# LOWER MOKELUMNE RIVER
# UPSTREAM FISH MIGRATION MONITORING
# Conducted at Woodbridge Irrigation District Dam
# August 2000 through April 2001

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Key words: lower Mokelumne River, fall-run chinook salmon, steelhead, escapement

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***Abstract*: From August 15, 2000 through April 23, 2001 7,418 fall-run chinook salmon (*Oncorhynchus tschwaytscha*) were observed passing Woodbridge Irrigation District Dam (WIDD) on the lower Mokelumne River (LMR). The run consisted of 6,157 (83%) adult, 1,261 (17%) grilse, including 3,421(46%) adult females, 2,736 (37%) adult males, 320 (4%) grilse females and 941 (13%) grilse males. Salmon passage was observed from August 20, 2000 through February 12, 2001. Fifty percent of the run passed WIDD by October 30, 2000. Highest daily passage (462) was recorded on November 8th. Forty-eight adult steelhead (*O. mykiss*) passed WIDD between August 15, 2000 and April 23, 2001. Peaks in steelhead passage occurred in January and February. Other species using the WIDD fishways include: Pacific lamprey *Lampetra tridentata*; common carp, *Cyprinus carpio*; largemouth bass, *Micropterus salmoides*; Sacramento pikeminnow, *Ptychocheilus grandis*; Sacramento sucker, *Catostomus occidentalis*; Sacramento blackfish, *Orthodon microlepidotus*; Sacramento splittail, *Pogonichthys macrolepidotus*; and tule perch, *Hysterocarpus traski*.**

## INTRODUCTION

East Bay Municipal Utility District (EBMUD) has been monitoring adult fall-run chinook salmon, *Oncorhynchus tshawytscha*, escapement in the lower Mokelumne River (LMR) using video surveillance and trapping at Woodbridge Irrigation District Dam (WIDD) since fall 1990. Initially, monitoring documented the timing and magnitude of the adult salmon escapement to the LMR with a secondary focus on steelhead, *O. mykiss*. Monitoring started between August and mid October, and ended between December and March, during the 11-year monitoring period (Table 1).

Fifty percent of salmon passage at WIDD usually occurs by the end of October (Marine and Vogel 2000), and steelhead spawning migrations occur between December and April in the Central Valley (IEP Steelhead PWT 1999).

To encompass the full range of adult salmon and steelhead spawning migrations and document other fishes utilizing the fishways, video monitoring and trapping were conducted from August 15, 2000 to April 23, 2001.

Table 1. Inclusive dates for upstream fish passage monitoring at Woodbridge Irrigation District Dam on the lower Mokelumne River 1990-2001.

| Year | August | September | October | November | December | January | February | March | April |
|---|---|---|---|---|---|---|---|---|---|
| 1990/91 | | | 10/2 | | 12/17 | | | | |
| 1991/92 | | | 10/2 | | 12/29 | | | | |
| 1992/93 | | | 10/26 | | 12/31 | | | | |
| 1993/94 | | | 10/14 | | 12/31 | | | | |
| 1994/95 | | | 10/7 | | 12/31 | | | | |
| 1995/96 | | 9/1 | | | 12/31 | | | | |
| 1996/97 | | 9/3 | | | 12/10 | | | | |
| 1997/98 | | 9/5 | | | | | 2/3 | | |
| 1998/99 | 8/17 | | | | | | 2/9 | 3/17 3/31 | |
| 1999/2000 | 8/17 | | | | | | 2/15 | 3/25-3/31 | |
| 2000/01 | 8/15 | | | | | | | | 4/23 |

Note: From 90/91 through 95/96 monitoring did not extend past 12/31. From 96/97 to present, monitoring ended when flows exceeded 1,400 cfs.

## OBJECTIVES

The objectives of this study were to monitor fish passage of native and non-native fishes through the WIDD fish ladders and describe the relationships of these fish movements to flow, temperature, turbidity, precipitation, barometric pressure, and Delta hydrologic conditions.

## METHODS

Methods for video monitoring and trapping for the 2000/2001 monitoring period were consistent with past efforts (Marine, K.R. and D.A. Vogel 2000). Monitoring in the high stage fishway occurred between August 15, 2000 and November 6, 2000. Free spill passage was monitored from November 6, 2000 to November 14, 2000. Monitoring in the low stage fishway occurred from November 7, 2000 to March 15, 2001, and monitoring in the high stage was resumed between March 17, 2001 and April 23, 2001. These dates are when Lake Lodi is filled and drained by Woodbridge Irrigation District.

In 2000 the following modifications were made to the methods:

1) The monitoring period extended from August 15, 2000 to April 23, 2001.
2) Free spill passage was monitored for 20 minutes out of every hour during WIDD drawdown activities.
3) A single sVHS recorder with a three-tape changer was used. Tapes were set to record 24 hr/tape and could be operated unattended over weekend intervals and during periods of low abundance. During periods of high abundance, tapes were recorded at 8 hr/tape and reviewed more frequently. During periods of high turbidity and during underwater camera failure, an overhead Sony handycam was used to enumerate passage through the high stage fish ladder.

During low abundance periods, all tapes were reviewed twice for quality control. During high abundance periods, a 10% subsample of each tape reviewer's work was checked for accuracy. If any reviewer had an error rate of >10%, then all tapes completed by that reviewer were reviewed. All data were entered into a Microsoft ®Access 1997 database for data retrieval and analysis.

## RESULTS AND DISCUSSION

### Anadromous Fish

Pacific Lamprey

Prior to the fall of 1996, adult Pacific lamprey (*Lampetra tridentata*) observations at WIDD were not recorded. Numbers of adult lamprey observed during video monitoring on the LMR have been sporadic since recording began in 1996, from a high of 976 in fall 1999, to only 1 recorded passing upstream during video-monitoring in 2000. In 1996,

1997 and 1998, less than 20 adult lamprey were observed annually in the fish ladders (Table 2). Pacific lamprey are in decline in the Columbia and Snake River Basins and the same may be true in the Central Valley (Close et al 1995; Brown and Moyle 1993).

**Table 2. Adult lamprey observed moving upstream during video monitoring at Woodbridge Irrigation District Dam, 1996-2001.**

| Year | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|---|---|---|
| 1996 | n/a | 123 | 13 | 0 | 0 | n/a | n/a | n/a |
| 1997 | n/a | 12 | 7 | n/a | 1 | n/a | n/a | n/a |
| 1998 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 323 | 606 | 50 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Only one lamprey was observed in video monitoring during the fall of 2000. During the filling of Lake Lodi in March 2001, an estimated 6 adult lamprey were observed in the rip-rap near the ladder entrance. Two adult lamprey were also observed moving downstream in the ladder in April. Because of their body form, and narrow girth, adult lamprey may go undetected by the video station.

Steelhead

Steelhead have been observed since monitoring began in 1990 (Table 3). In most years prior to 1997 (1993 is the exception), adult monitoring was not continued past December. Spawning, however, typically occurs between January and March for winter steelhead in the Central Valley (IEP Steelhead PWT 1999).

**Table 3. Steelhead observed moving upstream during video monitoring at Woodbridge Irrigation District Dam, 1990-2001.**

| Year | Number | Year | Number |
|---|---|---|---|
| 1990 | 4 | 1996 | 12 |
| 1991 | n/a | 1997 | 6 |
| 1992 | 7 | 1998 | 12 |
| 1993 | 8 | 1999 | 80 |
| 1994 | 19 | 2000 | 48 |
| 1995 | 76 | | |

Hallock et al (1961) estimated adult steelhead at 15 inches (380 mm) fork length (FL) for three-year-old fish that had spent one season at sea based on length frequency data from known-age fish on the Sacramento River. This size criterion was used to distinguish between adult and subadult steelhead on the LMR. Forty-eight adult steelhead were observed moving upstream through WIDD from August 16, 2000 through March 30,

2001. Forty-five of the 48 were adipose-fin clipped. Of the 48 observed, 9 were males, 30 were females and 9 were not distinguishable to sex. Highest monthly abundances were in January and February (Figure 1). This coincides with historic periods of peak migration on some Sacramento River tributaries (Hallock 1989). Two spawned-out fish (kelts) were observed descending the fishway in February. One female which did not appear spawned-out also migrated downstream in March.

Between December 27, 2000 and January 3, 2001 the Mokelumne River Fish Hatchery released 112,373 subadult steelhead at New Hope Marina near the town of Thornton (Rich Bryant, personal communication). These fish were approximately 150-350 mm fork length. Beginning on January 5, 2001 there was a large influx of these fish migrating upstream through WIDD. As a result, 2,596 subadult steelhead ranging in size from 150-350 mm FL were observed moving upstream through WIDD.

Fall-Run Chinook Salmon

Of the 7,418 fall-run chinook salmon recorded passing WIDD, 4,526 (61%) passed using the high stage fishway (August 15th through November 6th), and 2,847 (38%) passed using the low stage fishway (November 7th through February 12, 2001). The remaining 45 (1%) were rescued from the rip-rap below Woodbridge Dam and manually passed over the dam during the drawdown of Lake Lodi. Fifty percent of the observed passage was reached on October 30, 2000. This coincides with run timing observed in past years (Table 4). Highest daily passage (462) was recorded on November 8th, after drawdown of Lake Lodi (Figure 2).

**Table 4. Dates when 50% of fall-run chinook salmon passed the Woodbridge Irrigation District Dam, 1990-2000.**

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date 50% Complete | Nov. 18 | n/a | Nov. 13 | Nov. 3 | Nov. 7 | Oct. 30 | Oct. 31 | Nov. 8 | Nov. 4 | Nov. 3 | Oct. 30 |

Since 1990 more fish have passed upstream during daylight hours than nighttime hours (Table 5). Day is defined as ½ hour before sunrise and ½ hour after sunset. An unpaired t-test was used to analyze passage patterns (Motulsky 1995). Daytime passage for 2000 was significantly higher than nighttime passage ($P$=<.001).

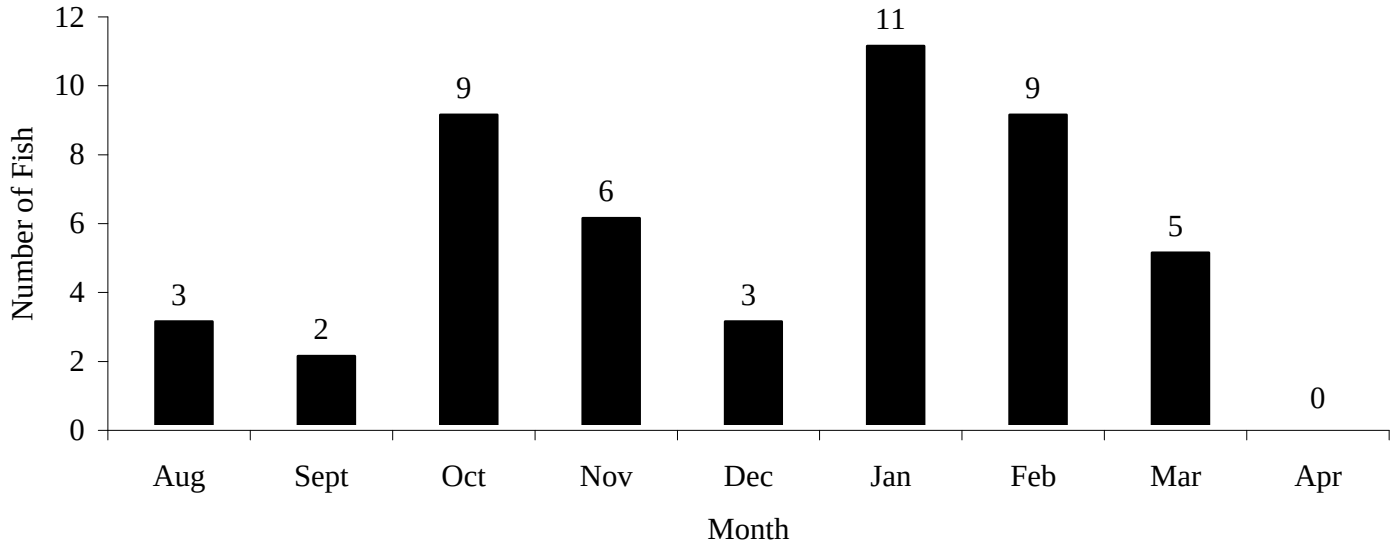



Figure 1. Monthly upstream passage of adult steelhead at the Woodbridge Irrigation District Dam, August 15, 2000 - April 23, 2001. (Data in Appendix A.)

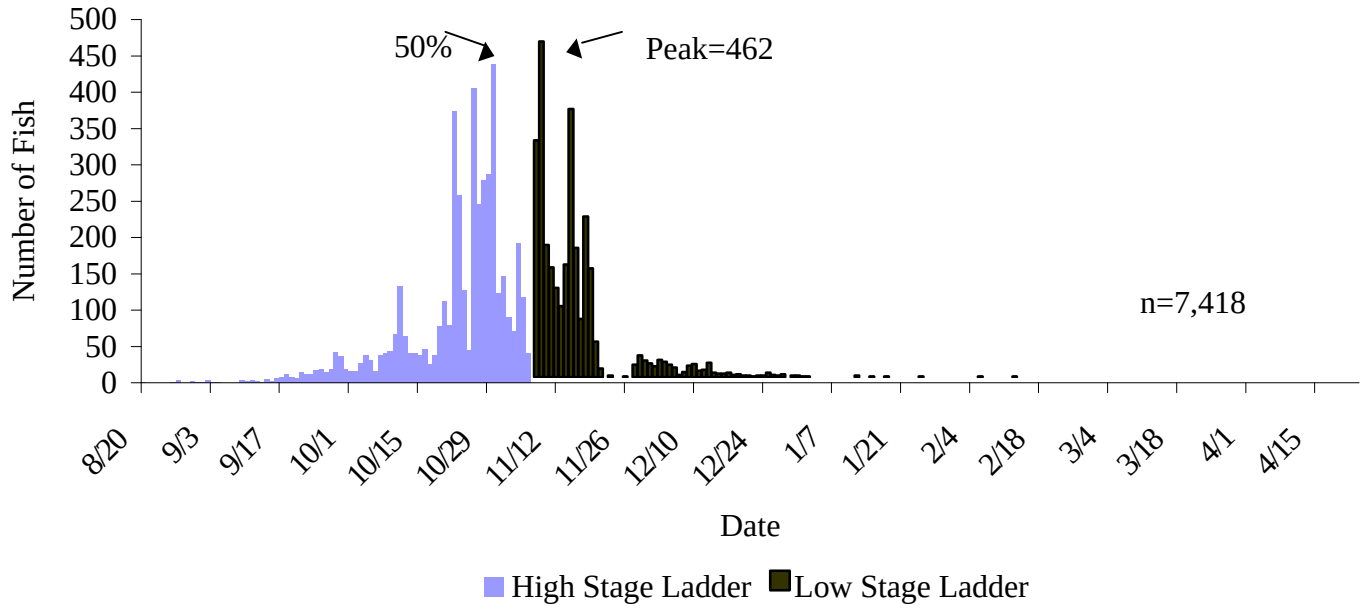



Figure 2. Daily abundance and timing of fall-run chinook salmon migrating past Woodbridge Irrigation District Dam, August 15, 2000 - April 23, 2001. (Data in Appendix A.)

**Table 5. Percent of annual fall-run chinook salmon passing Woodbridge Irrigation District Dam during day and night, 1990-2000.**

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 57 | 64 | 69 | 59 | 61 | 68 | 52 | 56 | 56 | 62 | 68 |
| Night | 43 | 36 | 31 | 41 | 39 | 32 | 48 | 44 | 44 | 38 | 32 |

Hourly passage was also investigated. Passage times were grouped in two-hour intervals for analysis. Two peak time periods emerged. A significantly higher number of fish passed from 0800 – 1000, and from 1600 –1800, than other daylight hour units ($P$=<0.05). (Figure 3). This pattern appears to be crepuscular.

The 2000/2001 run was composed of 6,157 (83%) adult-size, 1,261 (17%) grilse-size (≤ 60cm), 3,677 (50%) male and 3,741 (50%) female fish. Of the adult-size fish, 3,421 (55%) were female and 2,736 (45%) were male. Of grilse-size fish, 320 (25%) were female and 941 (75%) were male (Figure 4). Mean size (FL) for grilse was 56.6 cm and mean size for adults was 76.2 cm (Figure 5). During overhead video monitoring, sex of fish could not be determined. Total numbers represent expansions of observed ratios of male to female and adult to grilse.

Clipped adipose fins were observed on 326 (5%) of the fall-run chinook salmon. Eight percent of identifiable grilse (83), and 4% of identifiable adults (225) had adipose fin clips. The remaining 12 adipose-fin clips were observed on fish of undetermined life stage. The percentage of adipose clipped adults has ranged from 0.9% in 1993 to a high of 10.8% in 1999. The range for grilse has been from 1.7% in 1993 and 1997 to a high of 15.2% in 1995 (Table 6).

In addition to adipose-fin clips, observations of hook scars, fungal infections, abrasions, predator wounds and lacerations were recorded. Observations of hook scars this year appeared low, when compared to previous years. Hook scars in grilse were recorded for 0.5% of observable grilse. Hook scars in adults were recorded for 1.2% of observable adults. Other injuries and anomalies were categorized as abrasions, fungal infections, lacerations, and predator wounds. The most frequent injury for both age classes was abrasions. Fungal infections were much more prevalent in adults than grilse (4.8% in adults, 0.8% in grilse)(Table 6). During overhead video enumeration, assessment of adipose fin clips and other injuries or anomalies was not possible. As in previous years, actual number observed was used to determine the percent of these occurrences.

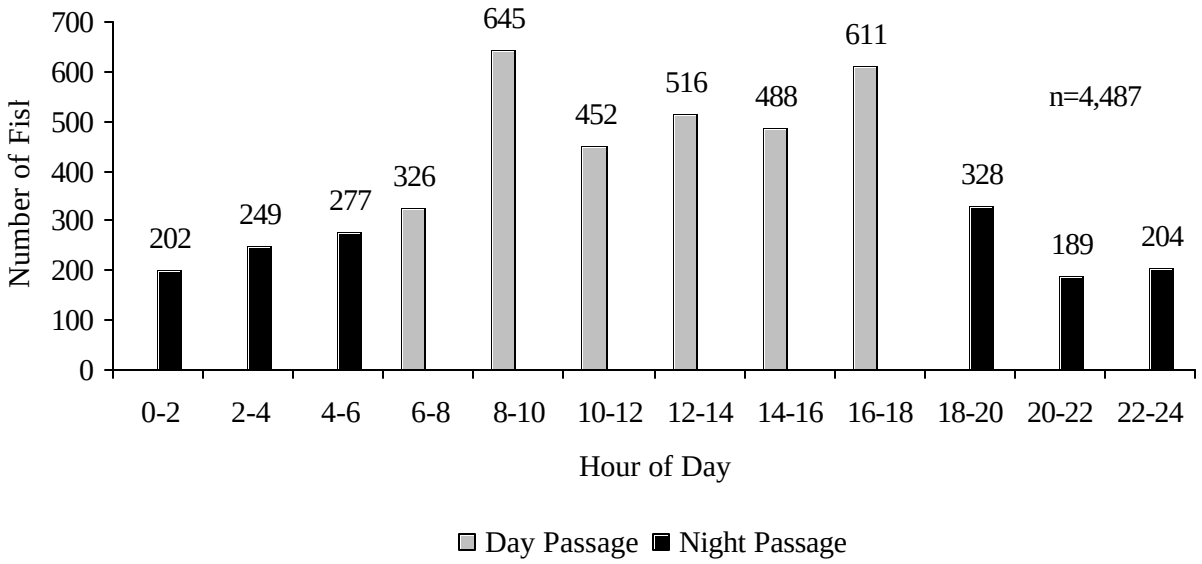



Figure 3. Fall-run chinook salmon passage (2 hour intervals) recorded from video monitoring at the Woodbridge Irrigation District Dam, Lower Mokelumne River, Ca., August 15, 2000 through April 23, 2001.

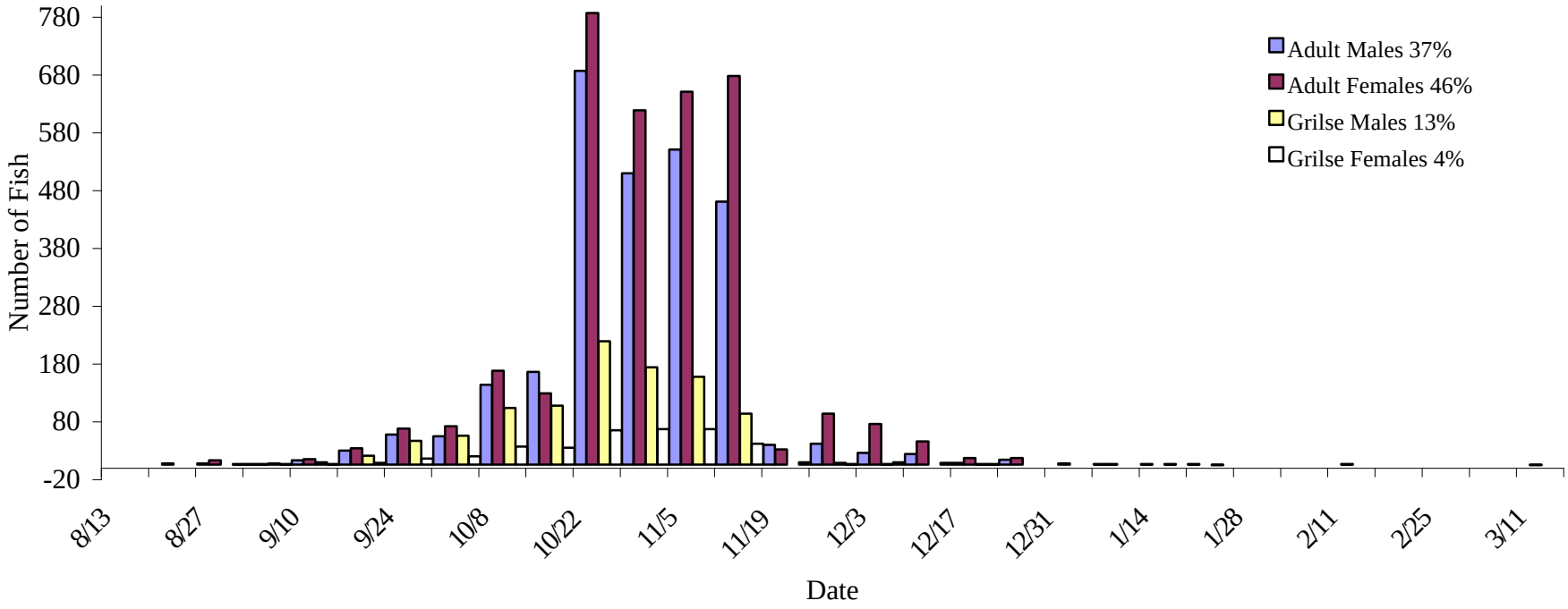



Figure 4. Weekly sex/age composition of fall-run chinook salmon passing Woodbridge Irrigation District Dam, August 14, 2000 - March 12,2001.(Data in Appendix A.)

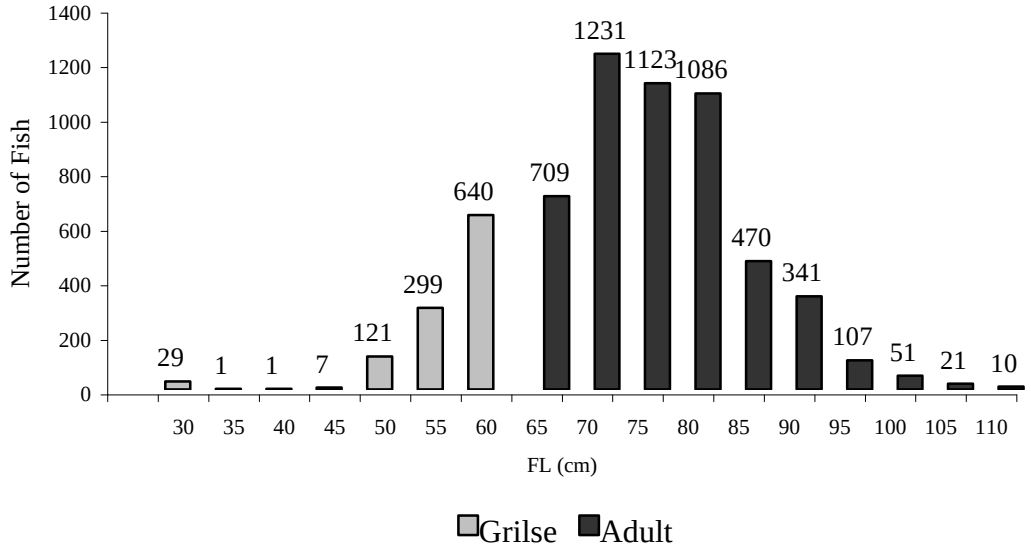



Figure 5. Length-frequency of fall-run chinook salmon passing Woodbridge Irrigation District Dam, 2000-2001.

**Table 6. Incidence of adipose fin clips, hook-scars and injuries on adult fall-run chinook salmon passing through the fishways at Woodbridge Irrigation District Dam, 1992-2001.**

| | Adipose Fin Clips | | Hook Scars | | Other Injuries | |
|---|---|---|---|---|---|---|
| Year | Number | Percent | Number | Percent | Number | Percent |
| **Adult** | | | | | | |
| 1992 | 10 | 1.4 | 24 | 3.4 | 20 | 2.8 |
| 1993 | 11 | 0.9 | 56 | 4.5 | 83 | 6.7 |
| 1994 | 244 | 10.3 | 151 | 6.3 | 218 | 9.2 |
| 1995 | 161 | 7.8 | 74 | 3.6 | 289 | 14.1 |
| 1996 | 169 | 9.2 | 97 | 5.3 | 258 | 14.1 |
| 1997/98 | 152 | 2.9 | 105 | 2.0 | 785 | 14.7 |
| 1998/99 | 427 | 7.4 | 38 | 1.2 | 615 | 10.7 |
| 1999/2000 | 327 | 10.8 | 46 | 1.5 | 392 | 13.0 |
| 2000/2001 | 225 | 4.0 | 87 | 1.2 | 855 | 11.7 |
| **Grilse** | | | | | | |
| 1992 | 35 | 3.8 | 41 | 4.4 | 21 | 2.3 |
| 1993 | 8 | 1.7 | 33 | 6.8 | 15 | 3.1 |
| 1994 | 22 | 4.0 | 59 | 10.6 | 27 | 4.9 |
| 1995 | 55 | 15.2 | 27 | 7.4 | 25 | 6.9 |
| 1996 | 47 | 3.5 | 68 | 5.0 | 44 | 3.2 |
| 1997/98 | 7 | 1.7 | 3 | 0.7 | 18 | 4.5 |
| 1998/99 | 175 | 12.0 | 9 | 1.1 | 55 | 3.8 |
| 1999/2000 | 139 | 6.1 | 46 | 2.0 | 160 | 7.0 |
| 2000/2001 | 83 | 8.0 | 7 | 0.5 | 71 | 5.5 |

Free passage of the dam spillbays has received limited attention in the past. Unimpeded spill bay passage was monitored systematically from 1600 hours on November 6$^{th}$ to 1600 hours on November 7$^{th}$ when lake elevations appeared appropriate for passage across all of the bays. Periodic monitoring continued for one week after lake drawdown. No free spill bay passage was observed during this monitoring. Free passage during drawdown activities has been observed, anecdotally, in previous years.

River flow, rainfall, temperature, turbidity, barometric pressure, and Delta outflow have been investigated for their relationship to salmon returns over the past 10 years. For the 2000/2001 migration period Camanche Dam releases ranged from 430-281 cfs (12.2-7.95 $m^3/s$). For most of the chinook salmon migration period, flows were stable at 330 cfs (9.34 $m^3/s$)(Figure 6a). EBMUD reallocated approximately 3,000 acre-feet of Camanche Reservoir flood control releases from the month of August to the second half of September to assess the affects of a small pulse in river flow on salmon passage at WIDD. Camanche releases were decreased by about 50 cfs (1.41 $m^3/s$) in August and

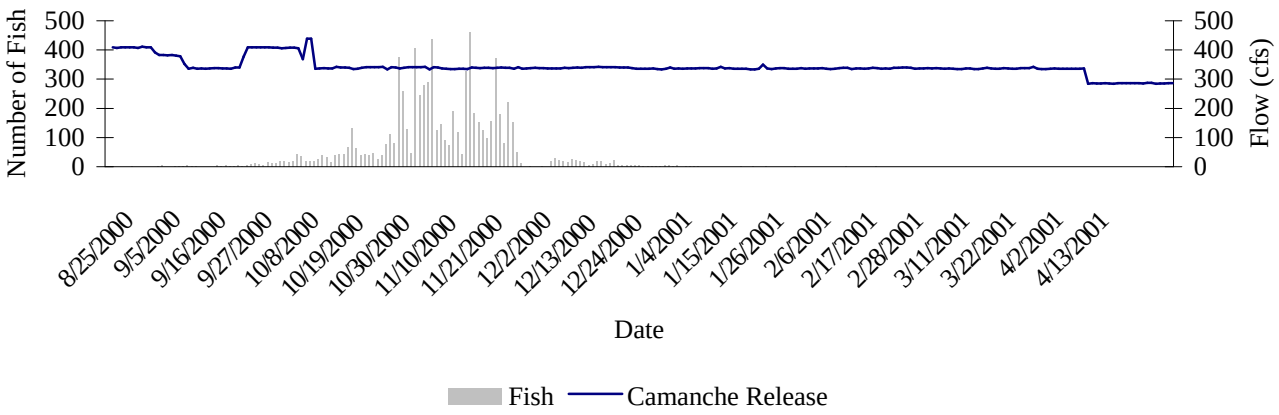
then increased from September 14 through 28 by an average of 73 cfs (2.06 $m^3/s$). Flows below WIDD increased 52 cfs (1.47 $m^3/s$) through the same period. Linear regression of flow v. fish passage from September 5 through October 20 showed little relationship ($R^2$ = 0.25). Using a few variations on stream flow response time (1-4 days) to account for travel time from WIDD to tidal influence, still resulted in no observable effect of the pulse flow on number of fish passing WIDD (1 day $R^2$ = 0.22, 2 day $R^2$ = 0.18, 3 day $R^2$ = 0.23, 4 day $R^2$ = 0.18) (Workman et al 2000).

Temperatures for the August through April monitoring period ranged from 49.5°-59.7°F (9.7°-15.4°C) at Camanche Dam and 47.6°-68°F (8.7°-20.0°C) at WIDD (Figure 6b). Barometric pressure ranged from 29.54-30.32 inches of Hg (74.8-76.8 cm Hg)(Figure 6c). Turbidity increases in the LMR with rainfall. Total rainfall for the survey period was 12.5 inches (31.75 cm). Peak daily rainfall was 1.05 inches (2.67 cm). Turbidity ranged from 1.50 to 18.50 ntu (Figures 6d and 6e). No relationship between fish passage and temperature, flow, barometric pressure, turbidity or rainfall was observed (all $R^2$ values <0.10).

Salmon migration was also compared to Delta hydrology. The Delta Outflow Index (DOI) is a measure of storm patterns and flood control releases on the Sacramento and San Joaquin rivers obtained by the California Department of Water Resources, California Data Exchange. Peaks in Delta outlfow from the past ten years, including the 2000/2001 monitoring period, have not occurred until early January. This is consistent with the tail end of the salmon run on the LMR. No association with the DOI and salmon migration was apparent on the LMR for the 2000/2001 immigration period (Figure 7).

**Non-anadromous fish**

In addition to fall-run chinook salmon, steelhead, and lamprey, other species were documented moving upstream through the WIDD fish ladders. The non-native fish using the ladders include one carp, *Cyprinus carpio*, in March, and one largemouth bass, *Micropterus salmoides*, in November. Native fishes observed using the ladder include Sacramento pikeminnow, *Ptychocheilus grandis*, Sacramento sucker, *Catostomus occidentalis*, Sacramento blackfish, *Orthodon microlepidotus*, Sacramento splittail, *Pogonichthys macrolepidotus*, and tule perch, *Hysterocarpus traski* (Table 7).



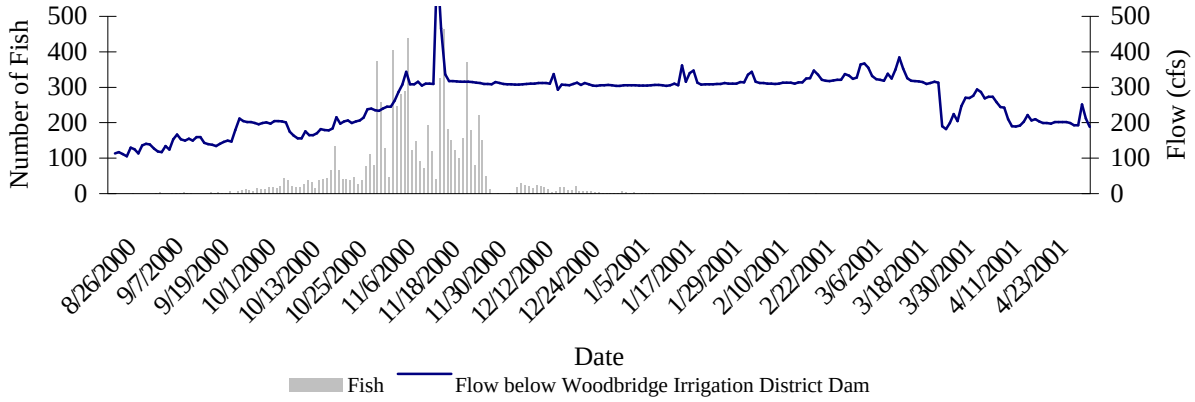
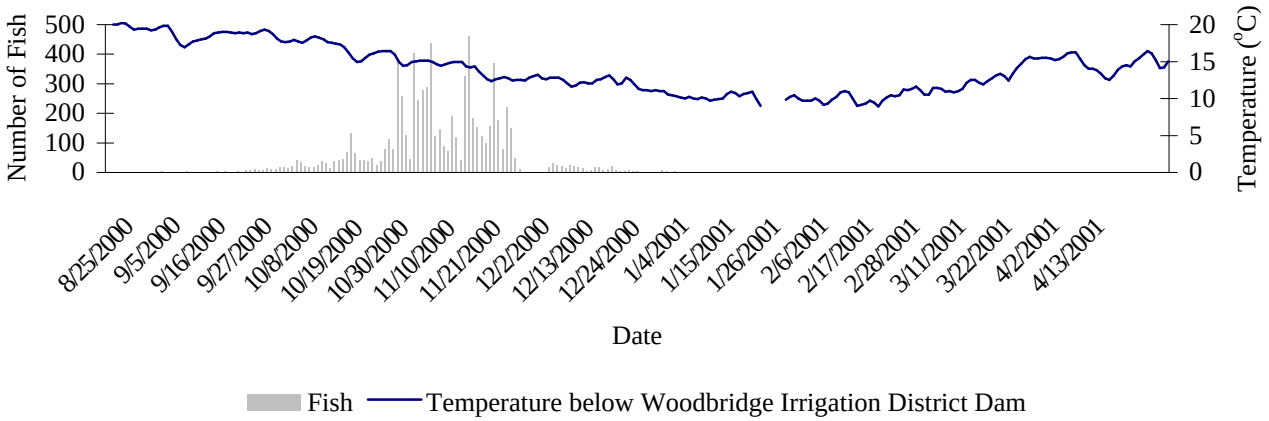




Figure 6a. Daily abundance of fall-run chinook salmon passing Woobridge Irrigation District Dam and flow, August 15, 2000 - April 23, 2001.



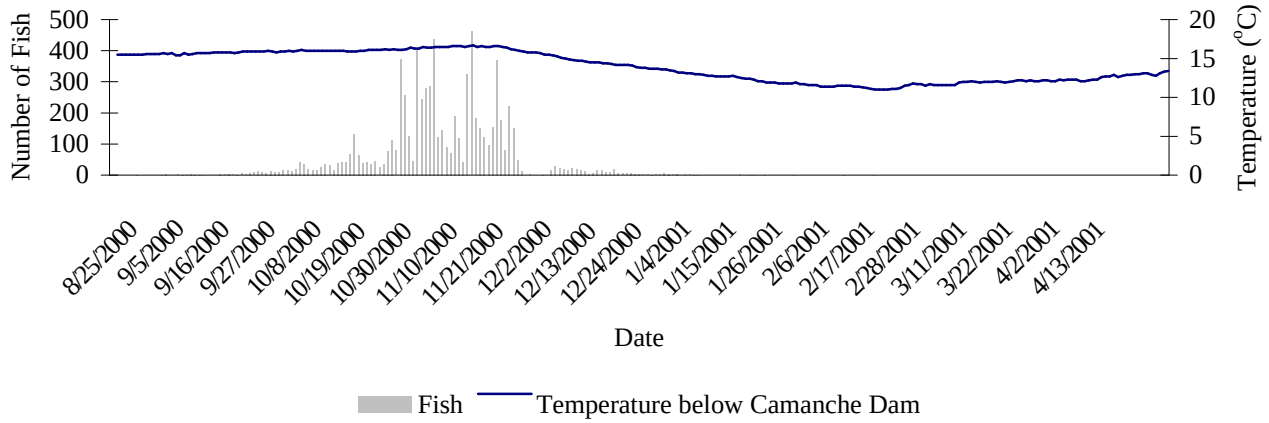




Figure 6b. Daily abundance of fall-run chinook salmon passing Woodbridge Irrigation District Dam and water temperature, August 15, 2000 - April 23, 2001.

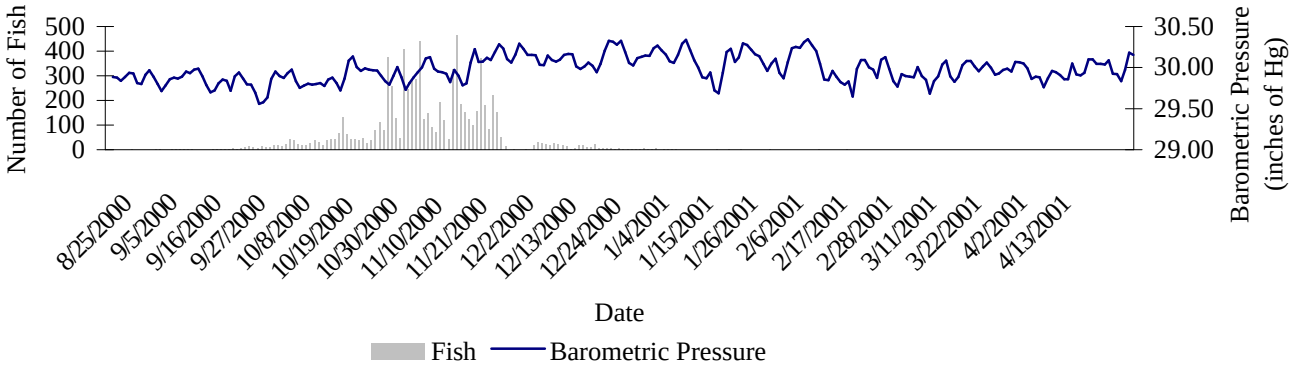



Figure 6c. Daily abundance of fall-run chinook salmon passing Woodbridge Irrigation District Dam and barometric pressure, August 15, 2000 - April 23, 2001.

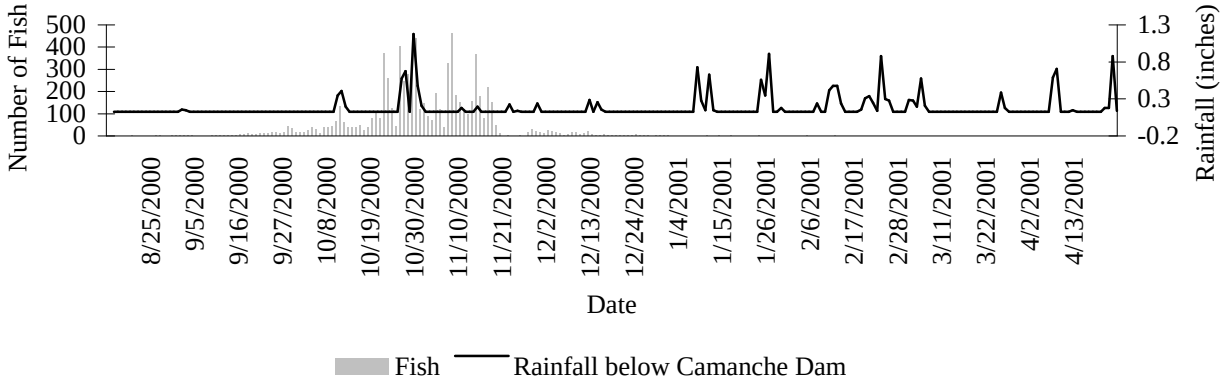



Figure 6d. Daily abundance of fall-run chinook salmon passing Woodbridge Irrigation District Dam and rainfall, August 15, 2000 - April 23, 2001.

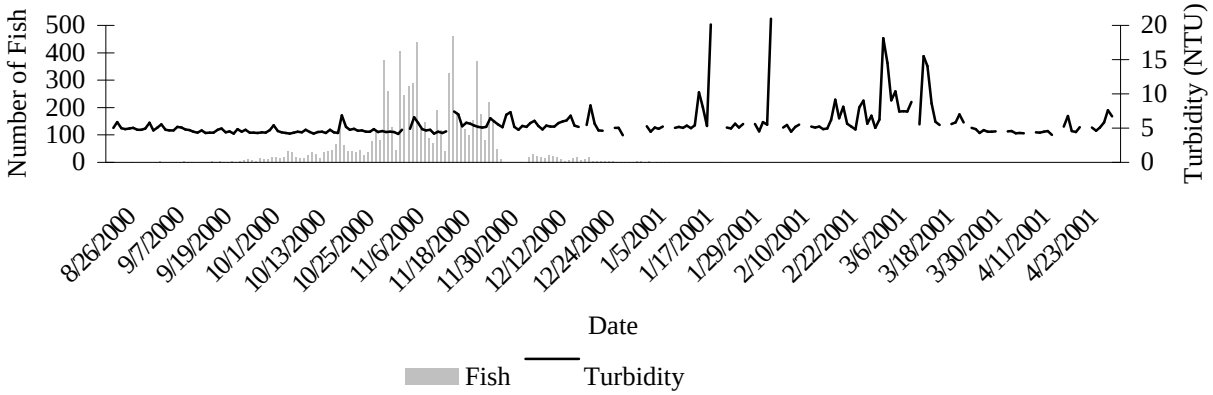



Figure 6e. Daily abundance of fall-run chinook salmon passing Woodbridge Irrigation District Dam and turbidity, August 15, 2000 - April 23, 2001.

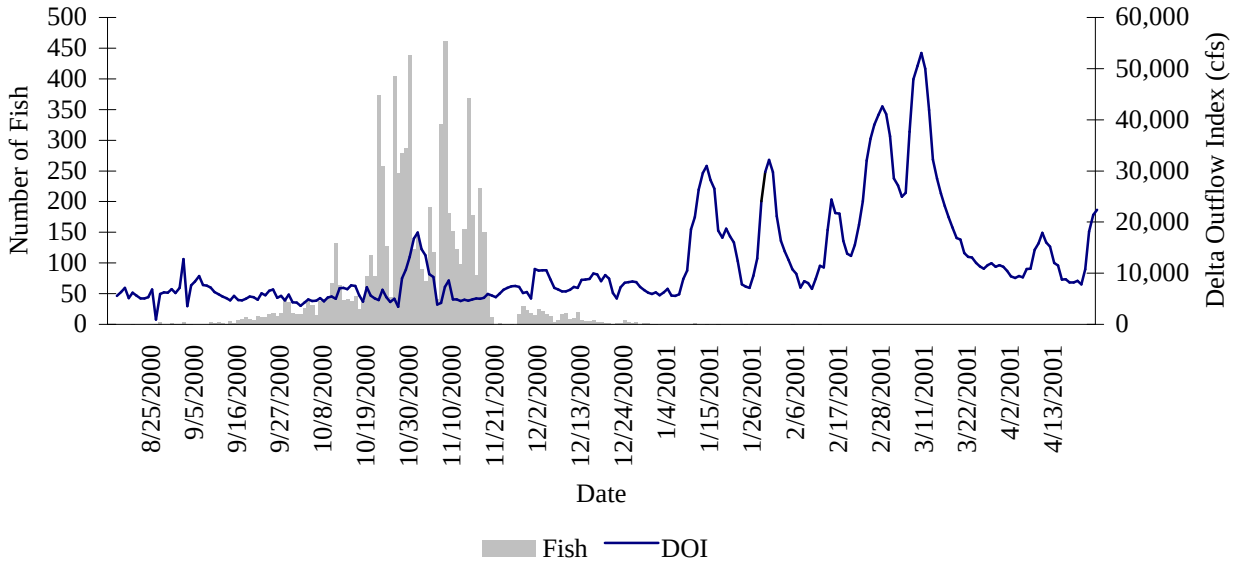



Figure 7. Delta Outflow Index (DOI) and fall-run chinook salmon passage at Woodbridge Irrigation District Dam, August 15, 2000 through April 23, 2001.

**Table 7. Non-anadromous fish observed in the Woodbridge Irrigation District Dam fish ladders, Aug 15, 2000-April 23, 2001.**

| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | April |
|---|---|---|---|---|---|---|---|---|---|
| Carp | | | | 1 | | | | 1 | |
| Largemouth bass | | | | | | | | 1 | |
| Sacramento blackfish | | | | | | | | | 2 |
| Sacramento sucker | 28 | 4 | 5 | | | | | 55 | 77 |
| Sacramento pikeminnow | 63 | 47 | 25 | 6 | 1 | | | 24 | 359 |
| Sacramento splittail | | | | | | | | | 93* |
| Tule perch | | | -1 | | | | | | |

*Number indicates fish measured and released.

Sacramento pikeminnow were observed in all months surveyed except January and February. Peak abundance occurred in April when ripe fish tend to move upstream to spawn (Moyle 1976).

Sacramento suckers typically congregate and begin moving toward spawning areas from February to June (Moyle 1976). Sacramento suckers were observed in the fishways in the fall (August through October) and spring (March and April), but absent from November through February, with peak abundance occurring in March and April.

Two Sacramento blackfish were observed using the high stage ladder in April. Adult blackfish have been observed above WIDD in the fall of 1997 and winter of 1999 during electrofishing surveys (EBMUD unpublished data).

One tule perch was observed moving downstream through the ladder in October. Although tule perch are rarely seen using the ladder, many adult tule perch have been observed in the rip rap below the dam, and juvenile tule perch are captured in seining surveys at the Highway 99 bridge upstream of Lake Lodi (EBMUD unpublished data). Tule perch are small enough to navigate the ladders through the drain holes at the base of each weir, and may use these to pass upstream unobserved.

Sacramento splittail were observed on April 25, 2001 throughout the high stage ladder during a temporary flow reduction to install equipment. Video equipment had already been dismantled and removed, so none were recorded in videotapes. Ninety-three were measured and released in pool 15 of the high stage ladder. Size ranged from 240-342mm. Many were in spawning condition and were releasing eggs and milt. Whether or not these fish were able to navigate the final orifice passage into Lake Lodi when full flow was resumed is not known. Fish were observed using both the drain holes in the base of the ladder bays and navigating the weirs between pools 14 and 15 for passage. A few fish were also observed passing through the final orifice when flow was reduced (J. Setka, personal communication). Existing literature states that splittail are incapable of passing many existing fishways (Moyle et al 1989). These fish had navigated 6 orifice-only bays and 8 weir passage bays to reach bay 15. Known spawning

areas include flooded rivers, sloughs and streams of the delta (Caywood 1974). Preferred spawning occurs in newly inundated vegetation in slow moving water (Moyle 1976). Lake Lodi provides appropriate spawning habitat for this species.

## Acknowledgements

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