OROVILLE FERC RELICENSING
(PROJECT NO. 2100)

INTERIM PROGRESS REPORT
SP-F3.1, Task 2C

EVALUATION OF LAKE OROVILLE WATER SURFACE ELEVATION REDUCTIONS ON BASS (*MICROPTERUS* SPP.) SPAWNING SUCCESS

REVIEW DRAFT

PREPARED BY:

SWRI SURFACE WATER RESOURCES, INC.

Contact: Paul Bratovich or David Olson
Telephone: (916) 563-6360

DECEMBER 6, 2002

EXECUTIVE SUMMARY

Spawning characteristics of largemouth bass, smallmouth bass and spotted bass were researched and historical records were examined to determine whether seasonal Lake Oroville water surface elevation reductions would result in spawning nest dewatering, and thereby affect spawning nest survival rates. A literature review concluded that black bass (*Micropterus* sp.) spawning activity extends from March through June, with the majority of spawning activity occurring from March through May. The California Department of Fish and Game (DFG) suggests that spawning nest survival rate of at least 20 percent is necessary to maintain the long-term population levels of highly fecund, warmwater fish, such as black bass. Nest survival curves, developed by DFG, illustrate that reductions of approximately 0.11, 0.11, and 0.23 meters per day would result in 20 percent nest survival for largemouth bass, smallmouth bass, and spotted bass, respectively. These water surface elevation reduction criteria were compared to monthly historical Lake Oroville water surface elevation records from 1967 to 2001.

Results indicate that water surface elevation reductions and, therefore, the potential for water surface elevation reductions to adversely affect black bass nest survival, may only occur up to approximately one-third of the time for the period extending from March through May. Black bass spawning nest survival during each month of the main spawning period (March through May) is relatively high, ranging from 80 to 100 percent for largemouth and smallmouth bass, and 96 to 100 percent for spotted bass, relative to the 20 percent spawning nest survival criteria established to maintain long-term population levels of black bass. Even during June, when relatively few black bass spawning nests would be expected to be present, long-term average monthly spawning nest survival ranges from 47 to 77 percent. In addition, Lake Oroville is recognized as supporting a very popular and important recreational sport fishery. Therefore, historic and ongoing project operations affecting water surface elevation in Lake Oroville result in conditions sufficient to maintain long-term population levels of largemouth, smallmouth and spotted bass.

INTRODUCTION

The Lake Oroville warmwater fishery is a self-sustained fishery consisting of fish of the *Centrarchidae* (sunfish) family, including species of black bass (*Micropterus spp.*), two species of sunfish (*Lepomis cyanellus* and *L. macrochirus*), two species of crappie (*Pomoxis nigromaculatus* and *P. annularis*), two species of catfish (channel catfish (*Ictalurus punctatus*) and white catfish (*I. catus*), as well as many other fish species. Project operations that influence warmwater fish habitat include water surface elevation fluctuations resulting from flood control, power generation, and downstream fisheries management activities. Reservoir water surface elevation fluctuations may hinder colonization of rooted aquatic vegetation in the lake's littoral zone, limiting the establishment of terrestrial vegetation within the fluctuation zone (DWR 2001). Terrestrial vegetation provides spawning and nursery habitat, offers protection from predation, and results in increased food availability for warmwater fisheries (DWR 2001; DWR and USBR 2000). The availability of such vegetation may affect the abundance and distribution of warmwater fish (DWR 2001). Fluctuations in water surface elevation also may result in bass nest dewatering during spawning and incubation periods.

Positive effects also may be associated with reservoir fluctuations. For example, low reservoir levels cause concentration of adult fish and the forage base because of the decrease in the total volume of water, resulting in adult fish with better condition factors. Aquatic weed growth is controlled with water surface fluctuations, and without these fluctuations, excessive aquatic plant growth may limit the amount of forgeable fish habitat. A certain amount of aquatic vegetation is beneficial to Lake Oroville fisheries because it provides escape cover for juvenile fish and increases food supply, but too much aquatic vegetation (greater than approximately 30%) may lead to negative impacts to planktonic communities, repressed feeding efficiency of adult fish, and seasonal decomposition-related oxygen depletion. Water surface elevation fluctuations in Lake Oroville are currently sufficient to prevent excessive aquatic vegetation growth.

The objective of this study is to evaluate the effects of Lake Oroville water surface elevation reductions on black bass *(Micropterus spp.)* spawning nest survival using criteria developed by DFG (Lee 1999) describing the relationship between water surface elevation reductions and black bass spawning nest dewatering. The following steps were taken to conduct the analysis.

- A literature review was completed to determine general water depth, water temperature, duration and time period of black bass spawning. The primary source was Lee (1999).

- Nest survival criteria were established using Lee (1999). Lee (1999) examined the relationship between water surface elevation fluctuation rates and nesting success for black bass, and developed nest survival curves for largemouth bass *(Micropterus salmoides)*, smallmouth bass *(M. dolomieu)*, and spotted bass *(M. punctulatus)*. Nest survival criteria developed by DFG suggests that, on average, a nest survival rate of at least 20 percent is necessary to maintain the long-term population levels of highly fecund, warmwater fish (D. Lee, pers. comm., 1999). Nest survival curves demonstrated that reductions of approximately 0.11, 0.11, and 0.23 meters per day (m/d) would result in 20 percent nest survival for largemouth bass, smallmouth bass, and spotted bass, respectively.

- The average daily reduction rate in reservoir water surface elevation (m/d) occurring during each month of the spawning period were determined by examining water surface elevation records for Lake Oroville. Because water surface elevation levels differ from year-to-year and vary among water year types, average daily water surface elevation reductions were calculated for each month using data from 1967 to 2001.

- Average daily reservoir water surface elevation reductions occurring each month were compared to the 20 percent nest survival criteria to evaluate potential effects of project operations on black bass spawning survival. Long-term average monthly spawning nest survival percentages were calculated during the black bass spawning period. In addition, the number of occasions that spawning nest survival rates equaled or exceeded the 20 percent nest survival criterion were enumerated and determinations were made on the significance of reservoir water surface elevation fluctuation rates on black bass spawning survival.

Several changes were made to the original SP-F3.1, Task 2C work plan. The work plan originally specified…"*average daily water surface elevation reduction will be calculated for*

each month (April to September) for three water year types (dry, normal, and wet) using data from several dry year, normal years and wet years." The assessment below focuses on the months extending from March through June from 1967 to 2001, which encompasses five water year classifications. The official water year types include wet, above normal, below normal, dry and critical. The reasons for these changes are explained in the sections below.

Literature Review

Lee (1999) suggests that the spawning and initial early rearing lifestages should be treated separately with respect to the potential for reservoir water surface elevation fluctuations to affect both distinct lifestages. Therefore, the description of the literature review targeting each lifestage is treated individually below.

Spawning

Lee (1999) describes spawning characteristics of black bass, including water depth, water temperature, duration, and the spawning period. The data were collected from DFG reprint files and libraries, State Resources Library, U.S Fish and Wildlife Service Reference computer search, and field observations at several California reservoirs. **Table 1** summarizes the data reported for the above traits (Lee 1999).

Further research supports Lee (1999) in that the primary spawning period for bass is from March to May. Moyle (2002) defines the spawning period of smallmouth bass as May to June in most northern California reservoirs. Wang (1986) specifies April to May as the spawning period. For largemouth bass, Moyle (2002) identifies the spawning period as March (in southern California reservoirs) through June. Wang (1986) defines the largemouth bass spawning period as April to June. The spawning timing for spotted bass is similar to largemouth and smallmouth bass. Moyle (2002) describes spotted bass spawning to occur from late March/early April through late May/early June; Wang (1986) specifies late March to June.

Table 1. Spawning characteristics of black bass defined by Lee (1999).

Fish Species	Spawning Period	Water Temperature (ºF)	Maximum Water Depth (ft)	Spawning Duration[1]
Largemouth Bass	Begin February-May, continue until June or July. Majority during March to May	Begin at 60ºF	3.2-13.1 ft CA reservoir maximum 7.2 ft	15 days
Smallmouth Bass	Shorter than largemouth	Begin at 60ºF, upper temperature not as high as largemouth	19.6 ft CA reservoir maximum 8.9 ft	20 days
Spotted Bass			22 ft	15 days

[1] Spawning duration is defined as maximum number of days from nest initiation to free swimming fry.

From the literature review, it was determined that the spawning period for black bass in Lake Oroville extends from March through June. The SP-F3.1, Task 2C work plan originally stated that the analysis would include April to September, but because the literature highlighted March as a key spawning time in California reservoirs, the analysis was extended to include the month of March. A description of the methods used to evaluate potential impacts to black bass

spawning nest survival associated with Lake Oroville water surface elevation reductions are provided below under "Methods and Materials".

Initial early lifestage rearing

The SP-F3.1, Task 2C work plan originally envisioned that the potential project affects analysis would extend from the bass spawning period through the initial early lifestage rearing period (July through September) as well. The initial early lifestage rearing period could potentially be affected by ongoing project operations and concomitant water surface elevation reductions by reducing the frequency with which water surface elevations inundate nearshore, littoral habitat. Nearshore, littoral habitat consisting of inundated reservoir riparian vegetation could provide predator escape cover for young-of-year black bass, and may provide food sources such as terrestrial insect drop, and aquatic macroinvertebrate colonization. However, no widely accepted general criteria has been generated that supports evaluation of the effects of reservoir fluctuations on initial early lifestage rearing of black bass. Lee (1999) states: *"Receding water levels that subsequently expose shoreline areas with little cover for juvenile fish can affect survival. The degree of impact will depend upon magnitude and timing of the drawdown, shoreline gradient, and amount and quality of habitat remaining inundated. Since these factors vary annually and from reservoir to reservoir, we do not believe that specific criteria can be developed for juvenile fish life histories without site specific evaluations."* Additionally, Lee (1999) provides no guidance regarding the type of site specific data that would need to be collected, how it should be analyzed, or what criteria should be used to assess the effects of reservoir water surface elevations on initial early lifestage rearing. In the absence of site specific analysis methodology or criteria for assessing the effects of reservoir water surface elevations on initial early lifestage rearing of black bass in Lake Oroville, habitat components including inundated vegetation, topographic planform geometry of the reservoir, and substrate characteristics were considered relative to the timing and magnitude of drawdown occurring in Lake Oroville.

Lake Oroville is a steep-sided reservoir with poor soils that hinder the establishment of rooted aquatic vegetation in the littoral zone of the reservoir, thus restricting the encroachment of terrestrial vegetation into the fluctuation zone (DWR 2001). Cover typically provides spawning and nursery habitat for warmwater fishes, including black bass, and is traditionally related to increased standing crops of centrarchid species as a result of increased food availability and decreased predation on young-of-year fishes (DWR 2001). However, Lake Oroville is a multi-purpose reservoir, and its use for flood control, water storage, and water supply necessitate water level fluctuations well beyond the elevation zone in which riparian vegetation is inundated. Examination of historic water surface elevation records for Lake Oroville indicates that water surface elevations during the summer and early fall (July to September) are typically at levels below which reservoir riparian vegetation occurs (E. See, pers. comm). Because water levels during the initial early lifestage rearing period for black bass are generally below the zone in which reservoir riparian vegetation occurs, drawdown occurring within the zone lacking riparian vegetation would not alter the availability of inundated vegetation. For example, if in July the reservoir is already drawn down to the level below the zone of existing riparian vegetation, additional drawdown will not result less acreage of inundated vegetation or reductions in food supplies.

With respect to topographic planform geometry, Lake Oroville is a steep-sided reservoir with low surface-to-volume ratio (DWR 2001). As is typical in steep-sided reservoirs, the area-elevation curve is smooth, indicating relative uniform slope of the sides of the reservoir (DWR 2001). Shallow water or littoral benches could provide predator escape cover for young-of-year black bass, but because of the uniform slope and steep-sided nature of Lake Oroville's morphometry, shallow water and littoral bench refuges are not available at the water surface elevations that would be typical in Lake Oroville during the July through September period. Because of the uniform slope of the sides of the reservoir, water surface elevation fluctuations would not be expected to result in less shallow water or littoral bench refuges for initial early lifestage rearing for black bass. Substrate may also play a role in provide refuge for black bass during initial early lifestage rearing, but because the substrate traditionally exposed from the July through September time period is relatively uniform and composed of fine sediments, little refuge from predators is offered at water surface elevations that would be generally expected to occur during the initial early lifestage rearing period.

Although inundated vegetation, shallow water, and slope or substrate-related escape cover from predators is not generally available during the June through September period, Lake Oroville continues to support a very popular and important recreational sport fishery which is recognized as one of the best bass fisheries in the western United States (DWR 2002; DWR 2001; E. See, pers. com.). As illustrated in **Table 2** below, Lake Oroville boasts one of the highest mean black bass catch rates in California, as well as one of the highest mean black bass catch weights in California.

Table 2. Lake Oroville Bass Fishery Comparison.

Waterbody	Most Abundant Black Bass Species	Mean Black Bass Catch Per Hour	Mean Black Bass Weight (lbs)
Lake Oroville	Spotted Bass	0.250	2.20
Lake Shasta	Spotted Bass	0.265	1.43
Trinity Lake	Smallmouth Bass	0.252	1.41
Lake McClure	Spotted Bass	0.221	1.29
Folsom	Spotted Bass	0.187	1.50
Lake Don Pedro	Largemouth Bass	0.186	1.55
New Melones Lake	Largemouth Bass	0.158	1.68
Millerton Lake	Spotted Bass	0.155	1.23
Isabella Lake	Largemouth Bass	0.088	2.18
Source: DWR 2001; data from DFG 1994.			

B.A.S.S. (Bass Anglers Sportsman Society), the largest fishing organization in the world with more than 600,000 members, has recently ranked Lake Oroville as the "...*best bass fishing spot in the state of California*..." in their *Bassmaster Magazine* publication in November of 1999 and in November of 2001. Of the nine B.A.S.S. fishing tournaments that have been held in California, two have been held at Lake Oroville (B.A.S.S. 2002). Additionally, U.S. Angler's Choice frequently holds bass fishing tournaments at Lake Oroville, including their 2002 Northwest Regional Championship, which was the largest Regional Championship held in the western U.S. (U.S. Anglers Choice, 2002).

Because no widely accepted general criteria has been generated that supports evaluation of the effects of reservoir fluctuations on initial early lifestage rearing of black bass, because water

surface elevations during the initial early rearing period (July-September) are typically below the riparian vegetation zone and the slope and substrate are relatively uniform within this zone, and because Lake Oroville is widely recognized as supporting a popular, important, and successful black bass fishery, comparative analyses evaluating potential water surface elevation-littoral reservoir riparian vegetation inundation relationships during the July through September period were not conducted. Therefore, the following evaluation focused on black bass spawning nest survival estimates for which criteria have been established.

METHODS AND MATERIALS

Spawning Survival Curve

Lee (1999) established a spawning survival curve based on the cumulative number of nests as a percentage of total nests observed (**Figure 1**). The percentage of successful nests was determined by dividing the nest depth by the estimated average number of days from nest construction to the free-swimming fry stage. If the drawdown did not exceed the nest depth, the nest was considered successful. The data used to derive the curves are described in Lee (1999). The curves establish reservoir reduction rates for the 20% spawning nest survival criterion used in this analysis. The curves in Figure 1 were recreated for purposes of this analysis using data available from Lee (1999).

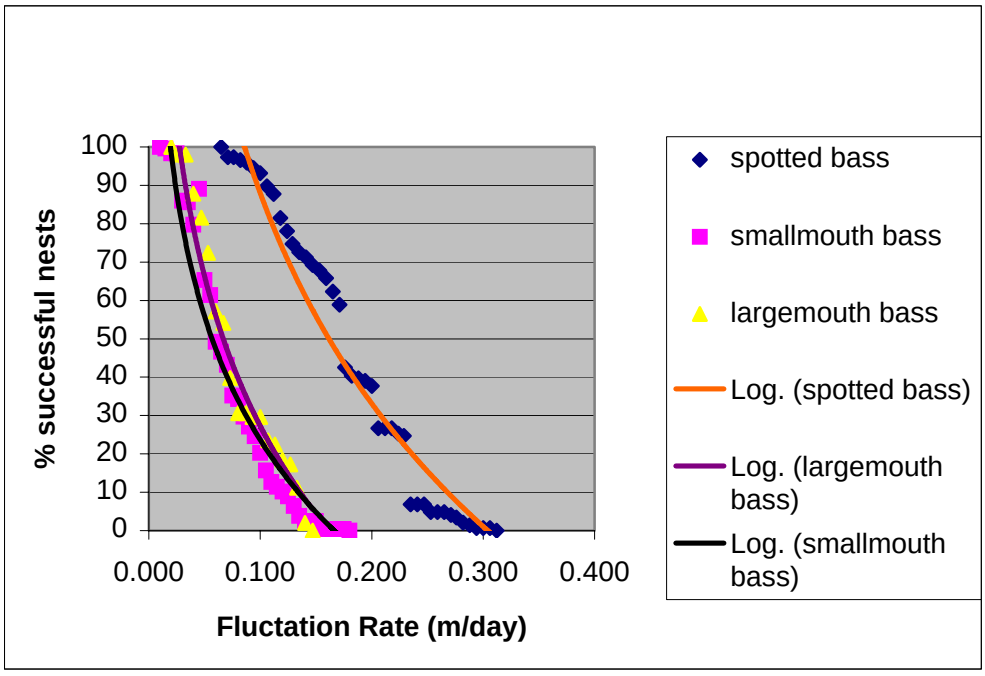

Figure 1 Black bass spawning nest success curves (from Lee 1999).

The equations corresponding to the curves are the following:

Largemouth Bass	Y = -56.378*ln(X)-102.59
Smallmouth Bass	Y = -46.466*ln(X)-83.34
Spotted Bass	Y = -79.095*ln(X)-94.162

Where: X is the fluctuation rate, m/day
Y is the percentage of successful nests

Using the equations, the 20 percent nest survival criteria were estimated to be 0.11 m/d, 0.11 m/d, and 0.23 m/d for largemouth, smallmouth, and spotted bass, respectively.

Reservoir Water Surface Elevation Records

Lake Oroville monthly water surface elevation records were obtained from the Department of Water Resources (DWR) California Data Exchange Center (CDEC). CDEC reports monthly reservoir storage data from October 1967 to present. Monthly data were chosen for this analysis because CDEC daily reservoir storage and water surface elevation data has only been documented since February 13, 1985. This data set represents a minimal sample of the various water year classifications (wet, above normal, below normal, dry, critical). Therefore, the monthly data set of reservoir storage levels from 1967 to 2001 was used in the study.

CDEC reports only monthly data from 1967 onward in reservoir storage levels (acre-feet). For purposes of this study, these data were converted to monthly reservoir elevation levels (feet) utilizing PROSIM 2000. The following equation was used, where Y is elevation level and X is storage level.

Y = A*X+(X**1/2)+C*(X**1/3)+ D
A = -0.002
B = -0.762
C = 50.101
D = 189.039

Daily data are calculated from the monthly data by dividing by the number of days in the month, and feet were converted into meters.

Analytical Procedures

Historic Lake Oroville water surface elevation reductions and reduction rates were compared with criteria which specify reduction rates that would sustain a minimum of a 20 percent spawning nest survival rate for black bass. Lee (1999) reports fluctuation rates in meters per day (m/d); therefore, reservoir water surface elevation fluctuation rates were converted to m/d. Bass spawning nest success (percent) was calculated for each month of the spring spawning period (March through June) for each year included in the analysis (1967-2001). The numbers of occasions for each month included in the analysis over the period of record in which black bass nest survival equaled or exceeded the 20 percent nest survival criterion were enumerated. Long-term (1967-2001) average mean monthly black bass spawning nest survival estimates were calculated overall, and for each month of the March through June spawning period. The literature review indicates that the majority of black bass spawning in California reservoirs occurs from March through May. Therefore, overall long-term average mean monthly nest survival estimates also were calculated for the period extending from March through May. Identical analyses were performed separately for largemouth bass, smallmouth bass, and spotted bass.

RESULTS AND DISCUSSION

The months extending from March through June were utilized to evaluate potential impacts to black bass spawning survival associated with Lake Oroville water surface elevation reductions. The bass nest survival assessment methodology by Lee (1999) states that bass nests would only be affected if reservoir levels were reduced during spawning, and would not be affected by nest flooding. **Table 3** summarizes the number of times during March through June (1967-2001) when reservoir levels were reduced, by examining first-of-the-month and end-of-the-month water surface elevations, for each month. Examination of Table 3 demonstrates that for the months extending from March through June, both water surface elevation increases and decreases have historically occurred. In fact, water surface elevation reductions occurred 11.8, 17.6, 35.3, and 82.4 percent of the time for the months of March, April, May and June, respectively. Thus, the potential to adversely affect black bass nest survival only occurs up to approximately one-third of the time for the primary spawning period extending from March through May, but nearly 80 percent of the time in June.

Table 3. Lake Oroville water surface elevation monthly reduction from 1967-2001.

Month	Number of Months Analyzed	Number of Times Monthly Elevation Reduced	Percent of Total Months
March	34	4	11.8%
April	34	6	17.6%
May	34	12	35.3%
June	34	28	82.4%

For all months (136 months) over the entire period of record included in the analysis (March through June, 1967 to 2001), historic operation of Lake Oroville resulted in water surface elevation reduction rates at which largemouth bass spawning nest survival would equal or exceed 20 percent in 117 out of 136 months (86 percent of the time) (**Table 4**). For the period of time (March through May) during which the majority of spawning occurs, largemouth bass spawning nest survival equaled or exceeded 20 percent in 97 out of the 102 months (95 percent of the time). Smallmouth bass and spotted bass spawning nest survival equaled or exceeded 20 percent approximately 85 and 99 percent of the time, respectively, for the time period March through June, and 95 and 100 percent of the time for the period extending from March through May.

Table 4. Number of months that black bass nest survival equaled or exceeded 20 percent, from 1967-2001.

	Largemouth Bass			Smallmouth Bass		Spotted Bass	
Month	Number of Months Analyzed	No. Months ≥ 20% Survival	% of Total Months	No. Months ≥ 20% Survival	% of Total Months	No. Months ≥ 20% Survival	% of Total Months
March	34	34	100%	34	100%	34	100%
April	34	32	94.1%	32	94.1%	34	100%
May	34	31	91.2%	31	91.2%	34	100%
June	34	20	58.8%	19	55.9%	33	97.1%
Total	**136**	**117**	**86%**	**116**	**85.3%**	**135**	**99.3%**

Long-term average nest survival for the entire period included in the analysis (March through June, 1967 to 2001) was approximately 79, 78, and 92 percent for largemouth bass, smallmouth bass, and spotted bass, respectively (**Table 5**). For the March through May period, which encompasses the majority of black bass spawning, overall long-term average spawning nest survival was about 89, 88, and 97 percent for largemouth bass, smallmouth bass, and spotted bass, respectively (Table 5).

For largemouth bass, average monthly spawning nest survival decreased over the March through June period. Largemouth bass spawning nest survival averaged nearly 100 percent during March, 89 percent in April, and 79 percent in May (Table 5). Of the relatively few largemouth bass nests expected to be present during the month of June, spawning nest survival averaged 49%.

Similar trends in average monthly spawning nest survival estimates were observed for smallmouth and spotted bass. Smallmouth bass spawning nest survival for each individual month of the primary spawning period (March through May) averaged about 99 percent during March, 88 percent in April, and 77 percent in May (Table 5). Average spawning nest survival for smallmouth bass during June was approximately 46%. Spotted bass spawning nest survival was estimated at about 100, 96, 96, and 77 percent for March, April, May and June, respectively.

Table 5. Black bass estimated spawning nest survival (percent) in Lake Oroville for March through June, over the 1967-2001 period of record.

Month	Average Monthly Spawning Nest Survival		
	Largemouth Bass	Smallmouth Bass	Spotted Bass
March	99.8%	98.8%	100%
April	88.9%	88.4%	96.2%
May	78.9%	77%	95.6%
June	48.6%	46.5%	77%
March - June Average	79.0%	77.7%	92.2%
March - May Average	89.2%	88.1%	97.2%

CONCLUSIONS

The literature review establishes that the majority of black bass spawning in northern California reservoirs occurs during the months March through May. Results indicate that water surface elevation reductions and, therefore, the potential for water surface elevation reductions to adversely affect black bass nest survival may only occur up to approximately one-third of the time for the period extending from March through May. Black bass spawning nest survival during each month of the main spawning period (March through May) is relatively high, ranging from 80 to 100 percent for largemouth and smallmouth bass, and 96 to 100 percent for spotted bass, relative to the 20 percent spawning nest survival criteria established to maintain long-term population levels of black bass. Even during June, when relatively few black bass spawning nests would be expected to be present, long-term average monthly spawning nest survival ranges from 47 to 77 percent. In addition, Lake Oroville is widely recognized as supporting a very popular, important and successful recreational black bass fishery, including frequent sponsored bass fishing tournaments, and black bass catch rates and poundage higher than those in other

California reservoirs. Therefore, historic and ongoing project operations affecting water surface elevation in Lake Oroville result in conditions sufficient to maintain long-term population levels of largemouth, smallmouth and spotted bass.

REFERENCES

Bass Anglers Sportsman Society. 2002. Accessed Dec. 4, 2002. Available at http://www.bassmaster.com.

California Department of Fish and Game. 1995. Assessment of California black bass angling regulations. Inland Fisheries Division. 130 pp.

California Department of Water Resources California Data Exchange Center (CDEC). 2002. http://cdec.water.ca.gov/

California Department of Water Resources. 2002. Accessed Dec. 4, 2002. Lake Oroville's Two-story Fishery. Available at http://www.lakeoroville.water.ca.gov/Fisheries-page2.html.

California Department of Water Resources. 2001. Initial Information Package, Relicensing of the Oroville Facilities, January 2001.

California Department of Water Resources and United States Bureau of Reclamation. 2000. Effects of the Central Valley Project and State Water Project on Steelhead and Spring-run Chinook Salmon, November 2000.

Lee, Dennis P. 1999. Water Level Fluctuation Criteria for Black Bass in California Reservoirs. Reservoir Research and Management Project – Information Leaflet No. 12.

Moyle, Peter B. 2002. Inland Fishes of California. University of California Press, Berkeley. p. 397-406.

See, Eric. California Department of Water Resources. Reservoir Biologist - Oroville Field Division. December 11, 2002.

United States. Anglers Choice. 2002. Accessed December 4, 2002. Available at http://www.anglerschoice.com/.

United States Bureau of Reclamation. PROSIM. 2000.

Wang, J. 1986. Interagency Ecological Program Technical Report #9. January 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories.