

nine sloughs with an otter trawl that drags along the bottom and samples much of the water column in the shallow sloughs. In small sloughs, the trawl samples much of the cross sectional area; in large sloughs, the sampling fraction is smaller. A monthly abundance index is calculated as mean catch per trawl. The annual abundance index is calculated as the mean of the monthly index values (Sommer *et al.* 1997). While the splittail catches are dominated by YOY, the sampling also consistently catches larger fish. In this regard, the Suisun Marsh OT sampling of splittail is perhaps the most thorough of the various sampling programs. Splittail collection in the Marsh is enhanced by reduced gear avoidance in narrow, relatively shallow sloughs sampled as part of the monthly survey. In such conditions, the net samples a larger proportion of the channel cross sectional area than in any other survey. Larger sizes of splittail, however, apparently become progressively less vulnerable to the trawls, a limitation shared by all trawl-based surveys. Spawning occurs only sporadically in the marsh, and in most years YOY recruit from upstream in the Sacramento River, including the bypasses (Sommer *et al.* 1997). Recent modeling studies indicate that the Yolo Bypass, a major spawning and nursery area, may be hydrologically connected to Suisun Marsh (N. Monsen, Stanford University, unpubl. data) so juvenile trends in the marsh are likely to be heavily influenced by upstream production in the Yolo Bypass during those years when inundated for a sufficient period of time. Suisun Marsh Otter Trawl data from 1980 through 2001 was used in our abundance analysis.

Chippis Island Survey

The U.S. Fish and Wildlife Service conducts a sampling program for juvenile salmon in the deep water channel near Chippis Island at the western terminus of the Delta. A midwater trawl is pulled at the surface in ten 20 minute hauls per day during May and June (Sommer *et al.* 1997). Data are compiled to produce an index based on the catch per hour of trawling for the months of May and June combined (Sommer *et al.* 1997). The program was initiated in 1975, but data before 1979 must be viewed with some caution as many splittail were not measured (Baxter 1999a); as only data related to the number of splittail caught were recorded. Length data from 1987 through 1993 was recorded such that determinations of age from the data cannot be done, and is therefore inadequate to calculate age-specific

abundance indices. The Age 0 index reached minor peaks in 1982 and 1986, declined to low levels during the 1987–1992 drought (based on total splittail catch), then increased sharply to a record level in 1995; minor peaks occurred in 1998 and 2000, and remaining data tracked water year variability. For Age 1 splittail, the Chippis Island index for the period 1976 to 2001 shows high variability.

The Chippis Island trawl seems to sample splittail best in high outflow years when all age groups are more vulnerable to trawls due to increased turbidity, as is likely true for all gear types and surveys. It is, however, difficult to discern actual abundance from year biases, and turbidity can be high at Chippis Island regardless of outflow. Regardless, because the trawl captures fish only in the top couple of meters (or yards) of water in open channels, relatively low numbers of the benthic-foraging splittail are caught. The indices are probably less precise at low population levels due to the infrequent captures of splittail, a characteristic shared by all surveys. The Chippis Island Survey data from 1976 through 2002 was used in our abundance analysis.

Central Valley and State Water Project (CVP and SWP) Fish Salvage

The CVP and SWP operate fish screening facilities to divert fish away from the pump intakes into holding facilities where they are counted, measured, and released. Data collection takes place at two hour intervals when the pumps are operating. Consequently, the fish salvage operations provide the highest number of splittail caught per survey, but the number of data points (annual indices) is comparable to the other surveys. All splittail age groups are collected, the surveys do not suffer from gear avoidance by fish, and sampling locations do not vary over time. Reliable CVP data and SWP data both start in 1979. The salvage abundance index is calculated based on the total number of fish salvaged divided by the volume of water pumped (Sommer *et al.* 1997). However, the pumps are not operated as sampling programs *per se* so the amount of “sampling” is related to the amount of water exported, which in turn is related to the amount of water available, water demand, and, in recent years, changes in pump operations to protect migratory salmon, splittail, and delta smelt (*Hypomesus transpacificus*) and to maintain appropriate salinities in Suisun Bay and Marsh. Also, the Salvage index does not address catch per volume per unit time. Lacking a time factor, the Salvage index may not

adequately describe the differential variability in catch that may occur as approach velocities at Clifton Court Forebay (SWP) or Old River (CVP) change.

Unlike the CVP and SWP salvage, several surveys do not account for the volume per unit time sampled. Trawl data, presented as fish captured per volume of water sampled, do not describe the trawl speed, or the perceived trawl approach speed when pulled against a current. Seine indices are expressed as catch of fish per haul and do not include factors for catch per unit volume and/or per unit time. Seines are employed at sites with low water velocities, but variation in velocity within and between sampling locations likely exists. Trawls and seines may be more effective when employed through higher velocity waters; splittail may be more vulnerable to capture when already navigating swifter currents. Trawls, seines, and pumps therefore share a common difficulty in expressing catch per unit volume per unit time. Each of these techniques may also differentially detect splittail under turbid conditions. The pumps differ from trawling and seining, however, in that the pumps may differentially entrain (collect) weak swimming juvenile and fatigued post-spawn adult splittail as velocities towards the facilities vary. Regardless of boat or current speed, or turbidity, trawls and seines do not draw fish towards them, whereas the pumps may. The SWP catch also does not account for the predation that occurs in the Clifton Court Forebay, nor the latent mortality that may occur when salvaged fish are released.

Comparisons between CVP and SWP salvage and other sampling operations have to be made with caution. Nevertheless, the general patterns are similar to other studies, with diminished catches of both adults and juveniles during periods of drought and large catches of juveniles following wet winters. The CVP and SWP fish salvage data from 1979 through 2002 was used in our abundance analysis.

Surveys Not Employed in Abundance Analyses

US Fish and Wildlife Service Beach Seine Survey

The survey provides the broadest geographical coverage of all of the sampling programs but is focused on outmigrating juvenile salmonids. The beach seine primarily captures YOY splittail but any fish less than 25 mm (1 in) long are not identified. The limited data show low catches of splittail during