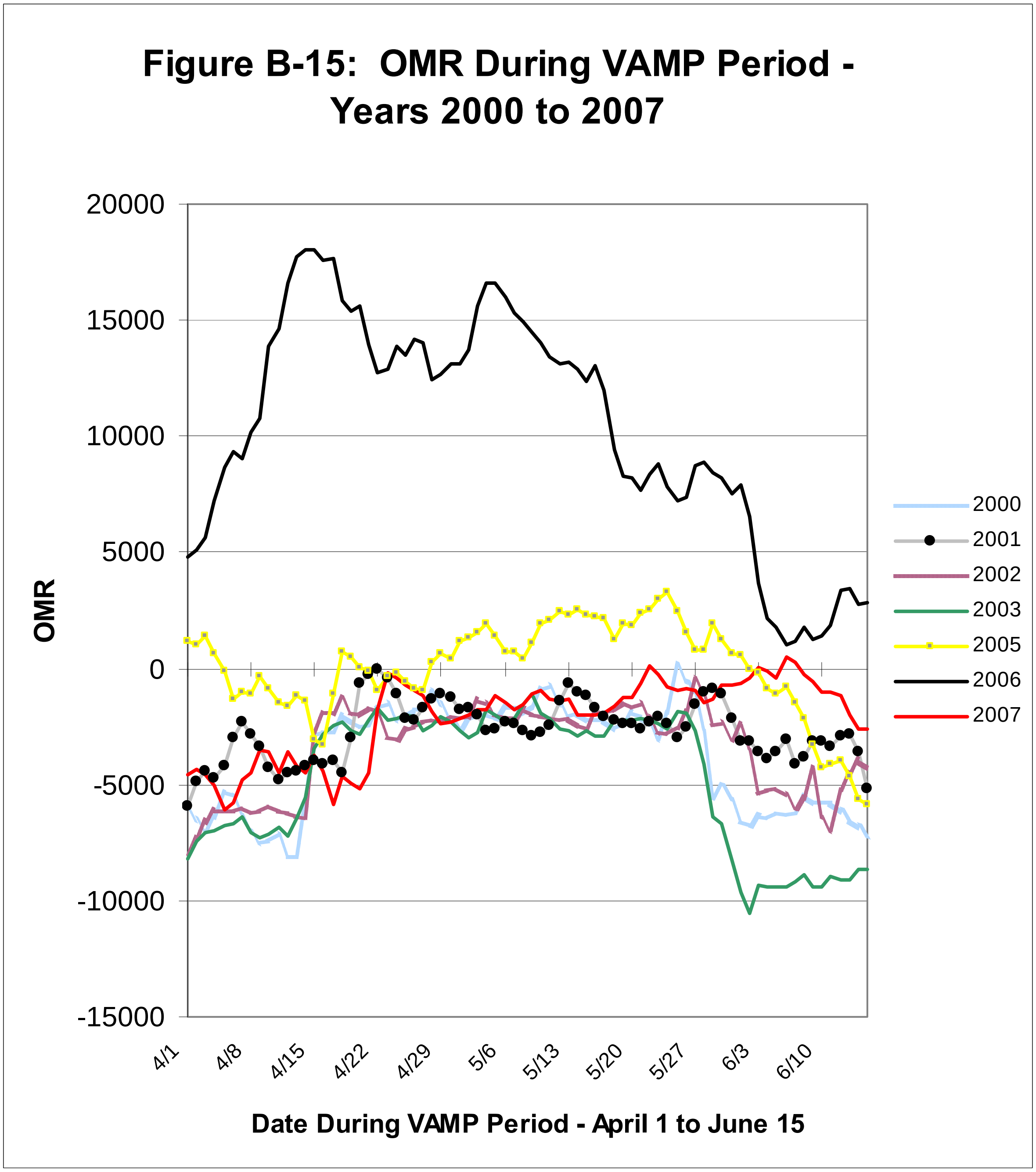


Figure B-15. OMR flows across VAMP period (usually April 15-May 15). Note that although exact VAMP conditions vary across years, the period is easily identified by OMR flows no more negative than -2000 cfs.

The following examples provide the insight on when exceptions to the ranges of OMR flows above would be used. In high risk years, when delta smelt are in the South Delta, suggesting that delta smelt are particularly sensitive to entrainment (as for example in 2003), a stricter limit on OMR flow of -1,250 cfs would be necessary to meet the defined protectiveness criterion. Alternatively, in years when sampling indicates that it appears that most adults have spawned in the Cache Slough complex and larvae may be at reduced risk of entrainment, an OMR flow of about -3,500 cfs may be possible while still meeting the protectiveness criterion. Later in the season, as more juvenile delta smelt are found seaward and while physical conditions in the Delta become less conducive to smelt larvae, OMR flow requirements could relax further. Once conditions in the Delta are inconsistent with smelt survival (i.e. South Delta waters are too warm), the larval protections of Action 3 cease.

Justification for Timing of Action 3

The window for delta smelt spawning generally begins during February, but is variable based on seasonal conditions of flow, temperature, and physiological condition of the current year spawning cohort. Further, low adult abundances make it very difficult to discern adult spawning distribution using current monitoring methods. Lastly, protective and successful flow restrictions during the winter may reduce the discriminatory power of salvage itself as an indicator of the distribution of spawning smelt and timing to initiate Action 3.

For these reasons, it is believed that an adaptive approach using recommendations from the SWG in real-time is preferred to protective prescriptions that are applied regardless of variation or nuance in actual conditions. By monitoring a combination of these factors, along with tracking of important parameters in real time that are indicative of smelt presence and the timing of smelt spawning activity, the SWG is best situated to judge when OMR actions should be initiated or adjusted in Action 3.

During Action 3 (generally March through June 30), the SWG will recommend OMR flows to the Service. These will be based upon the best-available predictive capacity of the experts within the group given available data in real-time, and will be protective of larval/juvenile delta smelt to the criteria defined above.

Justification for Different OMR Requirements of Action 3

Analysis of the birth dates of delta smelt collected from the Summer Townet Survey (Bennett 2008) indicates that in 2005 the delta smelt found in the summer were almost entirely born during the VAMP period. Collection of spawned adults suggests that larvae were produced throughout much of the February-May period, but only the late produced young survived. Thus, we have determined that managing the hydrodynamics of the Central Delta, e.g., by providing VAMP-like conditions throughout Action 3 will be beneficial to larval and juvenile delta smelt. During most year types, these OMR requirements will range between -2,000 to -3,500 cfs.

If sampling, salvage, or any applicable and available information suggests that delta smelt are at high risk in the Central or South Delta, then the OMR will need to be as low as a 14-day running average of -1,250 cfs. If for example, based on the sampling, minimal to no salvage at the export facilities, increase in temperature, decreases in turbidity or higher

San Joaquin River inflows suggest that delta smelt larvae are at lower risk in the South and Central Delta then flows may be held to no more negative than -3,500 cfs. As temperatures rise, trawl data continue to show no fish in the Central and South Delta, and salvage does not occur, OMR flows will be allowed to become as negative as -5,000 cfs. When temperature rises and turbidity drops to levels likely to be inimical to delta smelt (> 25^{o}C, turbidity <12 NTU), no further restrictions are needed as long as salvage remains at or close to zero.

The Influence-Exposure-Intensity-Response (IEIR) Analysis

On December 13, 2007, the Service requested the SWG to formulate a process to determine protective OMR flow recommendations for delta smelt larvae during the spring. The SWG agreed that a strict decision-tree approach was imprudent because it would be inflexible to real-time conditions. In such circumstances, where dynamic and interacting parameters determine delta smelt risk, static prescriptions tend to be imperfect moderators of such risk.

The process that has been developed is called "influence-exposure-intensity-response analysis" (IEIR Analysis). It involves four steps:

1) Particle tracking modeling of current and/or projected Delta conditions describes Banks and Jones' relevant hydrological influence at different flow rates.

2) Risk exposure of smelt larvae is determined by comparing Banks and Jones' relevant hydrological influence from the PTM results with current knowledge of smelt distribution using real-time data from surveys and salvage.

3) PTM runs are used to predict the probability of delta smelt entrainment at several OMR flow limits using "particle injection" points corresponding to 20mm survey sampling stations.

4) OMR flow recommendations are developed to reduce the projected entrainment risk to the extant delta smelt population, as estimated by the prior-year FMWT Index.

The levels of concern expressed through this analytical real-time adaptive approach have been classified into three categories: High Concern, Medium Concern and Less Concern. These correspond generally to the following realized values of key physical, operational, and biological parameters, and were applied in 2008 such as:

Factor	State
• Prior Year FMWT	<40 = High Concern; >300 = Less Concern
• Salvage	high numbers = high concern; low numbers = less concern
• Distribution	south = high concern; north/northwest = less concern
• X2 Location	>80 km = high concern; <75 km = less concern

- Temperature 12^{o}C to 25^{o}C = high concern; >25^{o}C = less concern

These five factors were chosen based on the following:

1. Size of spawning population: A low FMWT index indicates low abundance of potential spawners which makes population growth rate more sensitive to loss of individuals.

2. Salvage: Salvage of delta smelt indicates that larvae and juveniles are located in the Central and South Delta and are vulnerable to entrainment. Future entrainment becomes more demographically significant as cumulative entrainment numbers increase.

3. Fish Distribution: The hydrodynamic influence of Banks and Jones increases when larvae are closer to the intakes. Thus, smelt located in the Central and South Delta are exposed to greater intensity of entrainment risk than those located in the North or West Delta.

4. X2 Location: Estimating the distribution of larval smelt and their exposure to pumping effects from existing survey data includes high inherent uncertainty, with increasing magnitude at low population abundances. However, the majority of smelt larvae and juveniles are often located just inland of X2, and so an easterly X2 would indicate that the smelt are at greater risk of entrainment at Banks and Jones

5. Water Temperature: Laboratory studies of delta smelt temperature tolerance has shown increased mortality at temperatures exceeding 25^{o}C. An average south Delta water temperature of 25^{o}C corresponds in most years to a distribution of delta smelt juveniles towards Suisun Bay, and out of the zone of entrainment risk. Most delta smelt remaining in the San Joaquin River portion of the Delta are not expected to survive as water temperatures increase above 25^{o}C, so their loss at salvage will not affect recruitment success.

The balance of conditions relative to level of concern within the IEIR analysis determines the foundation upon which a final flow recommendation may be based.

Application of IEIR Analysis: Further Guidelines for the Adaptive Process

In light of the experience in 2008, the IEIR is adjusted to make the following amendments.

As before, the SWG will evaluate data from the 20-mm survey and other parameters and make recommendations for specific timing of the more protective levels of OMR flows based upon real-time assessment of entrainment risk of larval smelt based upon their proximity to Banks and Jones, forecast operations, and particle tracking modeling run results based on a control-point method using a protectiveness criterion of 1 percent per 14-day time interval salvage threshold at Station 815.

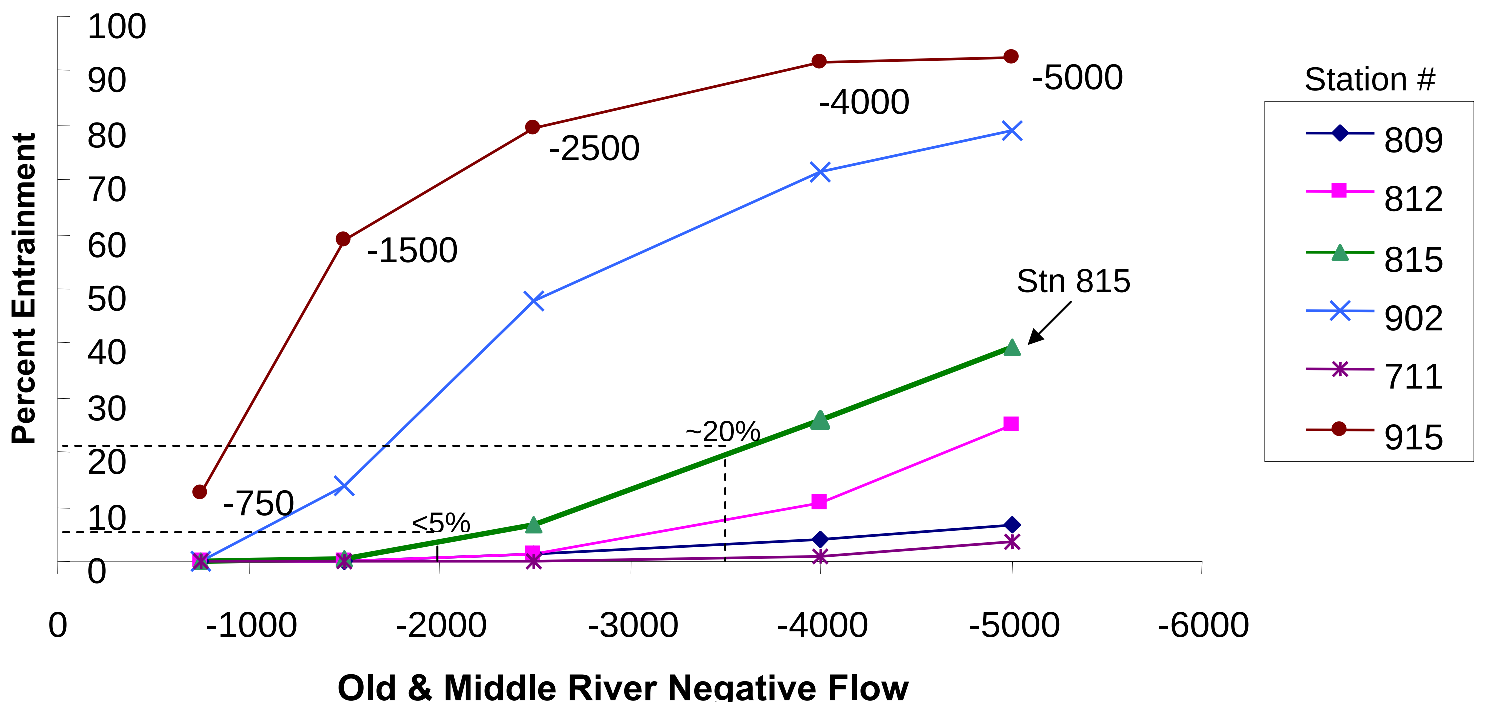
The SWG may recommend using the less stringent level of OMR restriction based on an average Recovery Index (RI) from the preceding two years exceeding 84 (the minimum for a recovery period in the Delta Native Fishes Recovery Plan, Service 1995); however, low San Joaquin River inflows, high cross-Delta flows or other conditions that degrade larval habitat in the Central Delta could preclude such relaxations. During periods of intermediate concern (recovery indices from the preceding year in excess of 239), a reduction to a shorter period of restriction to the -2000 cfs level in the larval period may be supported, if the SWG determines that a large part of the larval population would not be put at risk.

The most efficient protective measure for protecting the resilience and not precluding the recovery of the delta smelt population specific to the larval/juvenile lifestage is to prevent entrainment of fish in as large a portion of the Central Delta as is practical. Results of PTM modeling focusing on protections at station 815 (Prisoner's Point) indicates that precluding entrainment of larval/juvenile delta smelt at this station would also protect fish at station 812 (Fisherman's Cut) and other stations north and west (downstream) of station 815. While the target entrainment at station 815 would ideally also be zero, there appears to be little additional entrainment protection (less than 5 percent) at OMR flows at -750 cfs (the strictest level addressed by Interim Remedies). However, entrainment risk grows exponentially at OMR flows increasingly more negative than -2000 cfs.

Figure B-16 displays injection points for modeled particle tracking runs that were conducted in February 2008 with injection points at Stations 711, 809, 812, 815, 902, 915. This figure plots projected relationships for OMR flows by injection point, including entrainment probabilities for station 815 (over 30 days).

The results from these runs indicate an approximate <5 percent entrainment risk at OMR flow not more negative than -2000 cfs. At a requirement of -3,500 cfs OMR flow, entrainment risk at station 815 is roughly 20 percent over each 30 day interval. Assuming cumulative entrainment is additive, over a roughly four month (~120 days) interval in which Action 3 would be under effect, consistently operating at -3,500 OMR would yield a net entrainment probability placing at risk approximately 80 percent of the larval/juvenile subpopulation utilizing the South Delta at and below Station 815. If immigration of larval smelt from the Central or North Delta into the zone of entrainment during spring

Figure B-16: Pump Entrainment at Various Levels of Negative Flow at Old and Middle River Monitoring



were to occur, the population-level risk would be even greater. Such entrainment levels are potentially a significant adverse risk to delta smelt population.

Justification for Release from Prescriptions of Action 3

Calendar Date

The Interim Remedies specified the duration of Action 3 to extend to *around* June 20, or until the temperature metric below. Based upon salvage data observed during WY 2008 (see Figure B-17, above), this temporal window should be amended (extended) to June 30 in order to provide sufficient protections to late-spawned delta smelt larvae.

Temperature

When South Delta temperatures reach a daily average of 25^{o}C for three consecutive days at Clifton Court Forebay, it is expected that conditions are no longer suitable for smelt survival. This metric is a functionally adequate predictor that viable smelt will not be present within the entrainment zone of Banks and Jones.

ACTION 4: ESTUARINE HABITAT DURING FALL

Objective: Improve fall habitat for delta smelt by managing of X2 through increasing Delta outflow during fall when the preceding water year was wetter than normal. This will help return ecological conditions of the estuary to that which occurred in the late 1990s when smelt populations were much larger. Flows provided by this action are expected to provide direct and indirect benefits to delta smelt. Both the direct and indirect benefits to delta smelt are considered equally important to minimize adverse effects.

Action: Subject to adaptive management as described below, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 km in the fall following wet years and 81km in the fall following above normal years. The monthly average X2 must be maintained at or seaward of these values for each individual month and not averaged over the two month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall target. The action will be evaluated and may be modified or terminated as determined by the Service.

Timing:

September 1 to November 30.

Triggers:

Wet and above normal WY type classification from the 1995 Water Quality Control Plan that is used to implement D-1641.

Adaptive Management of Habitat Action:

To address uncertainties about the efficiency of the Action, it will be adaptively managed under the supervision of the Service. Adaptive management is a mode of operation that provides for learning and feedback to adjust an action undertaken in the face of uncertainty. To improve the efficiency of the Action and align its management more closely with the general plan articulated in Walters (1997) and endorsed by the independent peer review of this BO, the Service will supervise the implementation of a formal adaptive management process.

According to Walters (1997), an adaptive management plan should include a clearly stated conceptual model, predictions of outcomes, a study design to determine the results of actions, a formal process for assessment and action adjustment, and a program of periodic peer review. A conceptual model that is based on the best available scientific information underlying the present Action is described in the Effects section. Expected outcomes are described in general terms below, though there is a high degree of uncertainty about the quantitative relationship between the size of the Action described above and the expected increment in delta smelt recruitment or production.

The adaptive management plan will include the following new elements to ensure that performance measures and plans to evaluate the outcome of the Action are in place by the time it is implemented and that refinements to the Action can be developed as quickly as possible. These are listed in chronological order of implementation, but steps (2) through (6) are viewed as steps in an adaptive feedback loop that may cycle multiple times. The loop is closed when new information developed in (3) – (5) and/or Service decisions to alter the Action in (6) provide a basis for altering the conceptual model and/or study design in (2) or create a need to alter the performance measures in (3). The process will then continue from the re-entry step.

(1) Delta smelt habitat study group (HSG)

A panel of scientists will be convened by the Service to review and improve the habitat conceptual model, design performance measures for the Action, and prepare a study plan to improve scientific understanding of delta smelt habitat. Products produced by the HSG will be made publicly available by the Service.

(2) Conceptual model review and preparation of study design

In this instance, the conceptual model (summarized below and in the effects section) describes multiple mechanisms potentially contributing to the observed habitat/flow relationship that motivates the Action. Consequently, the study group will develop an improved conceptual model more clearly sorting out component mechanisms as an important goal. With the conceptual model in hand, two lines of investigation will be developed: one line will be designed to evaluate the performance of the specific Action described in Part A above, while the other will address the scientific uncertainties underlying the relationship between summer/fall habitat quality and delta smelt adult recruitment. The second line of investigation will provide new scientific information that is likely to aid in refinement of the Action in Part A.

(3) Performance evaluation of the Action

The study group will develop performance measures for the Action, and these measures will be subject to independent peer review. The study to evaluate the present Action will be implemented in accordance with its design prior to the first September following adoption of the biological opinion.

(4) Studies to elucidate the operative mechanism(s) controlling the relationship between delta smelt habitat features and quality and delta smelt production.

The HSG will develop a habitat investigation, and the plan will be subject to independent peer review. There are several potentially fruitful lines of investigation to pursue, including studies to elucidate the precise mechanisms by which habitat affects delta smelt and studies intended to develop management tools to improve habitat. The peer review panel provided several useful suggestions in its review of the proposed actions.

(5) Peer review

Studies conducted under the guidance of the study group will be subject to independent peer review both at the design stage (when possible) and after results are obtained. Conclusions regarding the efficiency of the Action and potential alternatives will also be independently peer reviewed prior to receipt for official consideration by the Service.

(6) Service review and Action adjustment

The Service will direct all stages of the adaptive management plan, and will adjust the Action if/when circumstances and improved scientific understanding warrant. The HSG will provide technical assistance in the interpretation of results, but the Service will have ultimate responsibility for drawing conclusions regarding the advisability of any changes to the Action.

The Service will conduct a comprehensive review of the outcomes of the Action and the effectiveness of the adaptive management program ten years from the adoption of the BO, or sooner if circumstances warrant. This review will entail an independent peer review of the full history of the Action. The purposes of the review will be (1) to evaluate the overall benefits of the Action and (2) to evaluate the effectiveness of the adaptive management program.

The adaptive management program will have specific implementation deadlines. The creation of the HSG, initial habitat conceptual model review, and formulation of performance measures, implementation of performance evaluation, and peer review of the performance measures and evaluation that are described in steps (1) through (3) will be completed before the first September following adoption of the BO. This will ensure that measures required to evaluate the effectiveness of the action are in place during the first autumn after adoption. Additional studies addressing elements of the habitat conceptual model will be formulated as soon as possible, promptly implemented, and reported as soon as complete. As described above, there will also be a ten year review of the Action and its consequences.

Background

Delta outflows of as much as 20,000 cfs formerly occurred in fall months of all but drought WYs. Currently, however, fall outflows are similar to historic droughts regardless of WY type. Fall Delta outflows in wet and above normal WYs (i.e., from 1993-98) average 8,000-10,000 cfs; whereas after 1998, monthly averages have been 5,600 cfs across all WY types and monthly outflow variation has been very small. High among-month variability in Delta outflows may be important for restoring estuarine habitat conditions favoring many native species (Lund et. al. 2007).

Habitat parameters for delta smelt have been well described for both the summer and fall seasons as combinations of salinity, temperature, and turbidity. In winter and spring, temperature seems to be a dominant driver of habitat suitability both for adult spawning and for larval occurrence (Bennett 2005). Summer habitat is controlled largely by changes in turbidity due to changes in sediment supply and in the distribution of the sediment-trapping aquatic weed, *Egeria densa*. (Nobriga et al. 2008) Fall habitat (and smelt) shifts in abundance and distribution largely due to fluctuations in salinity (Feyrer et al. 2007). X2, which reflects salinity distribution in the estuary (Jassby et al. 1995), fluctuates mostly in response to fluctuations in outflow, although atmospheric conditions and barrier operations can also affect it.

X2 is strongly influenced by tidal cycles, moving twice daily up and downstream 6-10 km from its average daily location. For example, when the average daily X2 is near Sherman Island, delta smelt habitat can range from Chipps Island to Franks Tract. When the daily average X2 is centered on Browns Island, delta smelt habitat can range from Honker Bay to Big Break. The daily fluctuation in X2 around an upstream point such as Brown's Island confines the population to narrow channels, where delta smelt may be exposed to more stressors (e.g., agricultural diversions, predation) relative to a downstream X2. Adverse effects on adult delta smelt during fall may be a part of the reason that Feyrer et al. (2007) found a statistical association between fall X2 and the production of young delta smelt during the following year.

Other factors can degrade the quality of smelt habitat, principally water quality degradation. In September 2007 all collected delta smelt were found at salinities much higher than ever before. This observation was coincident with a period when their usual salinity range was heavily infested with the cyanobacterium *Microcystis aeruginosa*. *Microcystis* produces toxins in its normal life, but the concentrations of these toxins in water sharply increase when the population dies, usually in September and October (Lehman pers. comm.). In September 2008, delta smelt were in their normal salinity range and *Microcystis* were less abundant than in September 2007 (pers. comm. Randy Baxter DFG and Peggy Lehman DWR). Low flow conditions are among the factors associated with *Microcystis* blooms (Lehman et al. 2008).

Protection and restoration of habitat is an essential element in any conservation strategy where habitat has been lost or degraded. However, identifying the exact role habitat quality and volume play in the growth and survival of a species comes with some uncertainty. In the case of fall delta smelt, habitat area is a significant covariate in its stock-recruit relationship, indicating evidence of an effect on the population. Westward and variable locations of fall habitat provide increased habitat area and moves the delta smelt population away from the risks of possible future entrainment in the Delta, and distributes it more broadly throughout the estuary.

This action is designed to increase baseline monthly outflows in the fall period of wet and above normal WYs to increase areas of habitat and move the habitat away from Delta impacts and into broader open waters west of Sherman Island; and to increase variability of monthly habitat extent by having 2-3 months above the baseline. This would be expected to distribute smelt into more diverse geographic areas, helping to reduce the risk of localized losses from future entrainment, contaminants, and predation. Finally, it may reduce the proliferation of other factors that reduce habitat suitability such as *Microcystis* and *Egeria* growth.

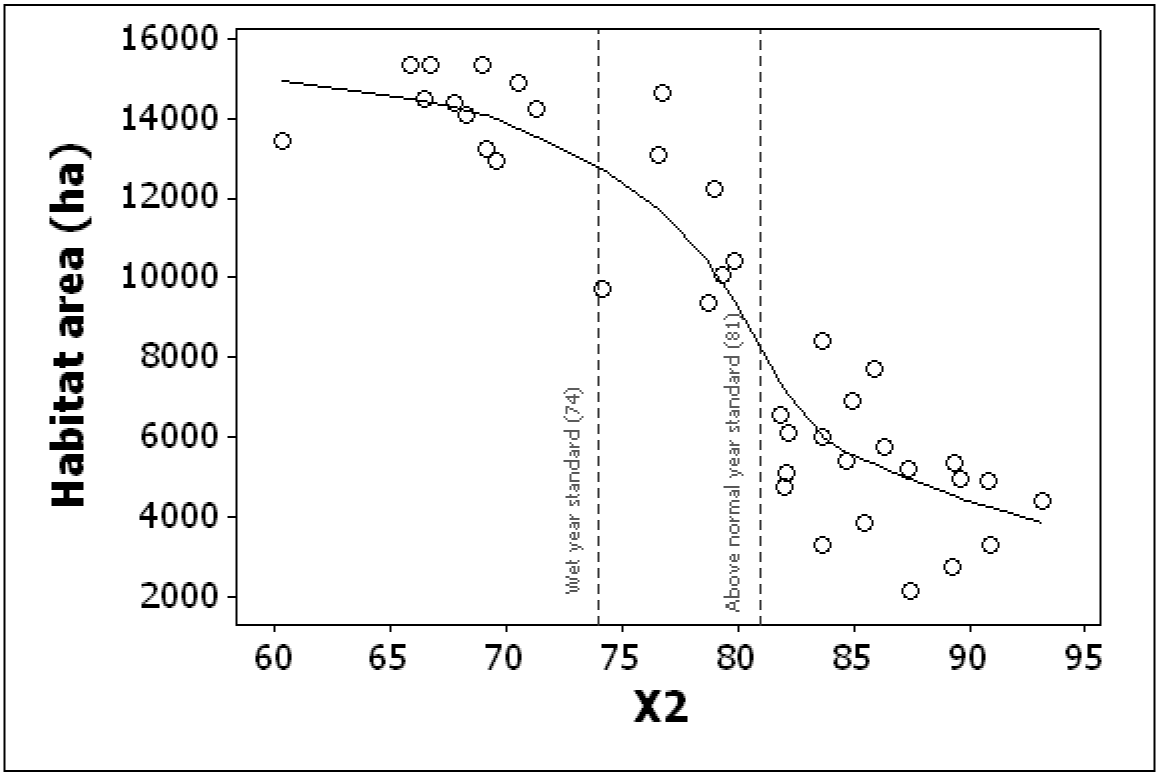
Justification:

The Effects section clearly indicates that there will be significant adverse impacts on X2, which is a surrogate indicator of habitat suitability and availability for delta smelt in all years (Figures E-19 and E-25 in Effects section). Moreover, the results of Feyrer et al. (2007) suggest that adverse effects on adult delta smelt during fall may be part of the reason that there is a statistical association between fall X2 and the production of young delta smelt during the following year. The action is focused on wet and above normal years because these are the years in which project operations have most significantly adversely affected fall (Figure E-27 in Effects section) and therefore, actions in these years are more likely to benefit delta smelt.

The action is designed to be governed by hydrologic conditions and therefore will be ecologically-based. For the purposes of implementation of this action, water year type is defined as the water year that ends in the September of the calendar year in which the action will be implemented. The standards of 74km in wet years and 81km in above normal years are designed to mitigate the effects of X2 encroachment upstream in current and proposed action operations, and provide suitable habitat area for delta smelt (Figure B-17).

The long-term trend in which all falls have Delta outflows indicative of dry or critical years matches long-term upward trends in the E:I ratio and X2 (Figure E-28 in effects

Figure B-17. Relationship between X2 and habitat area for delta smelt during fall, with standard shown for wet and above normal years.



section). The overall effect is readily observed as a substantial divergence in the difference between fall X2 and X2 the preceding spring (April-July). Given that these conditions will persist under the proposed CVP/SWP operations, the modeling also shows they may be exacerbated under various climate change scenarios (Figure E-28 in effects section).

The persistence of this significant hydrologic change to the estuary threatens the recovery and persistence of delta smelt. Outflow during fall determines the location of X2, which determines the amount of suitable abiotic habitat available to delta smelt (Feyrer et al. 2007, 2008). The long-term upstream shift in X2 during fall has caused a long-term decrease in habitat area availability for delta smelt (Feyrer et al. 2007, 2008), and the condition will persist and possibly worsen in the future. This alone is a significant adverse effect on delta smelt.

However, the problem is further complicated because there are several lines of published peer reviewed scientific research that link habitat alteration to the decline of delta smelt (Bennett 2005; Feyrer et al. 2007; Nobriga et al. 2008). An important point regarding this action is that because of the current, extremely low abundance of delta smelt, it is unlikely that habitat space is currently a limiting factor. However, it is clear that delta smelt have become increasingly habitat limited over time and that this has contributed to the population attaining record-low abundance levels (Bennett 2005; Baxter et al. 2008;

Feyrer et al. 2007, 2008; Nobriga et al. 2008). Further, as detailed in the Effects section, persistent degraded or worsened habitat conditions are likely to contribute to depensatory density-dependent effects on the delta smelt population while it is at historical low levels, and would at some point in the proposed term of this project, limit delta smelt recovery.

Therefore, the continued loss and constriction of habitat into areas of low habitat quality under the proposed action significantly threatens the ability of the delta smelt population to recover and persist in the estuary at self-sustaining levels higher than the current record-lows. While it is not yet proven why habitat quality under this constant dry-year fall X2 scenario has been degraded for rearing delta smelt, the coincidence of this pattern with sustained and significant population level losses for this lifestage (as measured in survival rates and smelt physiological condition), along with the increasing body of support ascribing the aforementioned hypothesized mechanisms of action to habitat degradation and smelt condition, and finally the current critically low level of the current population, make the implementation of a fall action essential to the maintenance of the population resilience for delta smelt. In short, the historically high variability in summer/fall survival rates does not negate the need for protection from direct mortality losses due to adult and larval/juvenile entrainment, it actually highlights the need for restoring flow variability to the Delta environment so that smelt populations can recover through allowing these essential periods of population rebound.

Monitoring Component to Assess Performance of Action 4

The Service will require that Action 4 be implemented with an adaptive management program to provide for learning and improvement of the action over time. The adaptive management program will include commissioning studies to clarify the mechanisms underlying the effects of fall habitat on the delta smelt population and should, at the least, focus on the following general study questions:

i. What is the effect of habitat area and distribution on delta smelt distribution?

ii. How does fish condition/health vary across a gradient of habitat quality?

iii. Does fish condition/health in fall affect over-winter survival?

iv. Does fish condition/health affect fecundity and egg viability?

v. Does spatio-temporal salinity variation resulting from this fall action affect *Microcystis*?

vi. Does spatio-temporal salinity variation resulting from this fall action affect *Corbula* and the benthic invertebrate community?

Given the low numbers of delta smelt currently in the estuary, a suite of surrogate species is probably required to address questions ii-iv, although question iv could be examined directly with experiments on fish from the Tracy Fish Culture Facility. It is recommended that studies designed address these research questions be coordinated and implemented through the IEP and POD Management Teams. The research and monitoring plan will include reporting criteria, data sharing and dissemination requirements, oversight and contractual compliance elements for purposes of quality assurance and ensure the transparency and timely completion of necessary monitoring, research and assessment.

ACTION 5: TEMPORARY SPRING HEAD OF OLD RIVER BARRIER (HORB) AND THE TEMPORARY BARRIER PROJECT (TBP)

Objective: To minimize entrainment of larval and juvenile delta smelt at Banks and Jones or from being transported into the South and Central Delta, where they could later become entrained.

Action: Do not install the HORB if delta smelt entrainment is a concern. If installation of the HORB is not allowed, the agricultural barriers would be installed as described in the Project Description. If installation of the HORB is allowed, the TBP flap gates would be tied in the open position until May 15.

Timing: The timing of the action would vary depending on the conditions. The normal installation of the spring temporary HORB and the TBP is in April.

Triggers: For delta smelt, installation of the HORB will only occur when PTM results show that entrainment levels of delta smelt will not increase beyond 1 percent at Station 815 as a result of installing the HORB.

Offramps: If Action 3 ends or May 15, whichever comes first.

Justification for Action 5

The TBP change the hydraulics of the Delta, which can affect delta smelt. The HORB blocks San Joaquin River flow from entering Old River. This increases the flow toward Banks and Jones from Turner and Columbia cuts, which can increase the predicted entrainment risk of particles in the East and Central Delta by up to about 10 percent (Kimmerer and Nobriga 2008). In most instances, net flow is directed towards Banks and Jones and local agricultural diversions. Computer simulations have shown that placement of the barriers changes South Delta hydrodynamics, increasing Central Delta flows toward the export facilities (DWR 2000). In years with substantial numbers of adult delta smelt in the Central Delta, increases in negative OMR flow caused by installation of the TBP can increase entrainment. The directional flow towards Banks and Jones increases the vulnerability of fish to entrainment. Larval and juvenile delta smelt are especially susceptible to these flows.

The varying operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables limit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. In 1996, the installation of the HORB caused a sharp reversal of net flow in the South Delta to the upstream direction. Coincident with this change was a strong peak in delta smelt salvage (Nobriga et al. 2000). This observation indicates that short-term salvage can significantly increase when the HORB is installed in such a manner that it causes a sharp change or reversal of positive net daily flow in the South and Central Delta.

Many of these potential effects to delta smelt would be reduced by the OMR flows provided in Action 3. In order to determine if there will be adverse effects to delta smelt from the installation of the HORB, PTM will be completed during Action 3. The Service may use the control point method of maintaining an entrainment level at Banks and Jones below 1 percent at Station 815. If the PTM results show that entrainment would be higher than 1 percent during the period when the HORB would be installed, and would result in increased risk to juvenile delta smelt, then it would not be installed.

Additionally, the OMR flows provided in Action 3 or high San Joaquin River flows may provide beneficial conditions in the Delta for out-migrating salmonids and sturgeon, which would preclude the need for the HORB installation. This analysis, combined with the PTM results will provide data to help determine if listed fish would be adversely affected by the HORB. If the spring temporary HORB is not installed, the TBP would be operated as described in the Project Description.

Justification for Release from Prescriptions of Action 5

If Action 3 has ended, the entrainment concern has likely abated, and delta smelt larvae and juveniles are not likely to be present in the Central and South Delta. High flows on the San Joaquin River may also preclude the spring temporary HORB from being installed since it is not physically possible during these flows to install the HORB. The concerns for entrainment are reduced during high San Joaquin River flows.

ACTION 6: HABITAT RESTORATION

Objective: To improve habitat conditions for delta smelt by enhancing food production and availability.

Action: A program to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh shall be implemented. A monitoring program shall be developed to focus on the effectiveness of the restoration program.

Timing: The restoration efforts shall begin within 12 months of signature of this biological opinion and be completed within a 10 year period.

Background

The historic Delta was a tidal wetland-floodplain system including about 350,000 acres of tidal wetland. Almost all of the historic wetlands in the Delta have been lost due to conversion to agriculture and urban development. The Delta currently supports less than 10,000 acres of tidal wetland, all of which is small and fragmented. This conversion of the Delta's wetlands beginning in the mid-nineteenth century has resulted in a landscape dominated by agricultural lands intersected by deep and comparatively uniform tidal channels.

Delta smelt feed mainly on zooplankton throughout their life cycle (Nobriga and Herbold 2008) with the copepod Pseudodiaptomus forbesi being the dominant prey item for juvenile delta smelt in the summer (Lott 1998; Nobriga 2002; Hobbs et al. 2006). Diatoms form the base of the pelagic foodweb and primary consumers (e.g. copepods) appear to be food-limited in the Delta and Suisun (Muller-Solger et al. 2002; Sobczak et al. 2002). Pelagic productivity in the Delta and Suisun Bay has been declining for several decades with a steep decline following the introduction of the overbite clam in 1986 (Kimmerer and Orsi 1996). Histopathological evaluations have provided evidence that delta smelt have been food-limited during the summer months (Bennett 2005). This finding has been corroborated by recent work on juvenile delta smelt as part of ongoing studies on the POD. Moreover, recent studies suggest a statistical association between delta smelt survival and the biomass of copepods in the estuary (Kimmerer 2008).

Overall research in other estuaries has indicated that tidal wetlands are highly productive. Although definitive studies have not been done on the type and amount of productivity in freshwater tidal wetlands of the Delta, brackish tidal wetlands of Suisun Marsh are one of the most productive habitats in northern San Francisco Bay-Delta estuary (Sobczak et al. 2002). It is likely that restored freshwater tidal wetlands in the Delta would have higher productivity than the brackish wetlands of Suisun (Odum 1988). A large portion of the production in Suisun Marsh consists of high quality phytoplankton-derived carbon (Sobczak et al. 2002) that is an important food source for zooplankton and therefore can contribute to the base of the pelagic foodweb. Modeling suggests that the tidal wetlands of Suisun currently provide about 6 percent of the organic carbon to the pelagic habitats of Suisun Bay (Jassby et al. 1993). In addition, sampling in Liberty Island shows that these freshwater tidal habitats can be a source of high-quality phytoplankton that contribute to the pelagic food web downstream (Lehman et al. 2008). Thus, restoration of large amounts of intertidal habitat in the Delta and Suisun could enhance the ecosystem's pelagic productivity.

Justification:

Since it was introduced into the estuary in 1988, the zooplankton Pseudodiaptomus forbesi has been the dominant summertime prey for delta smelt (Lott 1998; Nobriga 2002; Hobbs et al. 2006). There is evidence suggesting that the co-occurrence of delta smelt and Pseudodiaptomus forbesi has a strong influence on the survival of young delta smelt from summer to fall (Miller 2007). The Effects Section indicates that

Pseudodiaptomus distribution may be vulnerable to effects of export facilities operations and therefore, the projects have a likely effect on the food supply available to delta smelt.

The near complete loss of tidal wetlands from the Delta threatens the persistence of delta smelt by reducing productivity at the base of the pelagic foodweb. Primary production in tidal wetlands of the Northern San Francisco estuary has been shown to support high zooplankton growth (Muller-Solger et al. 2002). This action should therefore enhance the foodweb on which delta smelt depend. This action is designed to increase high quality primary and secondary production in the Delta and Suisun Marsh through an increase in tidal wetlands. Exchange of water between the tidal wetlands and surrounding channels should distribute primary and secondary production from the wetlands to adjacent pelagic habitats where delta smelt occur. This exchange should be optimized through intertidal habitat restoration designed to incorporate extensive tidal channels supported an appropriately sized vegetated marsh plain which will provide the necessary tidal prism to maintain large tidal exchange.

New evidence indicates how tidal marsh may benefit delta smelt even if they do not occur extensively within the marsh itself. Specifically, monitoring suggests this species is taking advantage of recently-created tidal marsh and open water habitat in Liberty Island. The fact that delta smelt make heavy use of habitat in the Cache Slough complex has been evident in sampling by the DFG's Spring Kodiak trawl and 20 mm surveys (www.delta.dfg.ca.gov). The Spring Kodiak trawls show that delta smelt are present in channels of the Cache Slough complex during winter and spring; the collection of larval delta smelt in subsequent 20-mm surveys indicates that these adult delta smelt eventually spawn in the vicinity. In addition, the use of Cache Slough complex by delta smelt includes habitat on Liberty Island. The island flooded in 1998 and has evolved rapidly into a system of open-water and tidal marsh habitat. Recent sampling of Liberty Island by USFWS biologists (http://www.delta.dfg.ca.gov/jfmp/libertyisland.asp) revealed that delta smelt both spawn and rear in Liberty Island. Light traps collected relatively high numbers of larval delta smelt in several locations of Liberty Island during the 2003 spawning period for this species. Moreover, subsequent beach seine sampling showed that older delta smelt were present at all ten of their sampling stations during 2002-2004 and in all seasons of the year (USFWS, unpublished data). These results are particularly striking because they were from a period when delta smelt was at record low abundance. Collection of delta smelt from shallow inshore areas using seines indicates that the fish do not occupy deeper pelagic habitat exclusively. These results seem reasonable in light of the area's consistently high turbidity (Nobriga et al. 2005; DWR, unpublished data) and zooplankton abundance (e.g. Sommer et al. 2004), both of which are important habitat characteristics for delta smelt (Bennett 2005; Feyrer et al. 2007). In any case, these data suggest that freshwater tidal wetlands can be an important habitat type to delta smelt with proper design and location.

A monitoring program shall be developed to focus on the effectiveness of the restoration program. This program shall be reviewed and modified as new information becomes available.

Attachment C: Methods Used in Developing the Incidental Take Statement

Methods Used in Developing the Incidental Take Statement

The objective adopted by the Service to minimize take of adult delta smelt through entrainment is two-fold. First, adult entrainment shall be minimized during all year types through the RPA. More critically, demographic losses from periodic episodes of high entrainment will be eliminated through implementation of the RPA. These outcomes shall be accomplished through the application of measures as defined in RPA Components 1 and 2.

Adoption of the RPA included in this biological opinion is expected to appreciably reduce the number of delta smelt salvaged during certain years. Implementation of the RPA should avoid significant mortality during those years of high entrainment. The Service believes these high salvage year events (such as in WY 2003 for adult delta smelt) resulted in mortality at levels that were demographically significant to the delta smelt population. Further, at low abundances observed in the last few years, high entrainment events (observed more frequently, for adult delta smelt in 2003, 2004, and 2005, successively) further reduces the resilience of the current delta smelt population.

The Service anticipates that take of adult delta smelt via entrainment will be minimized when OMR flows are limited to -2,000 cfs during the first winter flush when adult smelt move within the zone of entrainment. OMR flows held between -1,250 and -5,000 cfs following the first flush until the onset of spawning will protect later delta smelt migrants and spawners. During frequent intervals within the timeframe for RPA Component 1, the SWG shall provide specific OMR flow recommendations to the Service; and the Service will then determine flow requirements using the adaptive process as described in the RPA.

This approach was adopted because it reflects the most reasonable strategy to allow continued CVP/SWP operations while providing necessary protection to the delta smelt population under real-time conditions. It accounts for uncertainty of adult smelt entrainment risk resulting from variable environmental, demographic, and operational conditions; and adapts operations in response to real-time data.

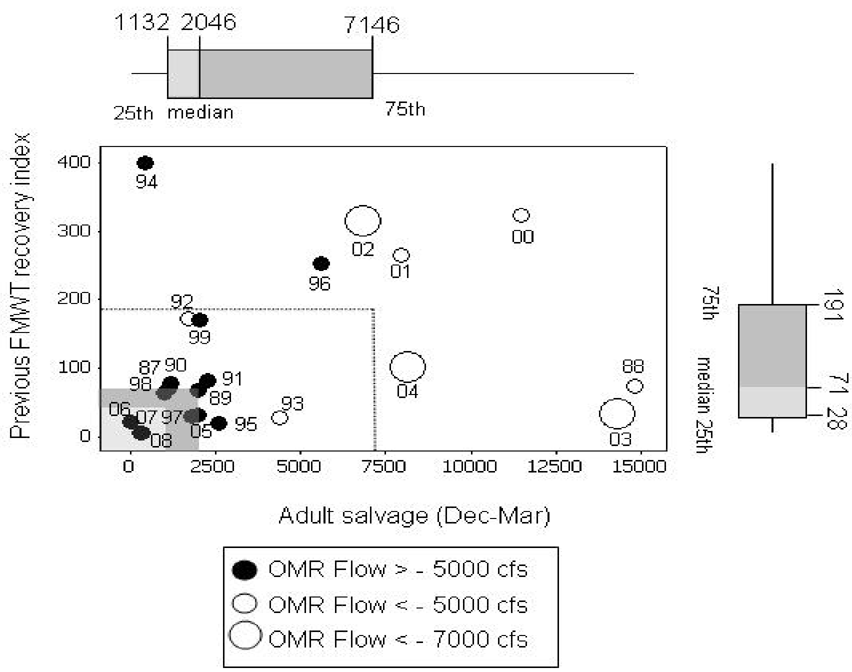
The specific level of take of adult delta smelt at the CVP/SWP pumping facilities is difficult to definitively project, due to inherent uncertainties. First, the only data available from which to derive population estimates come from monitoring that is not specifically designed to assess the abundance of delta smelt. Distribution of adult smelt is highly variable between years, and is driven by factors that are both inherently difficult to predict and also not completely understood. These factors are, at best, imperfectly controlled. Additionally, salvage data (our most definitive measurement endpoint) reflects only a portion of the total mortality associated with entrainment. Losses to predation and inefficient screening are significant, but unknown. Finally, salvage itself is clearly at least partially a function of abundance. In other words, the more delta smelt there are out there, the higher the salvage numbers will be, given the same operational conditions and delta smelt distribution. In short, entrainment and the population-level effect from direct mortality attributed to pumping is a multivariate and complex process, and this complexity defies ready predictive modeling.

The Service in past take statements has relied upon historic salvage as the most reasonable predictor of future salvage. Adult delta smelt salvage data (grouped by sorting entrainment years into quartiles by the total number salvaged between December and March) can be plotted by year and related to delta smelt population abundance and flows as shown in Figure C-1. The historic (1987-2007) median salvage levels with 25th and 75th percentiles are plotted versus the preceding FMWT Recovery Index (RI). The RI provides an indication of the status of the delta smelt population based on distributional and abundance criteria from a subset of September and October FWMT sampling data (Service 1995). A low RI indicates the delta smelt population is at a low level, whereas a high RI value (~400) indicates a larger population. Figure 1 uses 1987 to 2007 as the historic baseline dataset for this analysis because these years represent the period after which delta smelt experienced coincident declines in abundance and habitat quality (Feyrer et al. 2007), and because these are years for which salvage data are considered most reliable.

One benchmark for determining the severity of salvage is the 25th percentile (first quartile) of recent historic winter salvage of delta smelt at the CVP/SWP export facilities. For reference, the first quartile historic salvage count for 1987 through 2007 is 1,132 adult delta smelt, while the median value during this same interval is 2,046 individuals. Salvage above these levels is likely to lead to large losses of spawning delta smelt relative to the mean population size. For example, in 2003 and 2004, the projects salvaged 14,323 and 8,148 adult delta smelt respectively. These losses are disproportionately high (i.e., greater than the 75th percentile of historical salvage) for their given RI values, 33 (2003) and 101 (2004), respectively. According to Kimmerer (2008), 2003 and 2004 were years when entrainment accounted for 50 percent and 19 percent losses, respectively, of adults from the population. These are very high loss rates even by commercial fishery standards and for delta smelt, with such low population numbers, it is an even greater concern.

As presented in Figure C-1, using a rough estimate of expected future flows based on implementation of the RPA (i.e., >-5,000 cfs OMR) and when abundance indices are low (based on RI), adult salvage levels during WY's 2006, 2007, and 2008 best approximates adult salvage numbers expected in the future.

Figure C-1. Adult delta smelt salvage levels in relation to OMR flows and the FMWT RI for the period 1987-2007.



To estimate take with implementation of the RPA, the Service scaled projected salvage to abundance using the estimates provided by the prior year's FMWT Index (note that this differs somewhat from Figure C-1, which used the RI, reflecting a subset of FMWT Index data). The segregation of year types is based upon descriptive statistics comprising quartiles, as expressed above in Figure C-1, and quantified following the approach described below.

A *Cumulative Salvage Index*

The Cumulative Salvage Index (CSI) is calculated as the total year's adult salvage (the aggregate number for expanded salvage at both the Banks and Jones export facilities for the period December through March) divided by the previous year's FMWT Index. Taking all water year types together (regardless of abundance or OMR flows in a given year), the median CSI value for the period 1993 to 2008 is 12.0. The first and third quartile CSI values for this period are 6 and 26, respectively. These data are summarized below in Table C-1.

Incidental Take for Adult Entrainment (Salvage)

Water years 2006 to 2008 were years in which salvage, negative OMR flows, and delta smelt abundance were all relatively lower relative to the historic values. These are the only three years of lower negative OMR flows which coincided with salvage values below the first quartile within the historic range and low overall adult delta smelt abundances (below first quartile FMWT Index). The corresponding CSI values are: 8.3 (2006), 0.88 (2007), and 12.6 (2008). The Service therefore believes these years within the historic dataset best approximate expected salvage under the RPA Component 1.

The mean value for adult salvage during WYs 2006 to 2008 is 247 adult delta smelt. The average CSI value for WYs 2006 to 2008 was 7.25. Projecting this average rate of salvage to the years in which CVP/SWP operations will be conducted within the sideboards established by the RPA would yield estimates of salvage at 7.25 times the prior year's FMWT Index. The Service use this estimator to predict incidental take levels of adult delta smelt during each year that the RPA's will be in effect. This value, which can be calculated upon release of the final FMWT Index within the current water year, is regarded as the incidental take for adult delta smelt under the RPA.

Incidental Take: Cumulative Expanded Salvage = 7.25 * Prior Year's FMWT Index

As indicated in Table C-1, for the entire span of WY's since 1993, this numerical salvage threshold would have been exceeded in WY's 1993, 1995, and 2003-2005.

Table C-1: Adult Salvage Summary Statistics 1993-2008

Year	FMWT Index	Adult Salvage	Cumulative Salvage Index	Take Threshold
1993	156	4425	28.4	X
1994	1078	359	0.33	
1995	102	2608	25.6	X
1996	899	5628	6.3	
1997	127	1828	14.4	
1998	303	1027	3.4	
1999	420	2074	4.9	
2000	864	11505	13.3	
2001	756	8015	10.6	
2002	603	6865	11.4	
2003	139	14338	103	X
2004	210	8058	38.4	X
2005	74	2018	27.3	X
2006	26	216	8.3	
2007	41	36	0.88	
2008	28	352	12.6	
min	26	36	0.33	
max	1078	14338	103	
mean	364	4335	19.3	
25th	95.0	860.0	5.9	
median	183	2341	12.0	
75th	641.3	7152.5	26.0	

High Concern Level for Adult Entrainment (Salvage)

Delta smelt abundance is critically low, and without habitat quality conditions to appreciably improve juvenile growth and rearing from recent historic levels, is expected to remain so for the foreseeable future. The current population cannot tolerate direct mortality through adult entrainment at levels approaching even "moderate" take as observed through the historic record of recent decades. The method utilized herein to calculate take contains uncertainty within the estimates, and this fact translates into population-level risk. Further, there is a recognized need to provide a quantitative framework so that the Service and CVP/SWP operators have a common analytical methodology for reference and to futher guide the adaptive process.

Therefore, the Service is also providing a Concern Level estimate, meant to indicate salvage levels approaching the take threshold, and help guide implementation of the RPA. Reaching this expanded salvage figure within a given season may require that OMR flows be set to a more restrictive level, unless available data indicate some greater level of exports is possible without increasing entrainment (e.g., there is strong reason to presume the pre-spawning migration has passed). Throughout the water year, as the SWG convenes and reviews daily salvage data, reaching the Concern Level for adult salvage requires an immediate specific recommendation to the Service.

The Service believes this Concern Level value should trigger at 75 percent the adult incidental take, as an indicator that operations need to be more constrained to avoid exceeding the incidental take.

Concern Level: Cumulative Expanded Salvage = 5.43 * Prior Year's FMWT Index

The rationale for a value approaching 75 percent (as opposed to 50 percent, for example), is that the window for adult entrainment, once begun, is generally short (~1 month), and it is not expected that aggressive pumping restrictions would continue for long durations once salvage is occurring and data are available. The SWG will take timing into account during interpretation of salvage within a given season, and recommend OMR restrictions to the Service accordingly.

For reference purposes, the population level losses reported in Kimmerer (2008) appear in Table 2 compared to our CSI metric. Caution is necessary when comparing field data to take estimates from population models due to; (1) their high inherent predictive uncertainty based on broad underlying assumptions and limited monitoring methodology, (2) the crude discriminative capacity of the inherent methodology utilized within the CSI-derived risk thresholds, and (3) the paucity of available data. However, regressing the Kimmerer (2008) estimates against the CSI approach in order to make this comparison ($y = 0.4539x + 1.8905$; $r^2 = 0.9105$) yields an expected take under implementation of the RPA defined herein approximating delta smelt population level losses during the adult lifestage to around 5 percent. The concern level would roughly approximate salvage of 4 percent of the adult pre-spawning population.

Table C-2. Cumulative Salvage Index in comparison to adult take estimates in Kimmerer (2008).

Year	Estimate	Lower 95% Confidence Boundary	Upper 95% Confidence Boundary	FMWT Recovery Index	Total Salvage	CSI
2002	15	5	24	603	6865	11.4
2003	50	19	69	139	14338	103
2004	19	6	31	210	8058	38.4
2005	7	2	12	74	2018	27.3
2006	4	1	6	26	216	8.3

Table C-3 lists threshold levels of high concern and incidental take for a range of potential FMWT indices. This table is intended to be used as a reference to discern levels of salvage reflecting the range of expected adult delta smelt mortality with implementation of the RPA, and an indicator of adult delta smelt salvage levels that constitutes an increasing and adverse effect to the delta smelt population due to CVP/SWP operations.

Table C-3: Incidental Take Expanded Salvage Numbers by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	11	15	66	359	479	220	1197	1596	550	2992	3989
4	22	29	72	392	522	240	1305	1741	560	3046	4061
6	33	44	78	424	566	260	1414	1886	570	3100	4134
8	44	58	84	457	609	280	1523	2031	580	3155	4206
10	54	73	90	490	653	300	1632	2176	590	3209	4279
12	65	87	96	522	696	320	1741	2321	600	3264	4351
14	76	102	100	544	725	340	1849	2466	620	3372	4496
16	87	116	102	555	740	360	1958	2611	640	3481	4642
18	98	131	104	566	754	380	2067	2756	660	3590	4787
20	109	145	106	577	769	400	2176	2901	680	3699	4932
22	120	160	108	587	783	420	2285	3046	700	3808	5077
24	131	174	110	598	798	460	2502	3336	720	3916	5222
26	141	189	120	653	870	480	2611	3481	740	4025	5367
28	152	203	130	707	943	500	2720	3626	760	4134	5512
30	163	218	140	762	1015	502	2731	3641	780	4243	5657
34	185	247	150	816	1088	504	2741	3655	800	4351	5802
38	207	276	160	870	1160	506	2752	3670	840	4569	6092
42	228	305	170	925	1233	510	2774	3699	880	4787	6382
48	261	348	180	979	1305	520	2828	3771	920	5004	6672
54	294	392	190	1033	1378	530	2883	3844	960	5222	6962
60	326	435	200	1088	1450	540	2937	3916	1000	5439	7252

Take of Larval and Juvenile Delta Smelt

In contrast to adult delta smelt, there is no well established index of larval and juvenile abundance to reliably scale the take of this lifestage to abundance. Indices of abundance are constructed from fishery surveys performed by DFG (Figure C-2). The DFG has monitored the distribution and relative abundance of larval and post-larval delta smelt throughout their spring range since 1995. This survey is named the 20-mm survey for the size at which delta smelt are retained and readily identified by the fish salvage facilities, and provides near-real time information on larval abundance and distribution for individuals that have reached this size class. There is no established way to measure and document take of larval smelt below this size. Protection of this age class is afforded through the RPA, when setting OMR restrictions, but there is no reliable means to assess performance until later in the season when >20mm larvae are present. This should be kept in mind in light of salvage numbers, pre-emptive OMR prescriptions based on salvage predictions, and the take statement for the earlier part of the spring season (i.e., April).

Historically, as with adults, larval and juvenile delta smelt salvage has varied widely, as a function of overall abundance, distribution and Delta hydrology (Figures C-3 and C-4). This variability makes prediction of salvage of larvae and juvenile delta smelt difficult. In order for a survey to have significant predictive value, it must precede the period of entrainment with as few confounding variables (intervening factors) between the estimate and the event as possible. Larval and juvenile take cannot be scaled to either the 20-mm Survey Index or the TNS Index because both surveys overlap the period during which the salvage occurs. Further, as migration, spawning distribution and success, adult delta smelt entrainment and mortality (due to quantifiable and unquantified variables) occur between the FMWT (the parental generation) and salvage of their progeny (the following April through July); it is difficult to infer actual larval abundance reliably through the next spring. This dilutes the statistical reliability of the calculation of a larval/juvenile salvage index, corresponding to the CSI for adult delta smelt. However, review of the salvage data relative to actual OMR values within a given year does reveal that a relationship of fall parental abundance to salvage of progeny exists—enough so such that predictability does increase through scaling to current water year FMWT.

The Service has therefore largely followed the methodology for estimating incidental take of larval delta smelt similar to that utilized for adults. Specifically, an average of the last four years (2005-2008) cumulative larval/juvenile salvage by month (April through July) was calculated. This can be summarizes as a Juvenile Salvage Index (JSI), calculated as:

Monthly Juvenile Salvage Index = cumulative seasonal salvage ≥ 20 mm by month end divided by current WY FMWT Index

The mean values from 2005-2008 were used as an initial estimate of take under the RPA. The reason for selecting this span of years is that the apparent abundance of delta smelt since 2005 as indexed by the 20-mm Survey and the TNS is the lowest on record (Table

C-4). It was necessary to separate out this abundance variable, but also to account for other poorly understood factors relating salvage to OMR, distribution, and the extant conditions. In other words, the most recent conditions are our best available reflection of predicted salvage under the RPA. On a monthly basis (cumulative salvage across the spring), this estimate represents a concern level where entrainment has reached high enough numbers to indicate the need for more protective OMR restrictions. The average JSI for the last four spring seasons by month (April through July), equals: 0.29, 13.03, 33.02, and 37.47, respectively.

Concern Level = Monthly JSI 2005-2008 mean * Current WY FMWT

It was determined that the last four years average monthly cumulative salvage was sufficient as an estimate of the concern level for larval/juvenile smelt, as opposed to the incidental take under the RPA. It is acknowledged that salvage across years will be variable, as distribution, spawning success, prior entrainment of adults, enhanced survival of <20mm larval delta smelt under the RPA, and extant natural conditions determine. As mentioned above, this constrains predictability of take using this methodology, and is less reliable overall as the method used for adults. Also, it is believed that individuals of the larval/juvenile lifestage are less demographically significant than adults. Given these considerations, the incidental take estimate for ≥ 20 mm larval/juvenile delta smelt under the RPA will be above the four year average by 50 percent.

Larval/Juvenile Incidental Take = 1.5 * Concern Level

Lookup tables relating (current WY) FMWT to concern level and incidental take for cumulative salvage by month appears in Table C-5 through C-8, below.

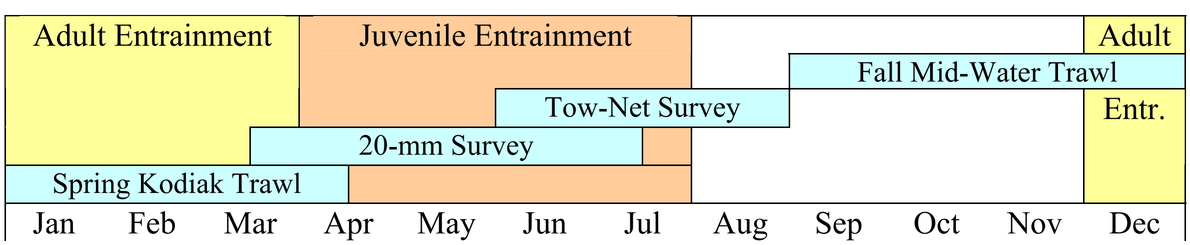


Figure C-2. Fishery surveys conducted by the California Department of Fish and Game that routinely collect delta smelt, and may be used to infer relative abundance.

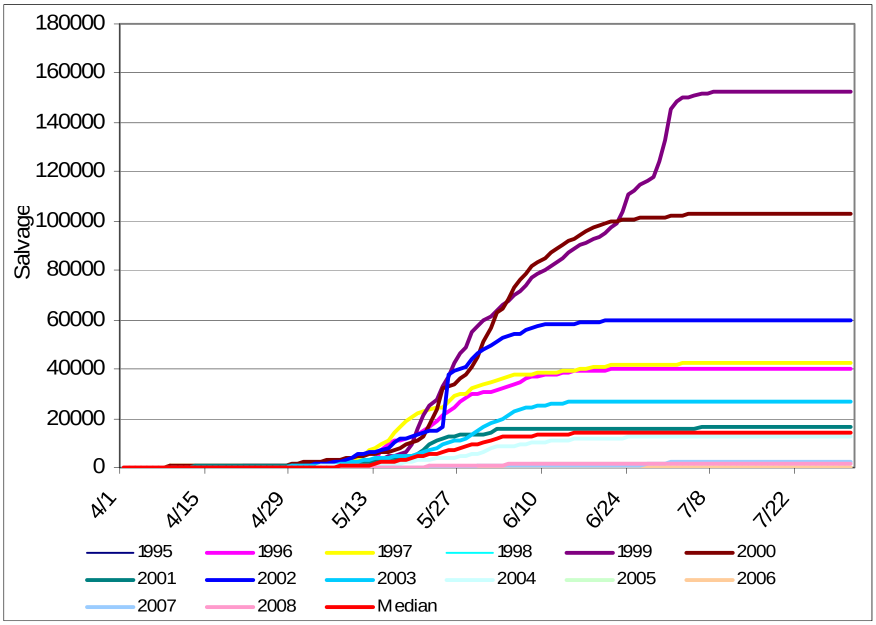


Figure C-3. Cumulative salvage of larval and juvenile delta smelt, 1995 through 2008.

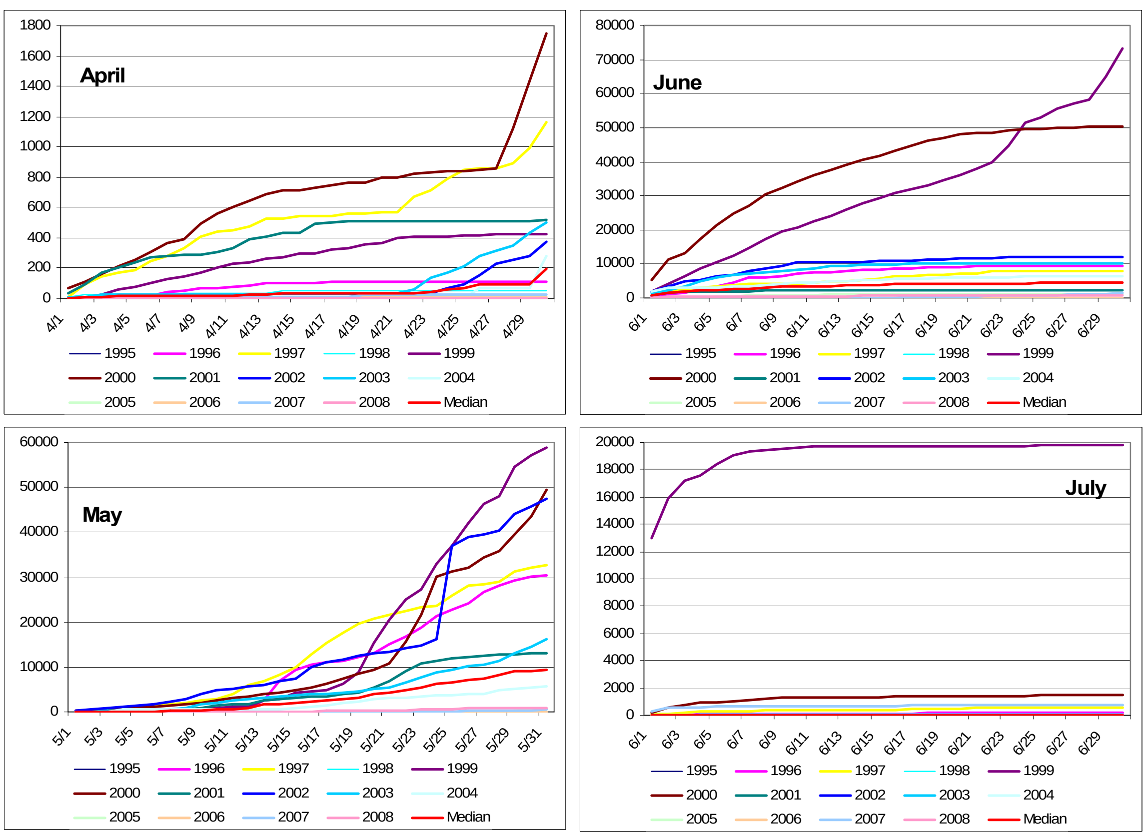


Figure C-4. Cumulative salvage of larval and juvenile delta smelt, 1995-2008, by month.

Table C-4. Larval/juvenile ≥ 20 mm delta smelt abundance and salvage statistics.

Water Year	Prior Year FMWT Index	20-mm Index	STNS	Salvage	Juvenile Salvage Index
1995	102	4.4	3.2	24	0.2
1996	899	33.9	11.1	40099	44.6
1997	127	19.3	4.0	42091	331.4
1998	303	7.7	3.3	242	0.8
1999	420	39.7	11.9	152526	363.2
2000	864	23.8	8.0	101783	117.8
2001	756	11.3	3.5	15984	21.1
2002	603	8	4.7	59652	98.9
2003	139	13.1	1.6	26220	188.6
2004	210	8.2	2.9	12441	59.2
2005	74	15.4	0.3	1734	23.4
2006	27	9.9	0.4	12	0.4
2007	41	1	0.4	2669	65.1
2008	28	2.9	0.6	1705	60.9
min	27	1	0.3	12	0.2
max	899	39.7	11.9	14213	363
mean	328	15.0	4.3	32656	98
25th	81	6.05	0.5	152526	22
median	175	10.6	3.25	1712	60
75th	557	17.3	4.3	41593	363
ITS	**April**	**May**	**June**	**July**	**Total**
Concern Level	0.29*FMWT	13.03*FMWT	33.02*FMWT	37.47*FMWT	37.47*FMWT
Incidental Take	0.44*FMWT	19.6*FMWT	49.5*FMWT	56.2*FMWT	56.2*FMWT

Table C-5: April Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	1	1	102	30	45	502	147	221
4	1	2	104	30	46	504	148	222
6	2	3	106	31	47	506	148	223
8	2	4	108	32	47	510	150	224
10	3	4	110	32	48	520	152	229
12	4	5	120	35	53	530	155	233
14	4	6	130	38	57	540	158	237
16	5	7	140	41	62	550	161	242
18	5	8	150	44	66	560	164	246
20	6	9	160	47	70	570	167	251
22	6	10	170	50	75	580	170	255
24	7	11	180	53	79	590	173	259
26	8	11	190	56	84	600	176	264
28	8	12	200	59	88	620	182	273
30	9	13	220	64	97	640	188	281
34	10	15	240	70	106	660	193	290
38	11	17	260	76	114	680	199	299
42	12	18	280	82	123	700	205	308
48	14	21	300	88	132	720	211	317
54	16	24	320	94	141	740	217	325
60	18	26	340	100	150	760	223	334
66	19	29	360	106	158	780	229	343
72	21	32	380	111	167	800	235	352
78	23	34	400	117	176	840	246	369
84	25	37	420	123	185	880	258	387
90	26	40	460	135	202	920	270	405
96	28	42	480	141	211	960	281	422
100	29	44	500	147	220	1000	293	440

Table C-6: May Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take
2	26	39
4	52	78
6	78	117
8	104	156
10	130	196
12	156	235
14	182	274
16	209	313
18	235	352
20	261	391
22	287	430
24	313	469
26	339	508
28	365	547
30	391	587
34	443	665
38	495	743
42	547	821
48	626	938
54	704	1056
60	782	1173
66	860	1290
72	938	1408
78	1017	1525
84	1095	1642
90	1173	1760
96	1251	1877
100	1303	1955

FMWT Index	Concern Level	Incidental Take
102	1329	1994
104	1356	2033
106	1382	2072
108	1408	2112
110	1434	2151
120	1564	2346
130	1694	2542
140	1825	2737
150	1955	2933
160	2085	3128
170	2216	3324
180	2346	3519
190	2476	3715
200	2607	3910
220	2868	4301
240	3128	4692
260	3389	5083
280	3650	5474
300	3910	5865
320	4171	6256
340	4432	6647
360	4692	7038
380	4953	7429
400	5214	7821
420	5474	8212
460	5996	8994
480	6256	9385
500	6517	9776

FMWT Index	Concern Level	Incidental Take
502	6543	9815
504	6569	9854
506	6595	9893
510	6647	9971
520	6778	10167
530	6908	10362
540	7038	10558
550	7169	10753
560	7299	10949
570	7429	11144
580	7560	11340
590	7690	11535
600	7821	11731
620	8081	12122
640	8342	12513
660	8603	12904
680	8863	13295
700	9124	13686
720	9385	14077
740	9645	14468
760	9906	14859
780	10167	15250
800	10427	15641
840	10949	16423
880	11470	17205
920	11991	17987
960	12513	18769
1000	13034	19551

Table C-7: June Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	66	99	102	3369	5053	502	16578	24868
4	132	198	104	3435	5152	504	16644	24967
6	198	297	106	3501	5251	506	16711	25066
8	264	396	108	3567	5350	510	16843	25264
10	330	495	110	3633	5449	520	17173	25759
12	396	594	120	3963	5944	530	17503	26255
14	462	694	130	4293	6440	540	17833	26750
16	528	793	140	4623	6935	550	18164	27245
18	594	892	150	4954	7431	560	18494	27741
20	660	991	160	5284	7926	570	18824	28236
22	727	1090	170	5614	8421	580	19154	28732
24	793	1189	180	5944	8917	590	19485	29227
26	859	1288	190	6275	9412	600	19815	29722
28	925	1387	200	6605	9907	620	20475	30713
30	991	1486	220	7265	10898	640	21136	31704
34	1123	1684	240	7926	11889	660	21796	32695
38	1255	1882	260	8586	12880	680	22457	33685
42	1387	2081	280	9247	13870	700	23117	34676
48	1585	2378	300	9907	14861	720	23778	35667
54	1783	2675	320	10568	15852	740	24438	36657
60	1981	2972	340	11228	16843	760	25099	37648
66	2180	3269	360	11889	17833	780	25759	38639
72	2378	3567	380	12549	18824	800	26420	39630
78	2576	3864	400	13210	19815	840	27741	41611
84	2774	4161	420	13870	20806	880	29062	43593
90	2972	4458	460	15191	22787	920	30383	45574
96	3170	4756	480	15852	23778	960	31704	47556
100	3302	4954	500	16512	24769	1000	33025	49537

Table C-8: July Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take
2	75	112
4	150	225
6	225	337
8	300	450
10	375	562
12	450	674
14	525	787
16	599	899
18	674	1012
20	749	1124
22	824	1236
24	899	1349
26	974	1461
28	1049	1574
30	1124	1686
34	1274	1911
38	1424	2136
42	1574	2360
48	1798	2698
54	2023	3035
60	2248	3372
66	2473	3709
72	2698	4046
78	2922	4384
84	3147	4721
90	3372	5058
96	3597	5395
100	3747	5620

FMWT Index	Concern Level	Incidental Take
102	3822	5732
104	3897	5845
106	3971	5957
108	4046	6070
110	4121	6182
120	4496	6744
130	4871	7306
140	5245	7868
150	5620	8430
160	5995	8992
170	6369	9554
180	6744	10116
190	7119	10678
200	7493	11240
220	8243	12364
240	8992	13488
260	9741	14612
280	10491	15736
300	11240	16860
320	11989	17984
340	12739	19108
360	13488	20232
380	14237	21356
400	14987	22480
420	15736	23604
460	17235	25852
480	17984	26976
500	18733	28100

FMWT Index	Concern Level	Incidental Take
502	18808	28213
504	18883	28325
506	18958	28437
510	19108	28662
520	19483	29224
530	19857	29786
540	20232	30348
550	20607	30910
560	20981	31472
570	21356	32034
580	21731	32596
590	22105	33158
600	22480	33720
620	23229	34844
640	23979	35968
660	24728	37092
680	25477	38216
700	26227	39340
720	26976	40464
740	27725	41588
760	28475	42712
780	29224	43836
800	29973	44960
840	31472	47208
880	32971	49456
920	34469	51704
960	35968	53952
1000	37467	56200