FIGURES

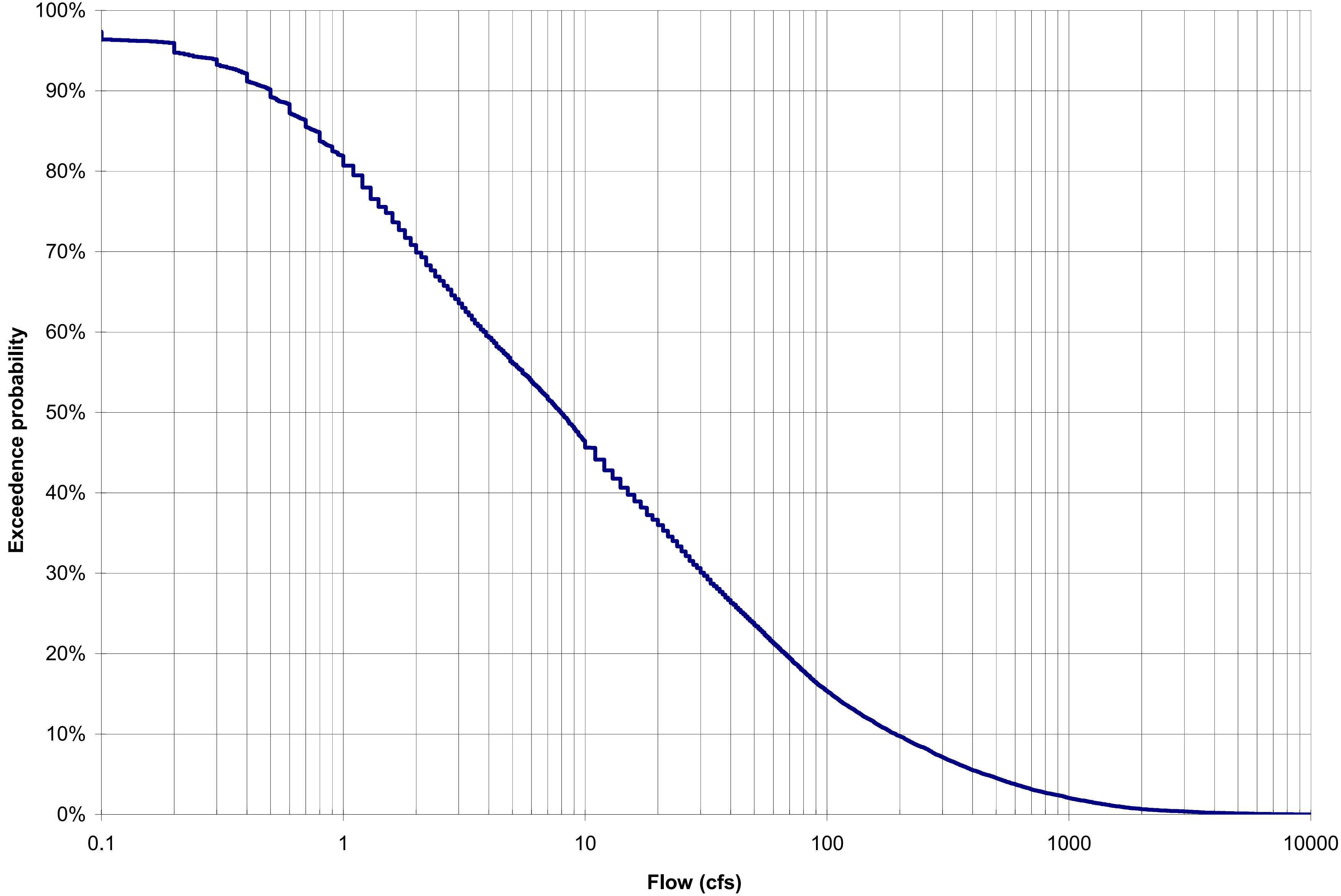

Figure 3-1. Flow duration curve for the USGS Napa River at St. Helena gage (number 11456000) from water year 1940 to 1995.

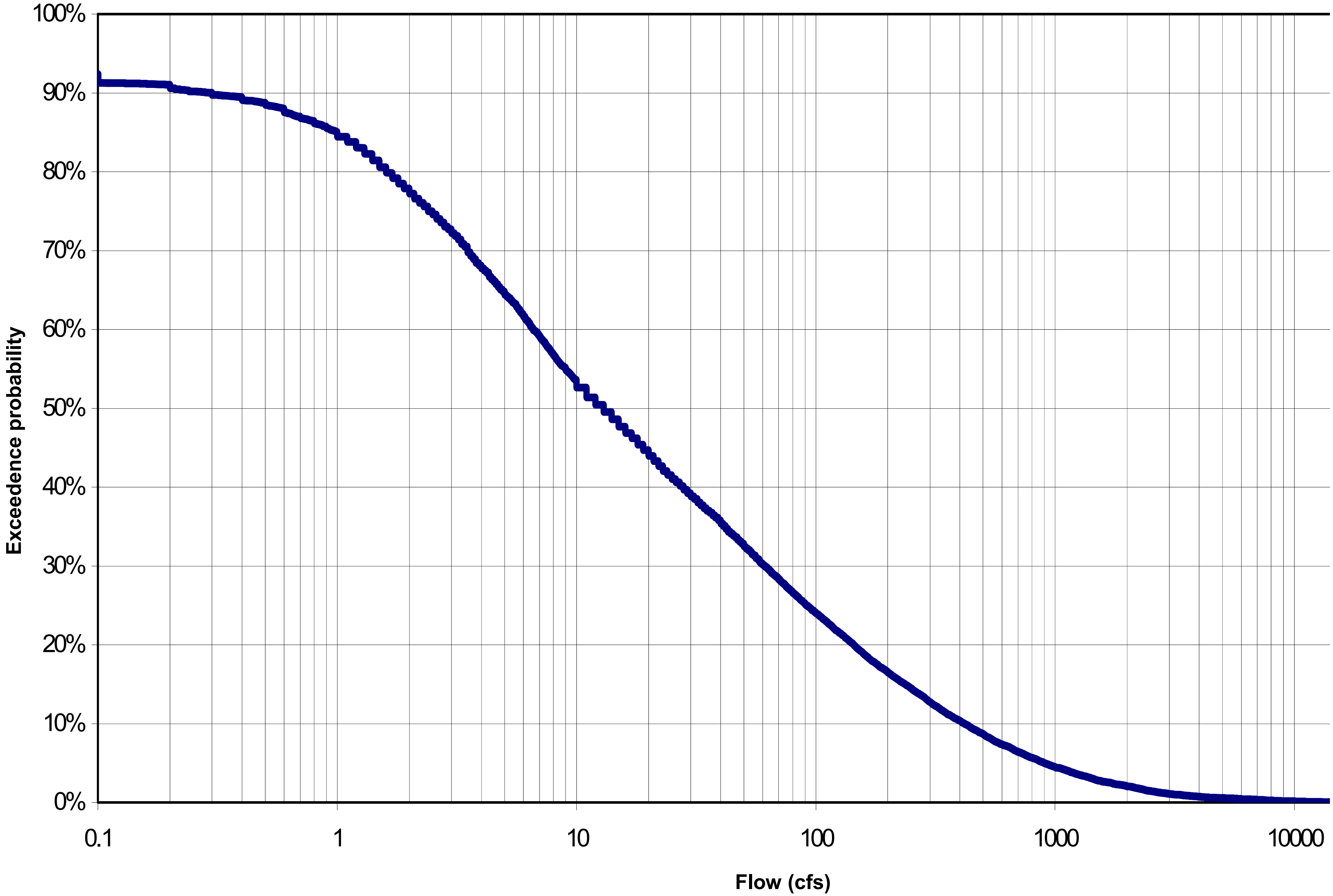

Figure 3-2. Flow duration curve for the USGS Napa River at Napa gage (number 11456000) for water year 1930-1932 and 1960 to 2000.

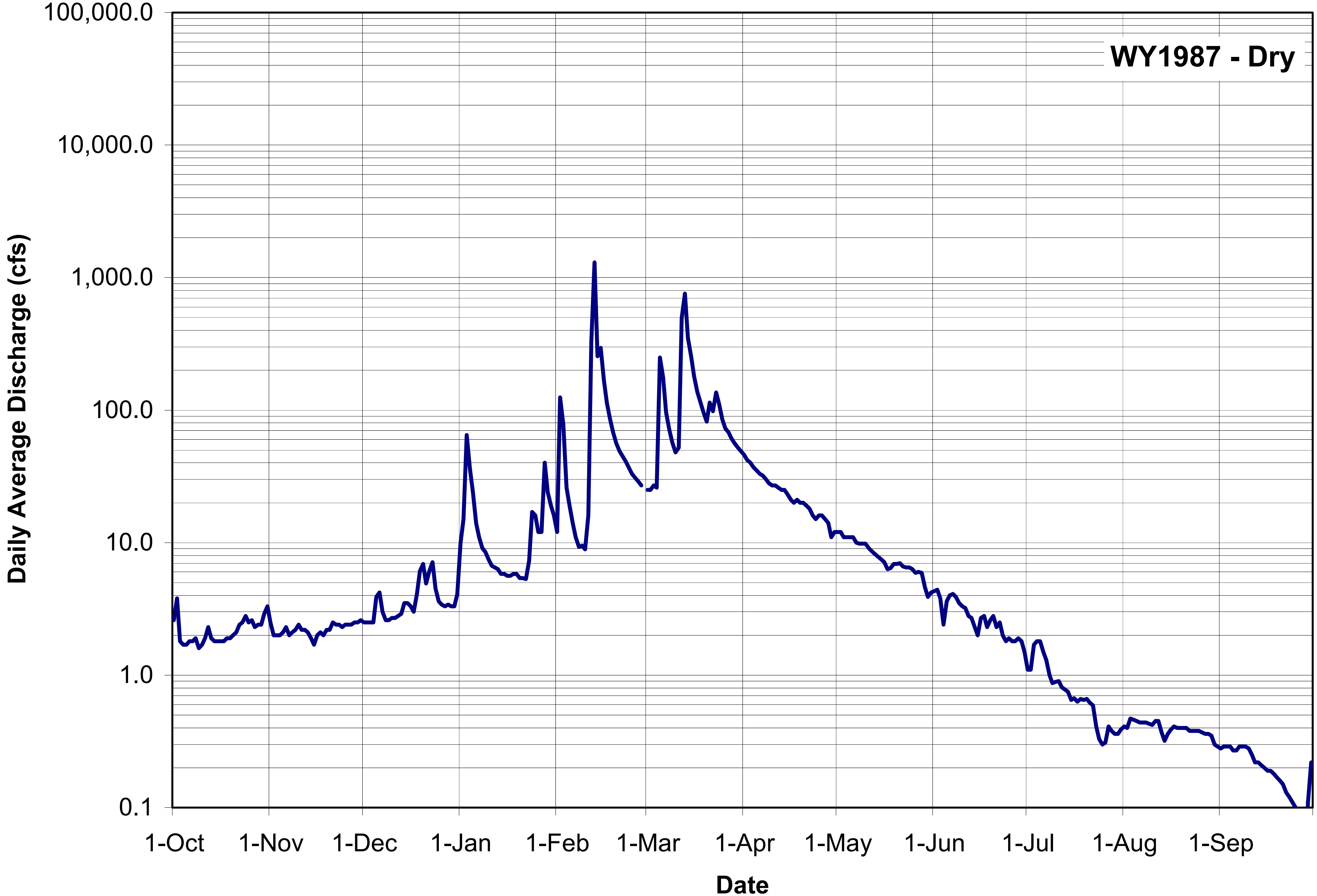

Figure 3-3. Typical daily average hydrograph for a dry water year (WY 1987) at the USGS Napa near St. Helena gage (number 11456000).

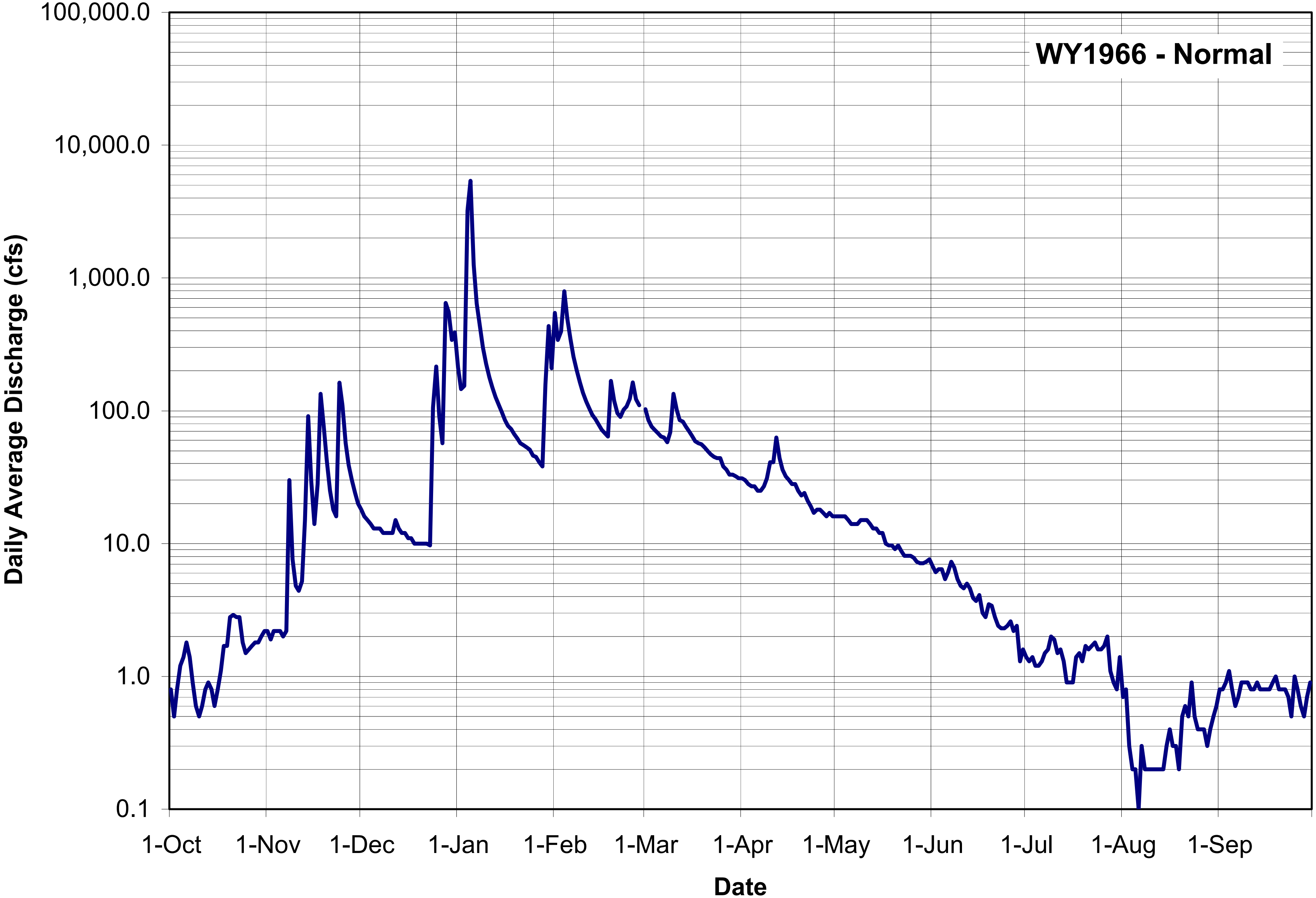

Figure 3-4. Typical daily average hydrograph for a normal water year (WY 1966) at the USGS Napa near St. Helena gage (number 11456000).

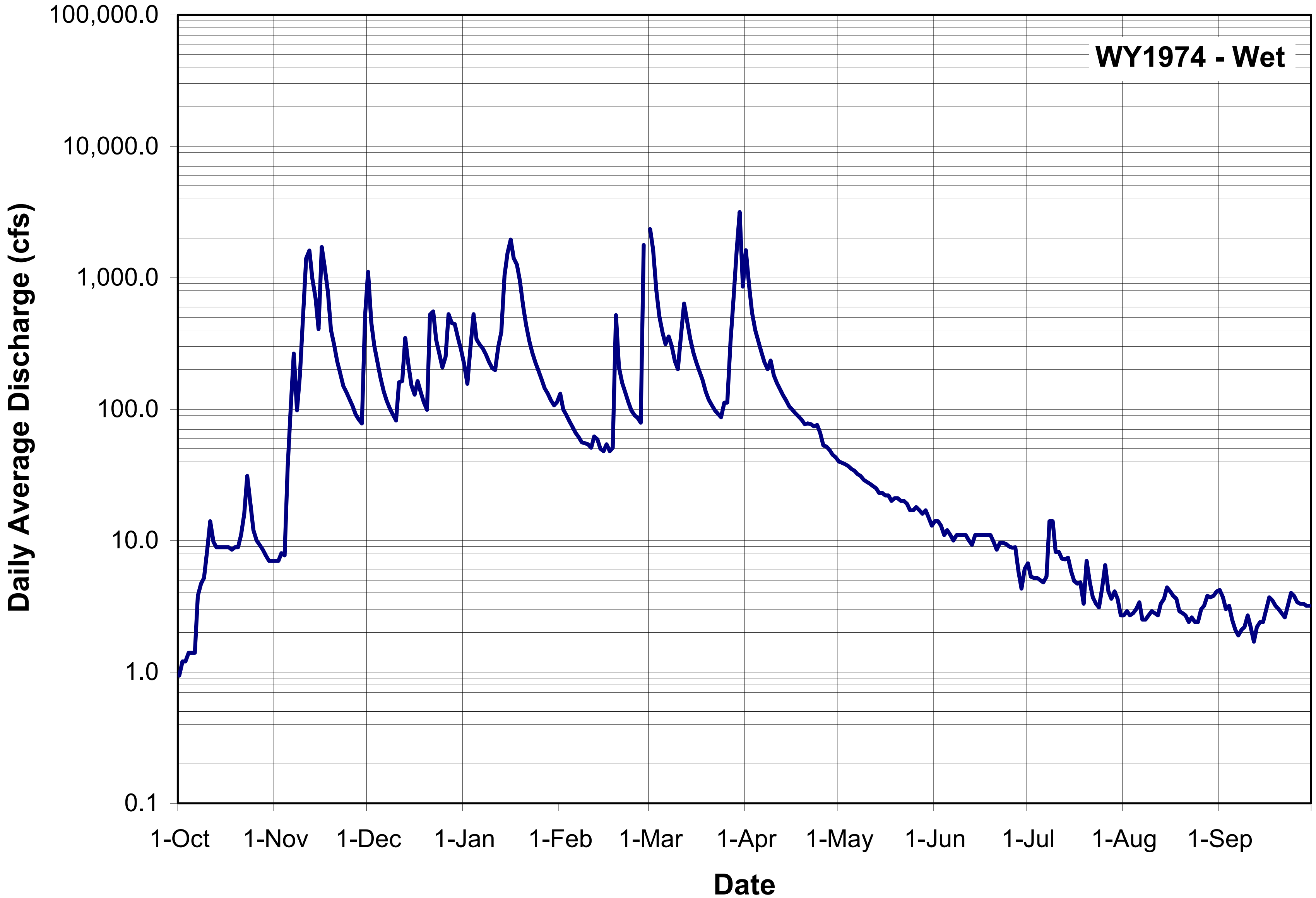

Figure 3-5. Typical daily average hydrograph for a wet water year (WY 1974) at the USGS Napa near St. Helena gauge (number 11456000).

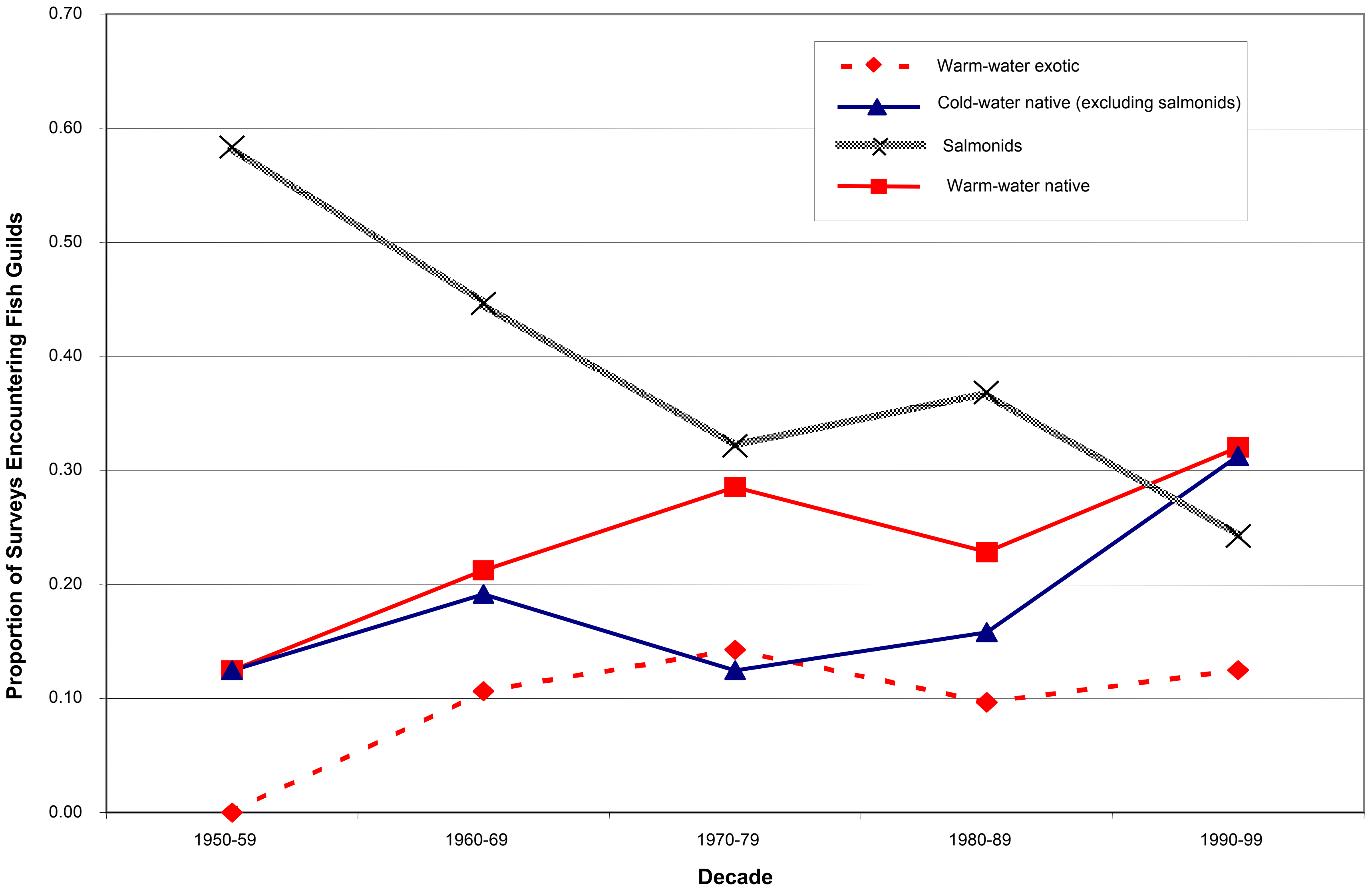

Figure 3-6. The average proportion of surveys encountering particular fish guilds (warm-water exotic species, cold-water native species excluding salmonids, salmonids, and warm-water natives) in the mainstem and tributaries of Napa River, by decade.

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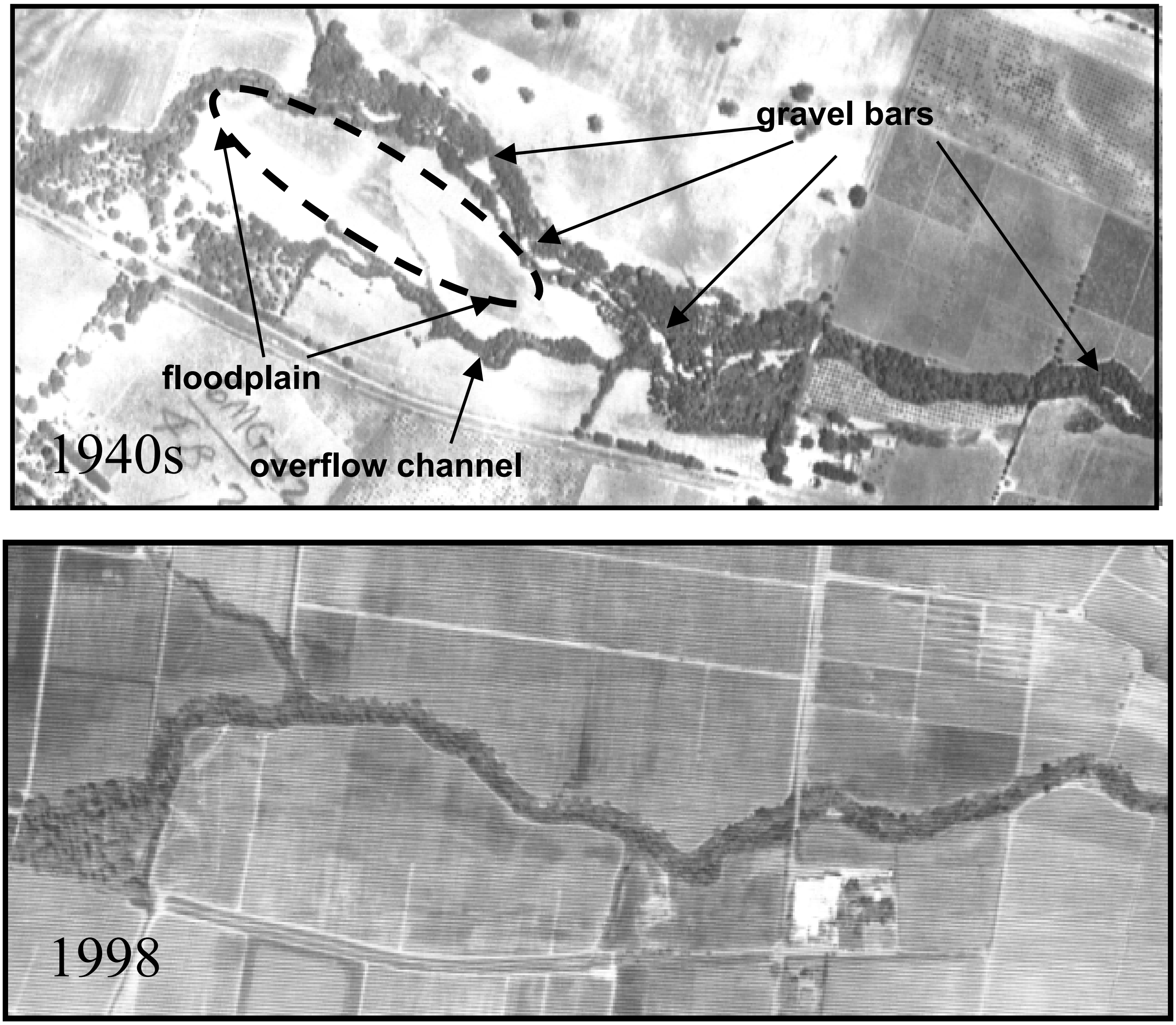

Figure 6-1a. Comparison of early 1940s and 1998 aerial photographs of the mainstem Napa River, north of Ritchie Creek. In the 1940s, the channel was characteristic of a wandering stream, with a single-thread channel with low sinuosity, and some reaches with mid-channel bars and islands. The channel in the 1940 aerial photograph was still connected to a relatively large, active floodplain with a well-defined overflow channel, which likely provided backwater rearing habitat for chinook salmon and steelhead.

The 1998 aerial photograph depicts a simplified channel where the channel has narrowed and has apparently abandoned its floodplain (note the lack of evidence of the previous overflow channel). These changes are most likely due to a combination of channel incision, levee construction, dam construction upstream and resulting loss of coarse sediment input, and LWD removal.

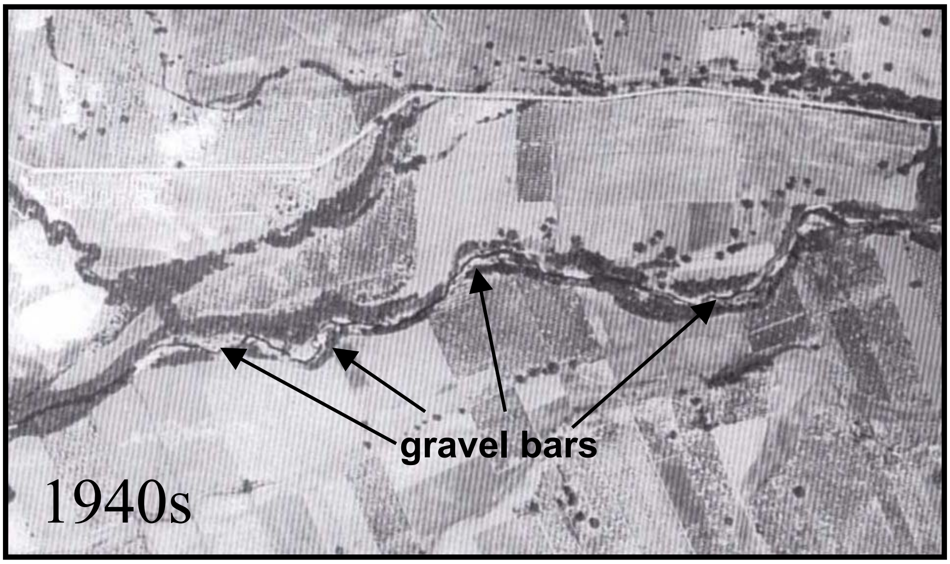

Figure 6-1b. Comparison of early 1940s and 1998 aerial photographs of lower mainstem Napa River near Soda Creek. This site, on the lower mainstem, near the present zone of tidal influence, shows many changes similar to those seen on the mainstem near Ritchie Creek (Figure 6-1a). In the 1940s photograph, alluvial gravel features were abundant and the channel had a bar-pool morphology. In the 1998 aerial photographs, the gravel features are absent and the channel has been narrowed and straightened.

The 1940s photo does not show significant high flow channels as was evident near Ritchie Creek (Figure 6-1a). This may be because the channel has greater flood conveyance capacity in this reach, but it could also be an indication that land use changes had already caused the floodplain to be abandoned in the lowermost reaches of the mainstem by the time the early photo was taken.

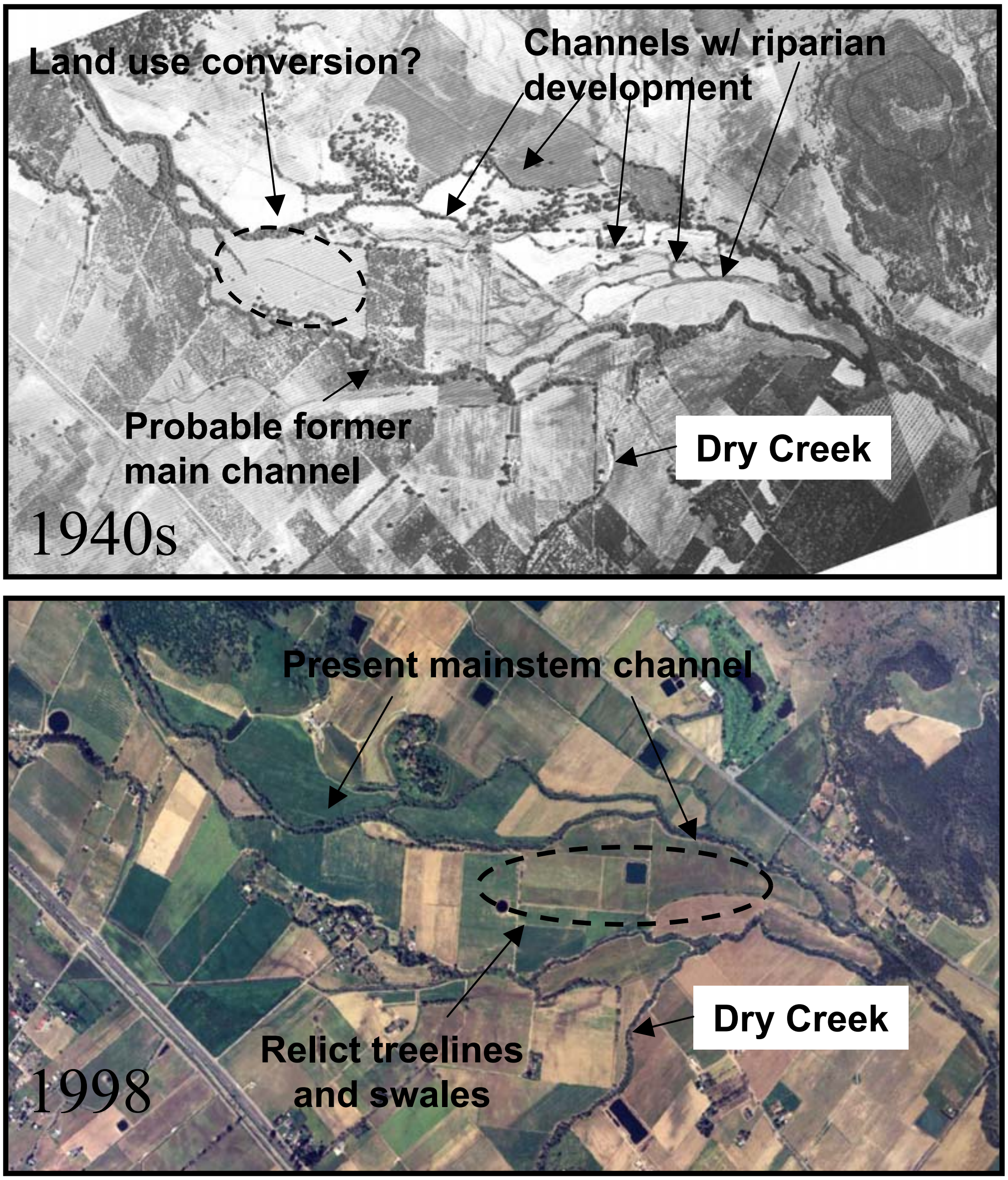

Figure 6-1c. Comparison of early 1940s and 1998 aerial photographs of the mainstem Napa River in the vicinity of the Dry Creek confluence. The 1940s photograph shows that the mainstem occupied multiple channels in this reach with a possible single low-flow channel (judging by greatest development of the riparian zone) on the western side of the valley floor. However, many of these channels show evidence of significant riparian development, indicating that they experienced flows frequently. The 1940s photo also appears to show that some land conversion had already occurred in the upstream portion of the reach, where evidence of multiple channels seems to be erased.

The present course of the mainstem is substantially simplified and occupies a single channel on the opposite side of the valley floor. Channel complexity has been entirely eliminated except for a small bifurcated reach that is probably active intermittently. These changes are almost certainly due to entrenchment of the mainstem and the resultant concentration of flows of the main channel. The only trace of former channels is relict treelines and swales occurring on land presently under agricultural use.

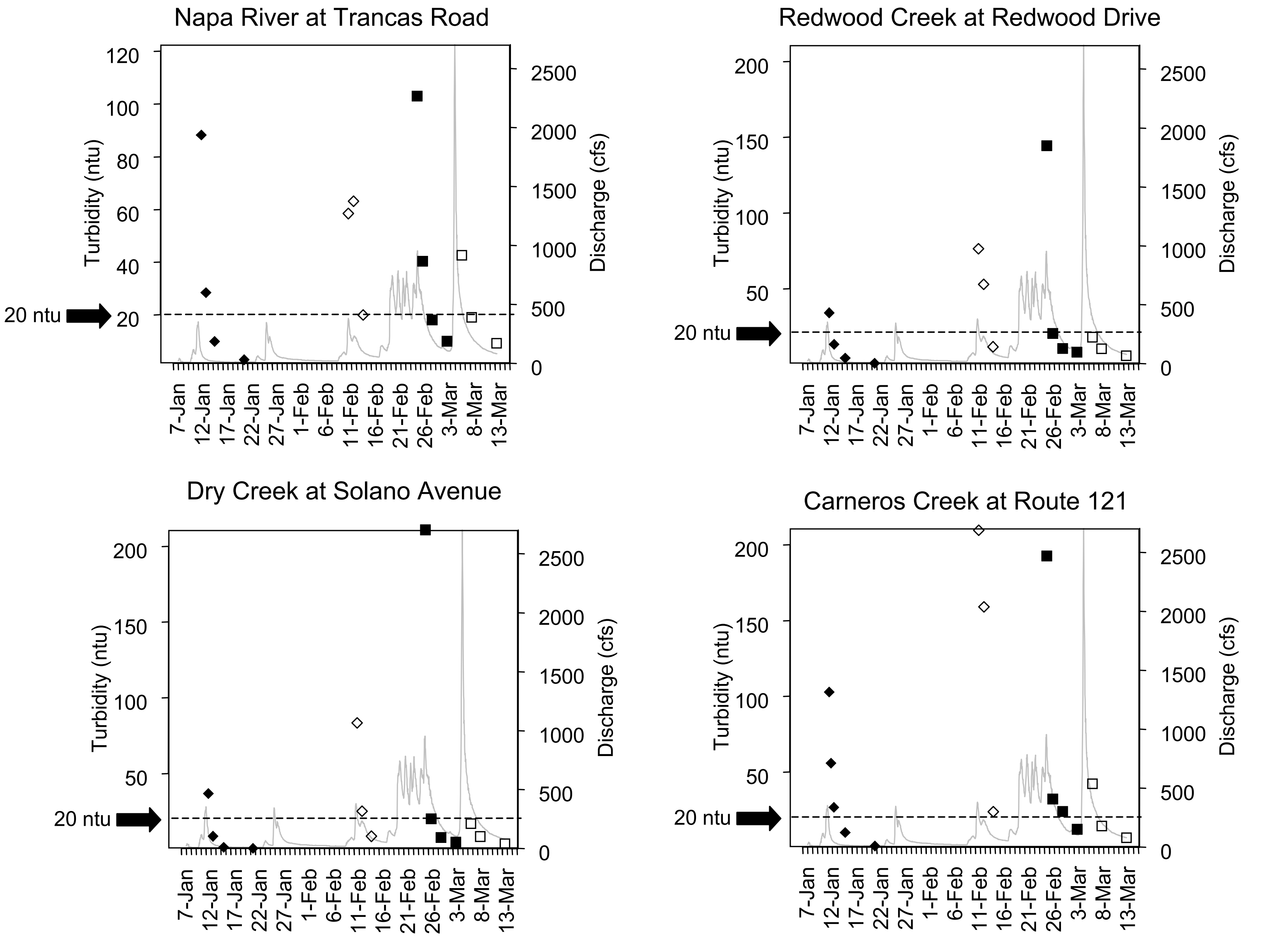

Figure 6-2. Turbidity and discharge measurements at four of the 24 sites sampled within the Napa River watershed in 2001. 20 NTU, the conservative threshold value for potential impacts to fish used in this analysis, is indicated with ➡. ◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

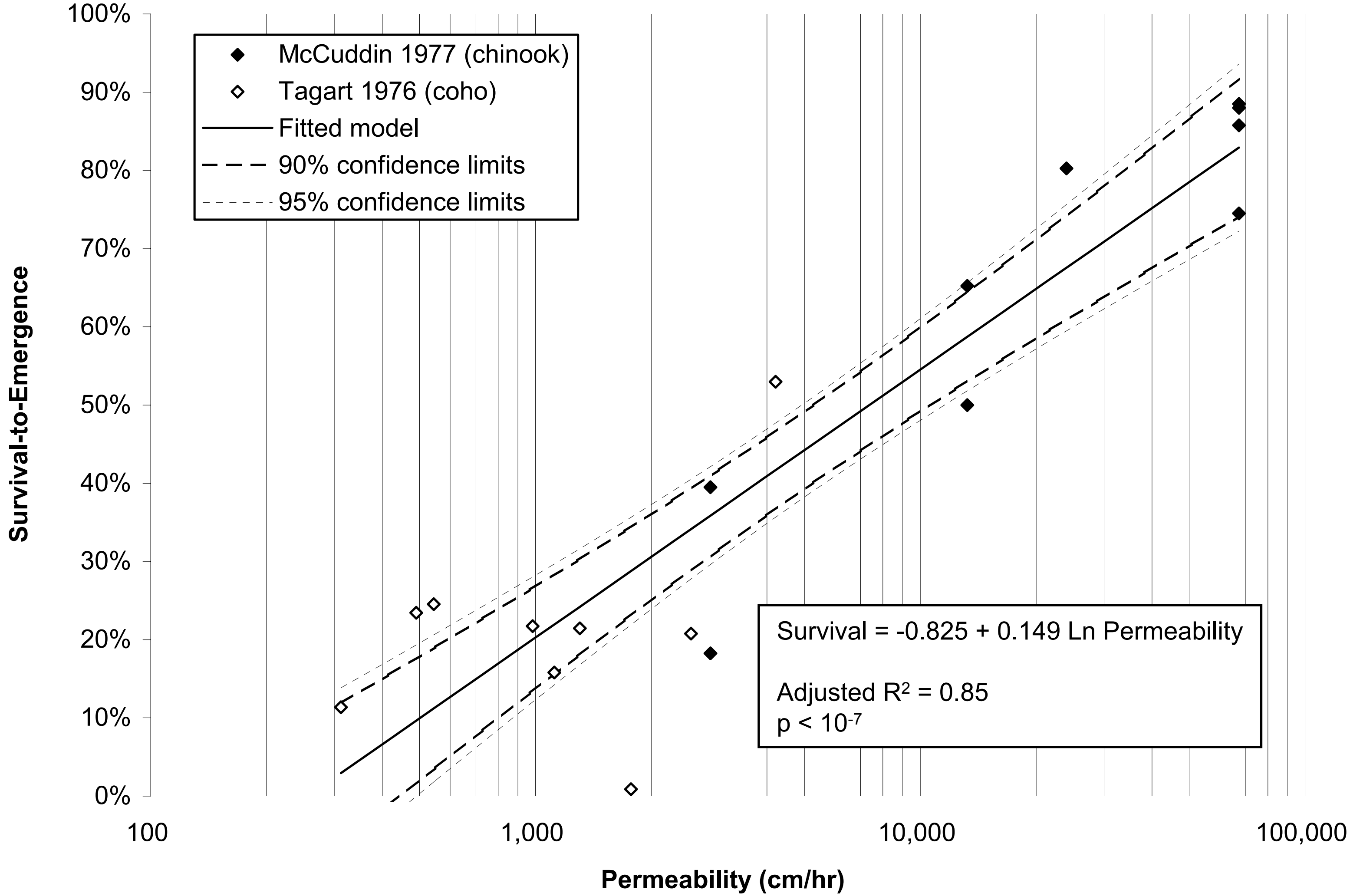

Figure 6-3: The egg survival-to-emergence index used to interpret the relative impact of measured permeability on steelhead production is based on the regression derived from data collected by Tagart 1976 for coho salmon and McCuddin (1977) for chinook salmon.

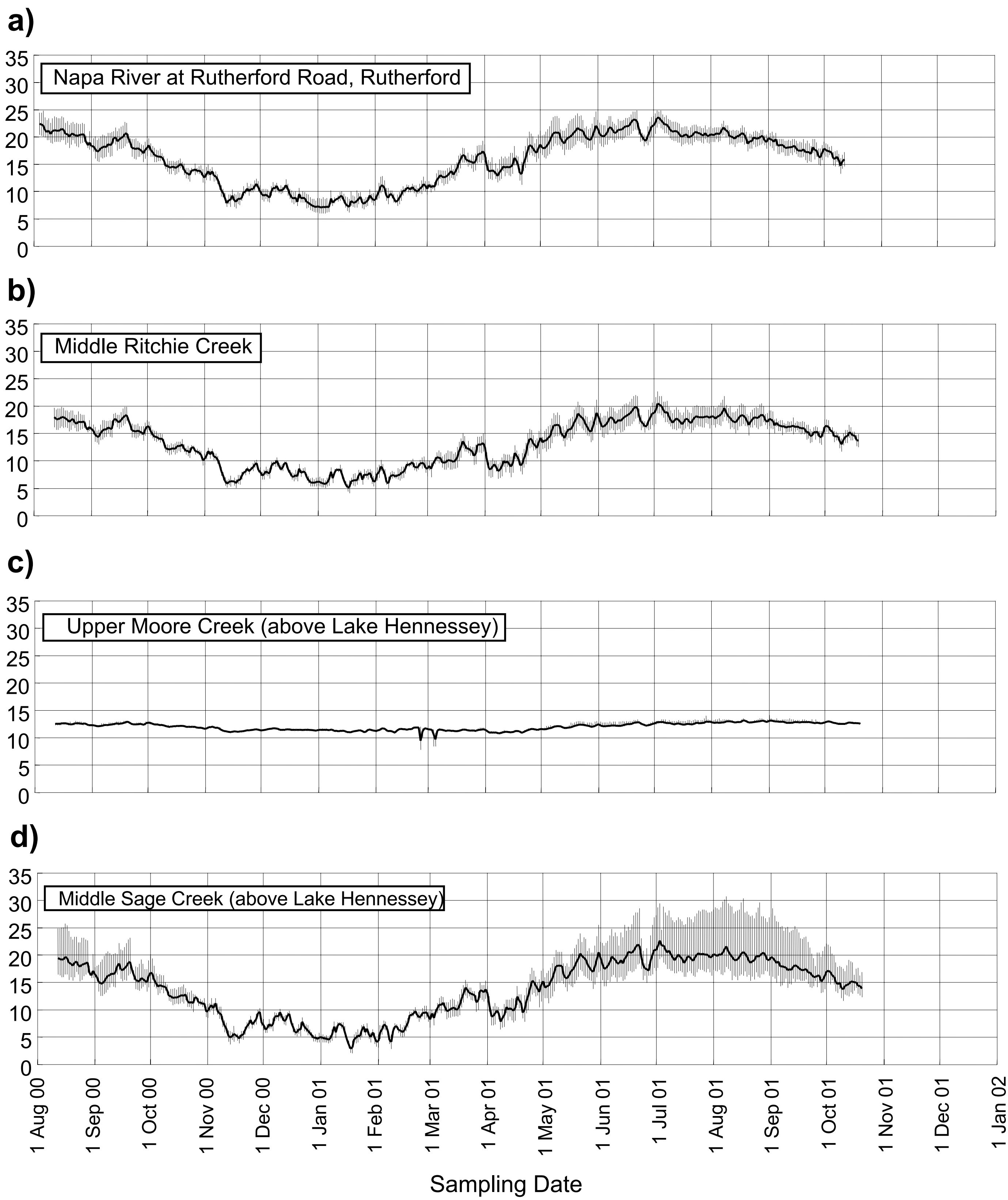

Figure 6-4. Water temperature sampled by continuous recording thermographs at four sites within the Napa River watershed at (a) Napa River at Rutherford Road, (b) Middle Ritchie Creek, (c) Upper Moore Creek, above Lake Hennessey, and (d) Middle Sage Creek, above Lake Hennessey.

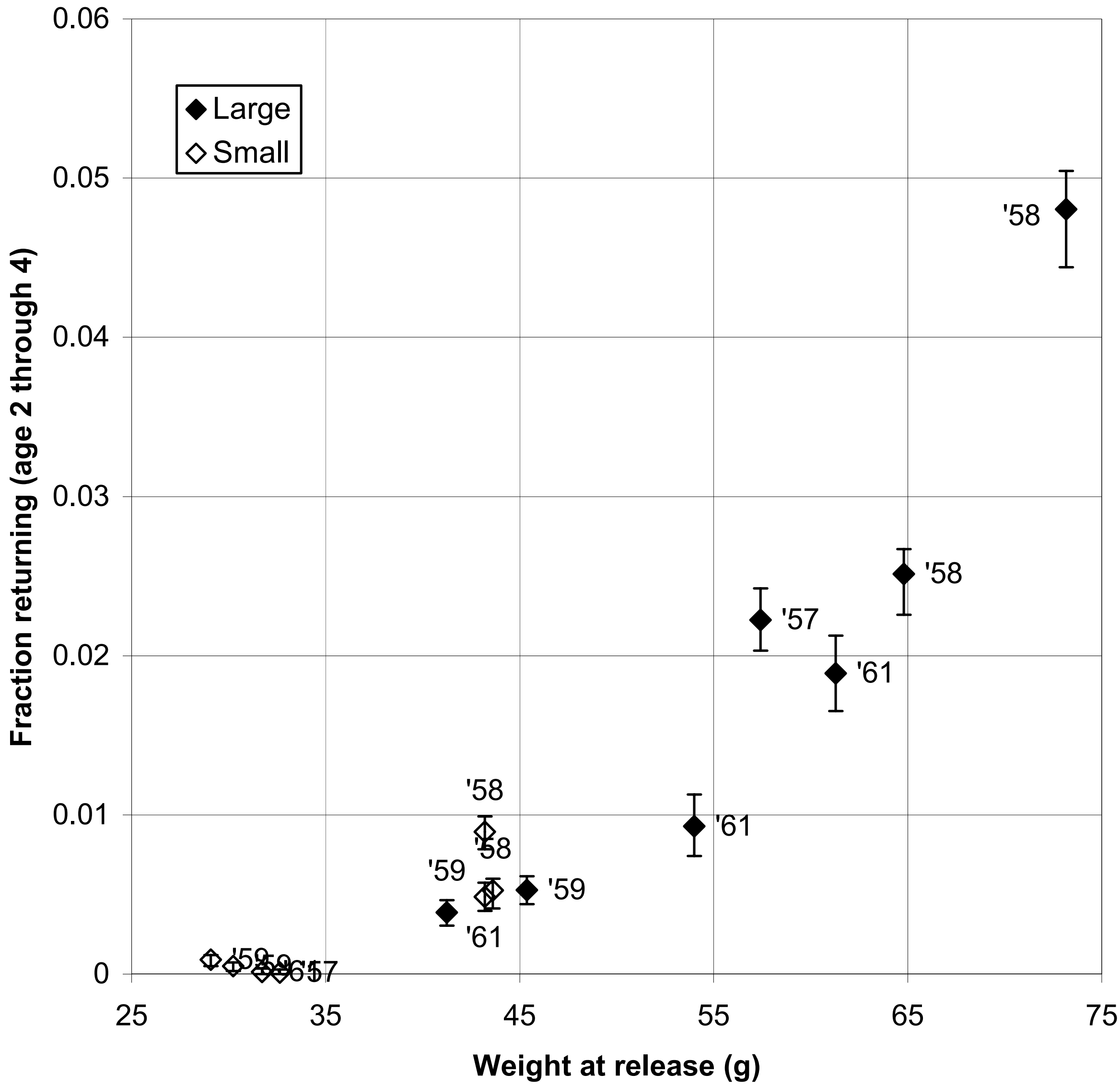

Figure 6-5. Results of a mark-recapture study on the Eel River, a coastal stream in Mendocino County, that divided cohorts of steelhead hatchery smolts into groups of small versus large individuals and evaluated the probability of return of groups of the different size groups released between 1957 and 1961. Results show an exponential relationship between smolt size at the time of outmigration and the chances of successful return as an adult, indicating that increased size at time of smolting strongly increases the probability of successful return to the system as an adult.

In light of these data, the potentially limited feeding opportunities in the Napa River system that result from drying of riffles and elevated temperatures led to the hypothesis that reduced juvenile growth could dramatically reduce the number of returning adults.

(Source: Kabel and German 1967)

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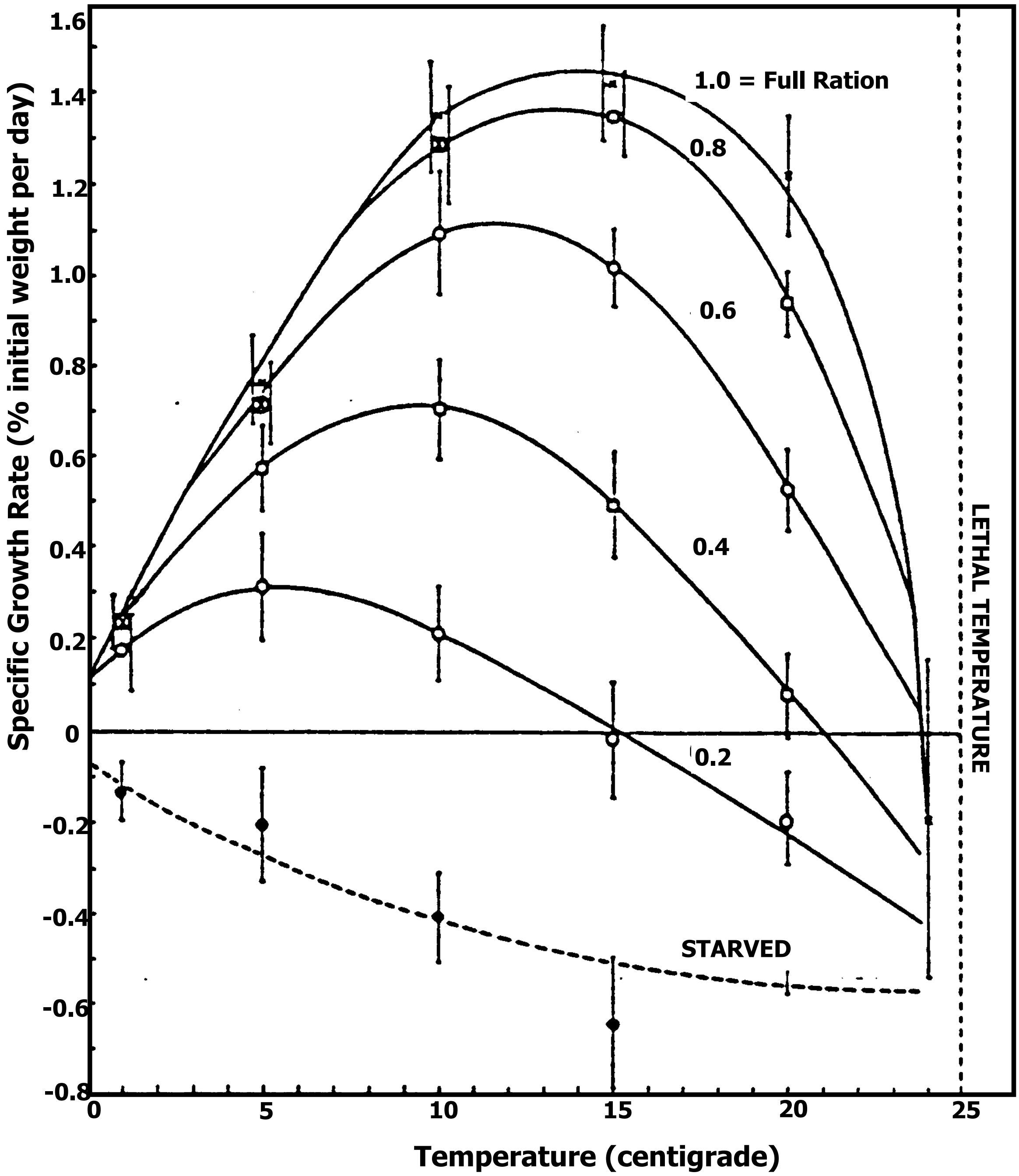

Figure 6-6. The effects of water temperature and food availability on steelhead growth, based on studies by Brett et al. (1969). Sockeye salmon juveniles were held at a variety of temperatures and groups at each temperature were fed different food quantities. During this laboratory experiment, increased temperatures resulted in increased growth rate up to some optimal point, beyond which growth rates declined. At all ration levels, the optimal temperature was 15 °C or lower, and at very low ration levels, temperatures common to tributaries in the Napa Basin (i.e., >15 °C) were sufficient to result in growth rates near zero or actual weight loss.

(Source: Brett et al. 1969)

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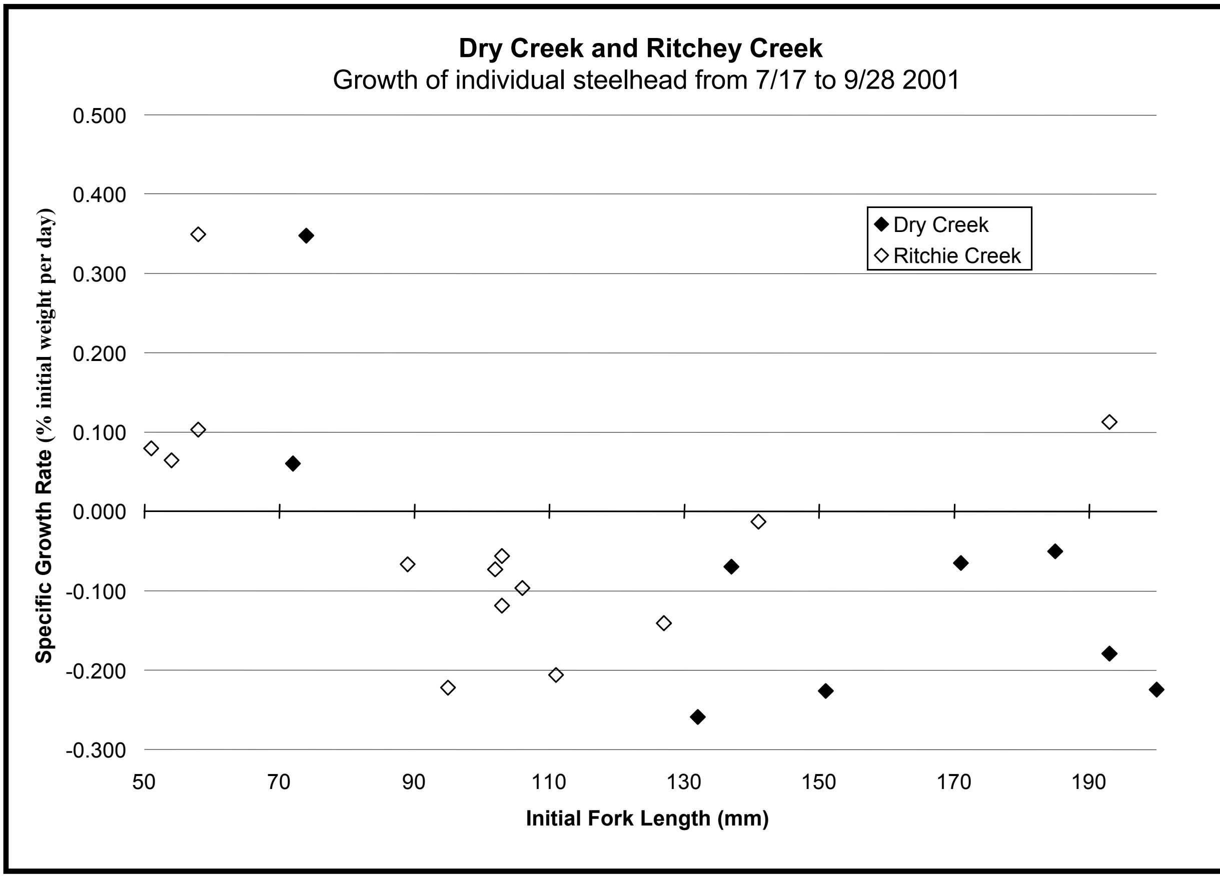
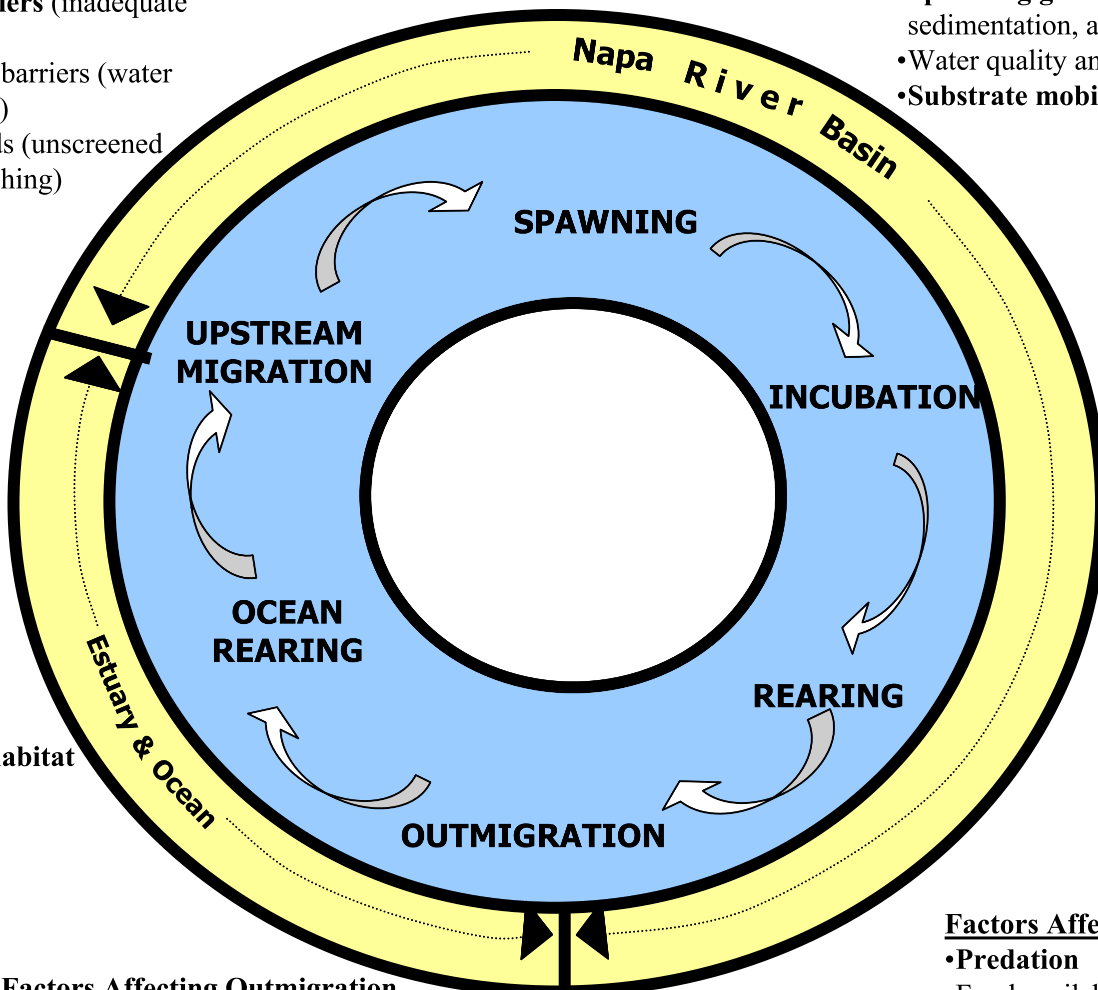


Figure 6-7. Results of juvenile steelhead summer growth pilot study. To explore whether warm temperatures and low food supply to pools from upstream riffles have an impact on summer growth of steelhead, we conducted a pilot study between July and late September 2001 on Ritchie Creek and Dry Creek, on the western side of the Napa River watershed. These tributaries were selected to represent different levels of riffle/pool connectivity, with Ritchie Creek having somewhat better connectivity between riffles and pools than Dry Creek. Steelhead juveniles were captured, measured, weighed, and given individual marks, using subcutaneous elasto-polymer injections, early in the summer. At the end of summer, fish were recaptured so that changes in length and weight could be determined.

The results of this pilot study indicate that most steelhead lost a significant amount of weight over the course of the study, with only the smallest fish increasing slightly in weight. This may be because the smaller steelhead could be feeding on smaller prey (invertebrates), prey that would be energetically unprofitable for larger fish (i.e., for larger fish the energetic or metabolic cost of pursuing, capturing, and eating these small prey may be greater than the energy provided by the prey). The data suggest that steelhead may not be gaining sufficient size by the time they migrate out of the basin to the sea, possibly lowering levels of returning adult spawners. Fish growth and potential invertebrate food sources will be further explored during Phase II.

<u>Factors Affecting Upstream Migration</u>
- Attraction flows
- **Physical migration barriers** (inadequate flows)
- Environmental migration barriers (water quality, water temperature)
- Migration corridor hazards (unscreened diversions, bypasses, poaching)

<u>Factors Affecting Spawning and Incubation</u>
- **Spawning gravel quantity** and redd superimposition
- **Spawning gravel quality** (intergravel flow, sedimentation, armoring)
- Water quality and temperature
- **Substrate mobility/scouring (redd scour)**



<u>Factors Affecting Fry Rearing</u>
- **Availability of suitable stream margin and off-channel habitat for fry rearing**
- Water quality (temperature, toxics)
- **Predation**
- Displacement by high flows

<u>Factors Affecting Estuary and Ocean Rearing</u>
- **Loss of estuarine rearing habitat**
- Temperature
- Water quality
- Dissolved oxygen
- Harvest
- Ocean conditions

<u>Factors Affecting Juvenile Rearing</u>
- **Predation**
- Food availability
- Water quality and **temperature**

<u>Factors Affecting Outmigration</u>
- **Adequate flows for outmigration**
- **Water quality and temperature**
- **Predation**
- Diversion hazards

Figure 7-1. Chinook salmon life cycle and potential limiting factors in the Napa River watershed. Key limiting factors are shown in bold.

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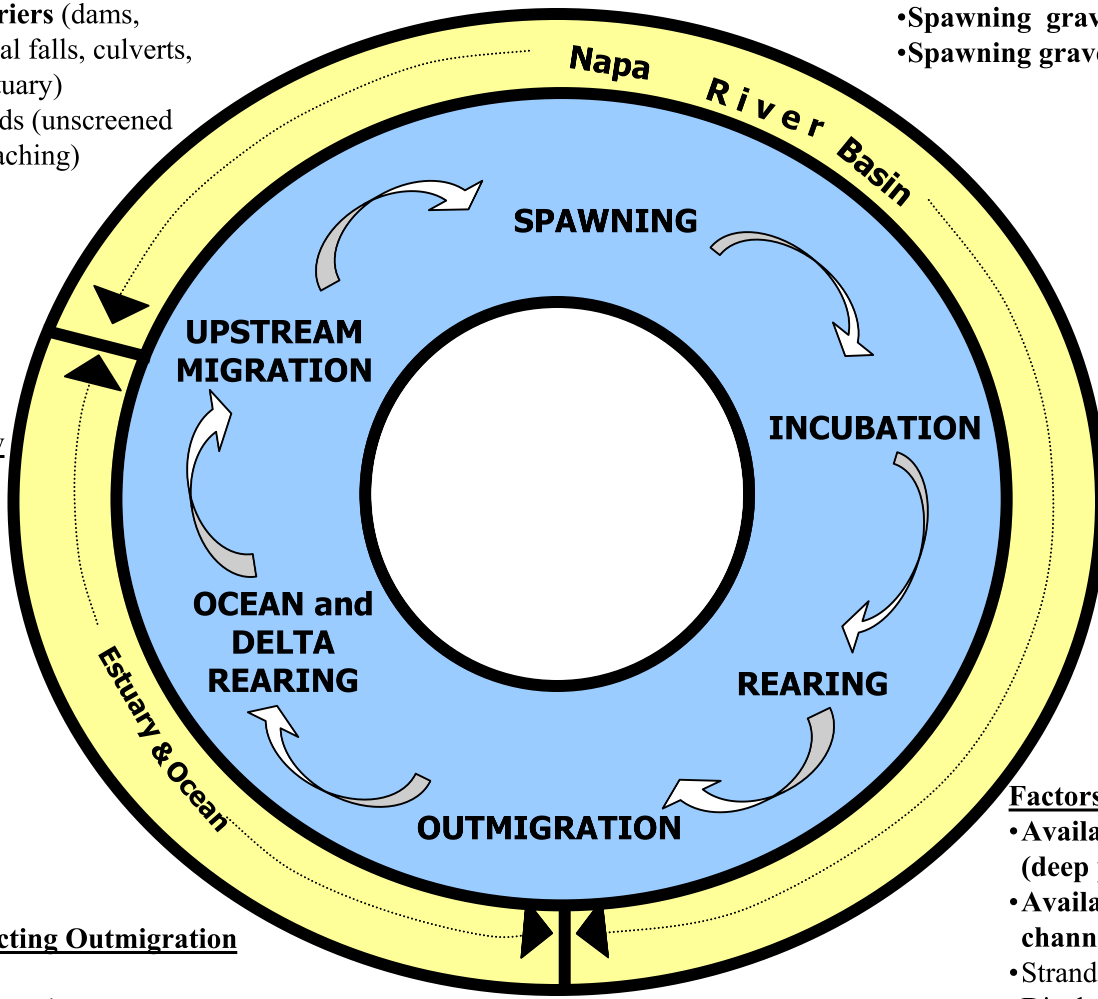
Factors Affecting Upstream Migration

- **Physical migration barriers** (dams, dewatered reaches, natural falls, culverts, sand bars at mouth of estuary)
- Migration corridor hazards (unscreened diversions, bypasses, poaching)

Factors Affecting Spawning and Incubation

- Redd dewatering
- **Spawning gravel quality (permeability)**
- **Spawning gravel mobility (redd scour)**



Factors Affecting Fry Rearing

- Proximity of fry rearing habitat to spawning areas
- Water quality (**temperature**, toxics)
- **Food availability**
- Stranding by low flows
- Displacement by high flows

Factors Affecting Estuary and Ocean Rearing

- Loss of estuarine rearing habitat
- Temperature
- Water quality
- Dissolved oxygen
- Harvest
- Ocean conditions

Factors Affecting Juvenile Rearing

- **Availability of oversummering habitat (deep pools, temperature refugia)**
- **Availability of overwintering habitat (in-channel LWD, interstitial habitat)**
- Stranding by low flows
- Displacement by high flows
- **Food availability**
- Water quality and **temperature**

Factors Affecting Outmigration

- **Predation**
- Diversion hazards

Figure 7-2. Steelhead life cycle and potential limiting factors in the Napa River watershed.
Key limiting factors are shown in bold.

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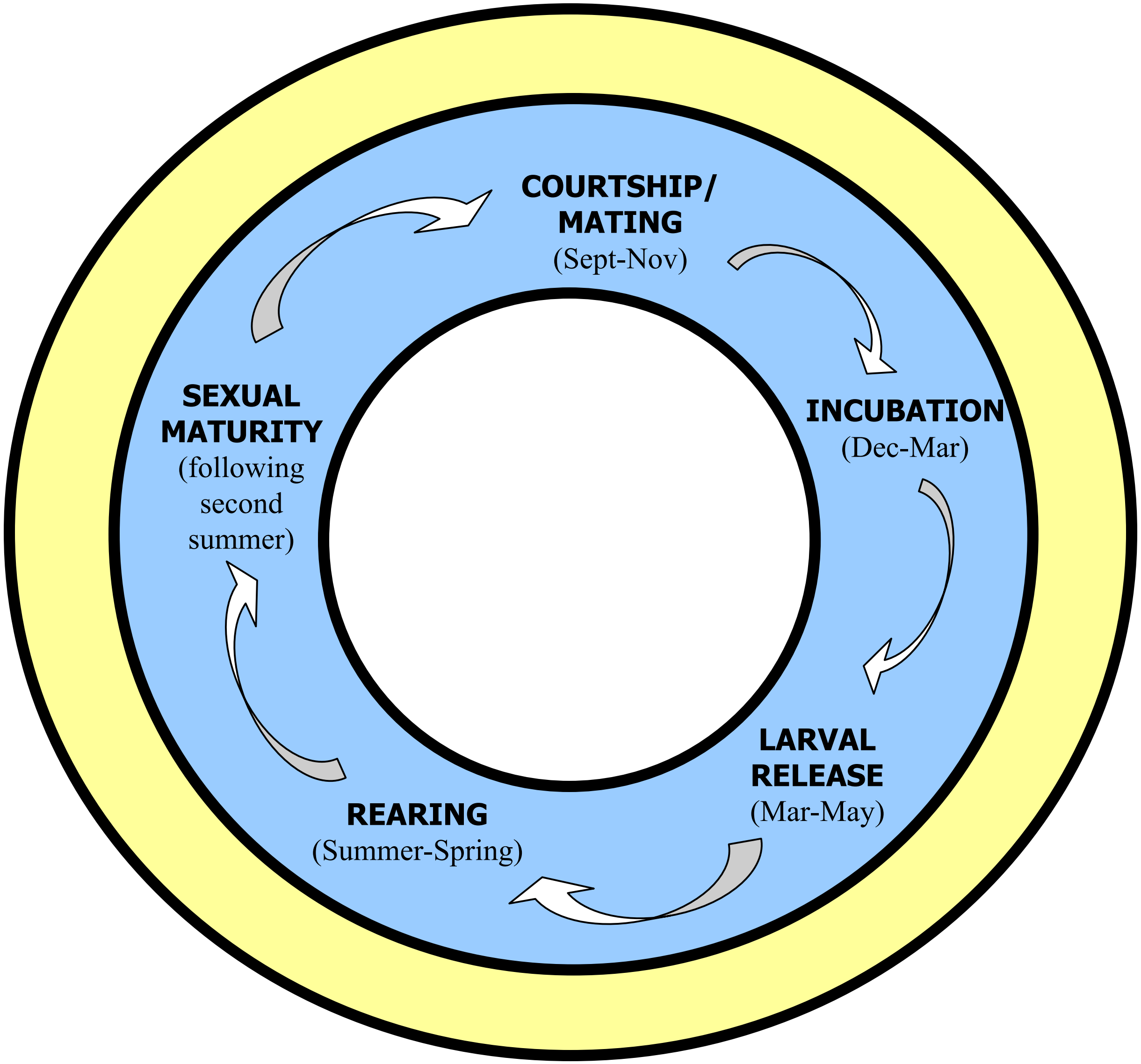

Potential Limiting Factors

- Water quality--temperature, dissolved oxygen, toxins
- Undercut banks with submerged vegetation (overhanging vegetation and root mats)
- Barriers (both physical and flow-related)
- Predation (by both native and introduced species)
- Disease/parasites

Figure 7-3. Simplified California freshwater shrimp life cycle and potential limiting factors in the Napa River watershed (based on USFWS 1998). Because there is so much uncertainty regarding details of California freshwater shrimp life history, factors are not identified specific to life history stage.

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