APPENDIX A

JSA Report: Use of Floodplain Habitat of the Sacramento and American Rivers by Juvenile Chinook Salmon and Other Fish Species

Use of Floodplain Habitat of the Sacramento and American Rivers by Juvenile Chinook Salmon and Other Fish Species

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SUMMARY

During February and early March, high flows in the Sacramento and American Rivers caused the Natomas East Main Drainage Canal (NEMDC) to backup and overflow the site 18a pond and surrounding areas, allowing fish to freely use flooded habitat. The water surface level over the floodplain subsequently dropped, stranding fish in the site 18a pond and providing the opportunity to assess habitat use and conditions required to trigger movement of juvenile chinook salmon and other species out of the pond.

Twenty four fish species were captured during this study, 6 of which were native. Total abundance, however, was dominated by native species, primarily juvenile chinook salmon. Over 3,000 juvenile chinook salmon were captured, including the winter-run chinook salmon that is listed as endangered under the federal and California Endangered Species Acts. A total of 262 winter- and spring-run sized chinook salmon were captured and 124 had adipose clips indicating the presence of coded wire tags. Reading of the coded wire tags confirmed that most of the tagged salmon were winter run.

Return of juvenile chinook salmon to river habitats seems to be determined by size and readiness to migrate downstream that is likely associated with smoltification, the physiological change that occurs prior to movement to sea water. Growth in floodplain habitat is fast (i.e., exceeding 1 mm each day), relative to growth in river habitat, and migration of fish rearing in floodplain habitat likely precedes migration of fish rearing in the main river channel. Mortality in floodplain habitat, however, may be high, and is partially attributable to predation. Stomach contents of crappie indicated significant predation on juvenile chinook salmon. The six crappie examined contained 10 juvenile chinook salmon, from 0 to 3 individual salmon in each crappie.

Floodplain habitat use by juvenile chinook salmon and stranding in isolated ponds indicates potential benefits of restoration actions. Removal of material from the bench in the lower American River will increase the frequency and duration of floodplain inundation, subsequently increasing habitat availability. Floodplain restoration projects should be designed to drain completely, minimizing the occurrence of ponds and associated fish stranding following receding flood flows. Connecting existing ponds to the NEMDC or the American River will provide juveniles access to the rivers and potentially increase overall production of juvenile chinook salmon in floodplain habitat.

INTRODUCTION

In March 1999, juvenile chinook salmon were observed surface feeding in a 17 acre borrow pond at site 18a (i.e., site 18a pond). The pond is adjacent to the Natomas East Main Drainage Canal (NEMDC) and is approximately 2 miles upstream from the mutual confluence of the NEMDC, American River, and Sacramento River. The pond was designed to retain water to support tules and riparian vegetation planted as mitigation at the borrow site.

During February and early March, high flows in the Sacramento and American Rivers caused the NEMDC to backup and overflow the pond and surrounding areas, allowing fish to freely use flooded habitat. On about March 15, 1999, flow in the Sacramento and American Rivers had decreased sufficiently to cause the water surface level in the NEMDC to drop below the elevation of the site 18a pond. Fish that remained in the pond after the overflow period were stranded, including juvenile chinook salmon.

Stranding of fish in the site 18a pond and the presence of a 30-inch gated culvert that drains the pond to the NEMDC provided an opportunity to assess habitat use and conditions required to trigger movement of juvenile chinook salmon and other species out of the pond. This study produced the following data:

- species composition and relative abundance of fish using the restored floodplain habitat;

- observations on the response of juvenile fall-run chinook salmon and other species to pond draining, pond depth, and water temperature conditions; and

- relative abundance of predatory fish and potential predation.

The study led to preliminary development of operations and design criteria to increase benefits of floodplain restoration projects to fish species.

METHODS

Activities included sampling ponds on the floodplain after flood waters had receded and left the ponds without surface connections to the river system. A beach seine was used to sample fish in the site 18a pond and in an adjacent borrow pond. A hoop net was used to sample water discharged from the site 18a pond. Juvenile chinook salmon were marked to enable estimates of abundance. In addition, water surface elevation and water temperature data was collected.

Beach Seine

A 3/16 inch mesh bagged beach seine, measuring 75 feet long and 5 feet deep, was used to sample the site 18a pond and a nearby borrow pond adjacent to the NEMDC .

Borrow Pond

Juvenile chinook salmon were captured from a borrow pond adjacent to the NEMDC and near the northeast corner of the site 18a pond. The fork length of all fish captured in the seine was measured to the nearest millimeter and each fish was categorized to species. Predatory species (i.e., introduced sunfish and catfish) were sacrificed and their stomach contents examined and recorded. Fall-run chinook salmon (i.e., salmon less than 80 mm fork length) were held for marking. All other chinook salmon and steelhead were immediately released to the NEMDC.

Juvenile fall-run chinook salmon were held in a trash can with approximately 20 gallons of water from the pond. Aeration of water in the trash cans was provided by air stones connected to an air tank and ice was added when needed to maintain the water temperature at or slightly below (i.e., within 5°F) the water temperature in the pond. About 0.75 grams of Bismarck brown was added for each 10 gallons of water (Sommer pers. comm.). The dye was thoroughly mixed in the water using dip net. For each batch of fish, between 500 and 1,000 fish were held for about 30 minutes. Fish were removed from the container using a dip net, transported in 5 gallon buckets, and released in the site 18a pond. The number and fork length of fish released was recorded. A sample of 8 marked fish and 8 unmarked fish were transferred to an enclosure submerged in the pond to allow observation of mark retention and handling mortality.

Site 18a Pond

Fish were captured by seine from several locations in the site 18a pond on April 11, 13, 17, 23, and 27. For maximum efficiency, the seine was fished in areas less than 4 feet deep and devoid of trees. The fork length of all fish captured in the seine was measured to the nearest millimeter and each fish was categorized to species. During sampling activities on April 11, fall-run chinook salmon were marked prior to immediate release. Approximately half the length of the left pelvic fin was clipped and all marked fish were immediately released back into the site 18a pond. During subsequent sampling, juvenile chinook salmon were examined for the pelvic fin clip and were either released back into the site 18a pond or into the NEMDC.

Hoop Net

A 3/16 inch mesh hoop net measuring about 5 feet in diameter at the large end, 1.5 feet in diameter at the small end, and 20 feet long was used to capture all fish exiting the pond through the gated culvert. The hoop net was fixed to the culvert apron in the NEMDC. All of the flow exiting the pond passed through the net and all fish larger than approximately 30 mm were effectively captured. When feasible, the net was fished continuously when the culvert gate was open. The hoop net was fitted with a fyke to increase capture efficiency and impede movement back into the pond.

The fork length of all fish captured in the hoop net was measured to the nearest millimeter and each fish was categorized to species. In most cases, all fish were immediately released to the NEMDC. Approximately 10 fish that were considered predatory species (i.e., introduced sunfish and catfish) were sacrificed and their stomach contents examined and recorded. All adipose and pelvic fin clips were noted for chinook salmon and steelhead. Juvenile chinook salmon with adipose fin clips are likely to have a coded wire tag imbedded in their head. The coded wire tag provides information on fish origin and release location. A sample of 20 adipose clipped chinook salmon was kept and sent to the U.S. Fish and Wildlife Service for removal and reading of the microscopic coded wires. All other juvenile chinook salmon were immediately released to the NEMDC. Adipose clipped steelhead are generally not tagged with coded wires and all were immediately released after measurement.

Water Surface Elevation and Water Temperature

Water surface elevation for the NEMDC was based on Sacramento River stage data recorded at I Street (California Department of Water Resources, Division of Flood Management, Operational Hydrologic Data, California Data Exchange Center: http://cdec.water.ca.gov). Water surface elevation in the pond was measured relative to the NEMDC surface elevation and recorded approximately hourly during all sampling activities.

Water temperature was recorded approximately hourly during all sampling activities. In addition, a recording thermometer (Onset Optic Stowaway Temp) was placed near the bottom of the deepest part of the site 18a pond on April 13 and remained in place through April 27.

Endangered Species Issues

Given the location of the site 18a pond in the floodplain, its proximity to the Sacramento River approximately 2 miles to the west, and flooding during February and March caused by high winter flows, species that occur in the Sacramento River and its tributaries may also occur in the pond. Species found in the Sacramento River and protected under the federal and California Endangered Species Acts (ESA) include winter-run chinook salmon, spring-run chinook salmon, steelhead, and splittail. Appropriate ESA take authorization for scientific research was obtained through contact with Mr. Dan Logan of the National Marine Fisheries Service, Ms Stephanie Brady of the U.S. Fish and Wildlife Service, and Ms Deborah McKee of the California Department of Fish and Game. Fortunately, National Marine Fisheries Service concurred that capture of winter-run could be covered under an existing California Department of Water Resources permit for an ongoing study on the Yolo Bypass. Mr. Logan confirmed that a special research take permit was not required for steelhead.

U.S. Fish and Wildlife Service verbally indicated that, given the short time frame for the study within the isolated ponds, a formal take permit would not be required as long as any splittail captured were immediately released to the NEMDC. Department of Fish and Game similarly indicated by verbal confirmation that the study could proceed as long as all spring-run sized chinook salmon were immediately released to the NEMDC.

RESULTS

On about March 15, 1999, flow in the Sacramento and American Rivers receded sufficiently to cause the water surface levels to drop below the elevation of the site 18a pond and subsequently sever connection with the NEMDC (Figure 1). The water surface level continued to drop and several days later on about March 18 the borrow pond was disconnected from the NEMDC. Field observations on March 25 confirmed the presence of chinook salmon in both the site 18a pond and the borrow pond. On March 29, with the onset of warm weather, surface water temperature in the ponds was approximately 65°F. Because water temperatures greater than 65°F potentially stress juvenile chinook salmon (Armour 1991), the decision was made to initiate the study. In all, 24 fish species were captured during the study, 6 of which were native. Although the diversity of non-native species exceeded diversity of native species, abundance was dominated by native species, primarily juvenile chinook salmon.

Winter-run sized (i.e., greater than 80 mm to 100 mm in fork length, depending on date) chinook salmon and steelhead captured during seining and trapping were processed prior to all other species and immediately released to the NEMDC. Release to the NEMDC allowed downstream migration to the Sacramento River. Splittail were not captured during this study. Of the 262 winter-run sized chinook salmon captured, 124 had adipose clips. A sample of 20 adipose clips was kept and sent to the U.S. Fish and Wildlife Service in Stockton for processing. As a prior condition for moving ahead with this study, a copy of this report has been provided to the appropriate permitting agencies.

Beach Seine: Borrow Pond

The borrow pond was sampled on April 3, 1999. The species and number of fish captured by seine from the borrow pond are listed in Table 1. For chinook salmon, run is indicated by body size at this time of year. Fall-run chinook salmon averaged 67 mm fork length (SD = 5, n = 77) and winter- or spring-run chinook salmon averaged 93 mm fork length (SD = 4, n = 8). All steelhead were hatchery produced as indicated by clipped adipose fins and averaged 225 mm fork length (SD = 22, n = 8).

A total of 2,043 fall-run chinook salmon were marked with Bismarck brown. Approximately 40 juveniles died or appeared to be near death at the time of release. On April 7, the fish held to determine mark retention were examined. Of the original 16 fish, 12 were alive and none of the fish retained any indication of the dye. Fish released in the site 18a pond were, therefore, assumed to be indistinguishable from unmarked fish.

Stomach contents of crappie and largemouth bass were examined. The six crappie examined contained 10 juvenile chinook salmon, from 0 to 3 individual chinook salmon in each crappie. Of the 4 largemouth bass examined, 1 contained a juvenile chinook salmon and 1 contained a crayfish. The 2 redear sunfish examined did not contain any prey organisms.

Beach Seine: Site 18a Pond

The site 18a pond was sampled on April 11, 13, 17, 23, and 27. The species and number of fish captured by seine from the site 18a pond are listed in Table 2. The length of chinook salmon varied by date, but generally averaged around 87 mm (standard deviation ranging from 6 to 12 mm) for fall-run chinook salmon. Frequency of juveniles in each size class illustrates possible growth of about 15 mm for fall-run sized chinook salmon between April 3 and April 11 and about 5 mm between April 11 and April 17 (Figure 2). Growth is not apparent between April 17 and April 23. Chinook salmon were not captured on April 27.

Of the juvenile chinook salmon captured on April 11, 491 fall-run sized fish were clipped (i.e., left pelvic fin). The clips were subsequently recaptured on April 13, 17, and 23. The ratio of pelvic fin clips to total fish averaged 6.46% (SD=0.04 for a total of 7 samples). The ratio of clips to total fish ranged from 0 to 11% over all samples. Based on the ratio of pelvic clips to unmarked fish, the estimated total abundance of fall-run sized chinook salmon on April 11 is 10,000 ± 5,000 (∝=0.05).

Juvenile chinook salmon captured by beach seine were primarily fall-run sized. Four winter- and spring-run sized chinook salmon were captured on April 11, including 2 adipose clipped. Only fall-run sized chinook were captured on April 13, 17, and 23. Efficiency of the seine on April 17 and 23 was high because the pond was shallow (i.e., < 2 feet deep) and the net reached across entire sections. Given the high net efficiency, it appears unlikely that any winter- and spring-run sized chinook remained in the site 18a pond after the culvert gate was open on April 15, allowing fish to freely move out of the pond and into the NEMDC.

Hoop Net

The culvert gate draining the site 18a pond to the NEMDC was opened on April 7 at about 8:00 a.m. and closed on April 8 at about 10:00 p.m. The flow through the net was approximately 20 cubic feet per second (cfs) for the entire 38 hour period. Although higher flow rates could have been released, the lower flow avoided abrasion and other injury to captured fish.

Table 3 lists the species and number of fish captured in the hoop net for April 7 and 8 and April 12. Between 8:00 a.m. and 8:00 p.m. on April 8, yellow bullhead and crappie were the primary species moving out of the pond. Examination of stomach contents for a white crappie and 4 black bullheads indicated that the crappie had eaten 2 fall-run sized juvenile chinook salmon and the bullheads were eating insect larvae.

During the first 12 hours of pond drainage, chinook salmon were not captured. With the onset of darkness, 5 winter-run sized chinook salmon (i.e., 120 to 135 mm fork length) moved out of the pond and were captured in the hoop net along with 7 adult suckers. Through the night, the catch consisted of winter- and spring-run sized chinook salmon, suckers, and steelhead, all native species. Two mitten crabs were also captured.

At dawn, another group of white crappie (ranging from 150 to 240 mm fork length) and black bullheads moved into the net. Between 8:00 a.m. and 10:00 a.m., no additional fish were captured. At 11:15 a.m., 20 winter- and spring-run sized chinook salmon and one steelhead were captured. Winter- and spring-run sized chinook salmon were greater than 100 mm fork length. The juvenile chinook salmon continued to exit the pond and enter the net throughout the day. During the study, the peak capture rate for juvenile chinook salmon occurred at about 3:00 p.m. on April 8 when over 100 winter- and spring-run sized chinook salmon entered the net during one hour. The rate of capture declined to less than 3 winter-run sized chinook salmon per hour after 5:00 p.m. With the onset of darkness, 27 winter- and spring-run sized chinook salmon moved into the net, similar to a pulse of fish that occurred on the preceding night. Through the evening, chinook salmon, steelhead , and suckers continued to move into the net. A riffle sculpin was also captured during this period, another native species. The culvert gate was closed at

10:00 p.m. and the hoop net was removed.

At 7:00 p.m. on April 12, fall-run sized juvenile chinook salmon (i.e., less than 100 mm fork length) were observed feeding in the site 18a pond and in the NEMDC. The hoop net was installed at 7:50 p.m. and the culvert gate was opened. Flow through the net was approximately 20 cfs. Initial catch consisted of black bullhead, crappie, and goldfish. At the onset of darkness, 10 winter- and spring-run sized chinook salmon and 4 steelhead were captured. Winter- and spring-run sized chinook salmon and steelhead continued to enter the hoop net until the culvert gate was closed at about 10:00 p.m. After removal from the culvert outlet, 2 mitten crabs were found in the hoop net.

Even though beach seine samples indicated that the majority of fish inhabiting the site 18a pond were fall-run sized fish (i.e., <100 mm fork length), only 4 fall-run sized chinook salmon moved into the hoop net (Figure 3). Winter- and spring-run sized chinook salmon, greater than 110 mm fork length, dominated the hoop net catch.

Of the winter- and spring-run sized fish captured, 124 out of 262 were adipose clipped, indicating the presence of coded wire tags in each fish at the time of release. Twenty of the adipose clipped juvenile chinook salmon were kept and subsequently sent to the U.S. Fish and Wildlife Service. The remaining fish were released unharmed to the NEMDC. The U.S. Fish and Wildlife Service found that seventeen out of the twenty adipose clipped chinook salmon had coded wire tags (Sauls pers. comm.). The numbers on the coded wire tags enabled the origin of each fish to be determined (Table 4). Sixteen of the fish were winter-run chinook salmon produced at Livingston Stone National Fish Hatchery and were released near Redding on January 28, 1999 (Niemela pers. comm.). The other coded wire tagged fish was a fall-run chinook salmon from the Feather River Fish Hatchery that was released on the Sacramento River near the Elkhorn Boat Ramp on February 11, 1999 (Sommer pers. comm.).

Water Surface Elevation and Water Temperature

Water Surface Elevation

As flows in the Sacramento and American Rivers declined in mid-March, water surface elevation in the NEMDC dropped and lost connection with the site 18a pond. Maximum pond depth was about 11 feet on March 15 (Figure 1). Evaporation, seepage, and leakage through the gated culvert caused about a 2 foot drop in pond surface elevation between March 15 and April 7.

On April 7, the gated culvert was opened and approximately 60 acre feet of water drained from the site 18a pond in 38 hours. Before the gated culvert was closed on April 8, the surface elevation of the pond dropped over 4 feet and reduced the maximum pond depth to about 5 feet (Figure 1). On April 12, the gated culvert was opened for about 3 hours and surface elevation dropped another 4 inches.

The gated culvert was opened for the last time on April 15, allowing the site 18A pond elevation to drop about 2.5 feet, reaching equilibrium with the water surface elevation in the NEMDC at about 10 feet above sea level (Figure 1). The surface elevation in the site 18A pond fluctuated with the elevation in the NEMDC over the following 9 days. On April 25, the surface elevation of the NEMDC had dropped to about 8 feet above sea level, equal to the elevation of the bottom of the gated culvert, and the connection between the site 18a pond and the NEMDC was cut off. Up to 1 foot of water remained at several locations in the site 18a pond, totaling approximately one quarter acre in surface area.

Water Temperature

Between March 29 and April 27, surface water temperature in the site 18a pond ranged from about 55°F to near 78°F (Figure 4). Surface temperature responds to daily weather conditions and was often substantially greater than water temperature near the bottom of the pond. On April 13 and 15, surface water temperature exceeded bottom water temperature by about 10°F (Figure 4). As pond depth was reduced, daily temperature fluctuation increased and surface temperature approached bottom temperature. Although the recording thermometer was not in place for the entire study period, bottom water temperature probably remained below 65°F until after April 15. With maximum depth of the site 18a pond reduced to 3 feet or less, bottom water temperature exceeded 75°F several times after April 15.

DISCUSSION

Floodplain habitat, seasonally available during high river flow, has substantial benefits to fish species in the Sacramento River system. High food abundance, a range of water temperature conditions, and improved water clarity may, depending on fish species, enable high growth rates and provide conditions needed for spawning and rearing. Inundation of floodplains also increases input of nutrients to the aquatic ecosystem, potentially increasing overall system productivity with benefits to many species.

Floodplain habitat may also present considerable risk to the survival of individual fish. Temporary and year-round ponds, primarily created by human activities (i.e., gravel mining, levee borrow areas), potentially strand fish as river flow recedes. Fish stranded in temporary ponds die when the ponds dry out. Many species, primarily non-native, thrive in year-round ponds, but other species cannot survive through the summer. Warm water temperature, disease, and predation cause high mortality of juvenile chinook salmon, steelhead, splittail, and other species stranded in perennial ponds as spring progresses toward summer (Shaul pers. comm.). The current study provides preliminary indications of why juvenile chinook remain in floodplain habitat and are sometimes stranded in isolated ponds.

Habitat Use

In the Sacramento River system, native species are adept at using seasonally inundated habitats, especially during the winter and early spring months. Although non-native fish communities dominate the lower Sacramento and American rivers and the Sacramento-San Joaquin Delta during most of the year (Moyle 1976), juvenile chinook salmon are seasonally abundant. Juvenile chinook salmon hare been the primary species observed in the flooded Yolo and Sutter Bypasses and on the floodplain of the lower Feather River during the winter and early spring (California Department of Water Resources 1999, Jones & Stokes Associates 1993, Shaul pers. comm.).

In February and March 1999, high flows backed water up the NEMDC and inundated portions of the floodplain. Consistent with observations in other areas, juvenile chinook salmon were the numerically dominant species in the floodplain habitat (Table 1 and 2). The presence of tagged winter-run chinook salmon illustrates the importance of floodplain habitat along the American River to fish originating from the entire Sacramento River system, not only chinook salmon in the American River. Juvenile winter-run chinook salmon moved out of the Sacramento River and up the NEMDC, onto floodplain habitat, and eventually remained in the site 18a pond. Upstream movement by juvenile chinook salmon has previously been documented for small intermittent streams (Maslin, Mckinney, and Moore 1995), and in both cases movement may be a response to warmer water temperature and increased food availability.

The duration of habitat use by juvenile chinook salmon is dependent on habitat availability and species needs. Habitat availability is a function of floodplain elevation and location; magnitude, timing, and duration of flood flows; and other physical, chemical, and biological conditions, including water temperature, water clarity, prey availability, and predator interactions. Species needs relate to growth, reproduction, survival, and migration. In 1999, floodplain habitat on the lower American River and adjacent to the NEMDC was inundated on February 9 and remained accessible to juvenile chinook salmon and other species through March 15. Although the date that chinook salmon moved into the floodplain habitat adjacent to the NEMDC is unknown, coded wire tagged juvenile salmon captured from the site 18a pond were released near Redding on January 28 and at Elkhorn boat ramp on the lower Sacramento River on February 11. The juvenile salmon potentially used floodplain habitat during most of the inundation period and, as indicated by their presence in the site 18a pond, would have continued to rear in floodplain habitat if inundation had extended beyond March 15.

Fish Stranding

As flow declined during March, the rivers and the NEMDC were again confined to their channels. Ponds on the lower American River flood plain were disconnected from the main rivers and many fish were stranded in the ponds. The beach seine samples from the borrow pond during early April illustrate the high abundance of juvenile chinook salmon relative to the abundance of other species (Table 1).

Magnitude of Loss

Although many species occur in floodplain ponds, high numbers of juvenile chinook salmon are stranded. Adipose clipped juveniles provide a rough basis for estimating initial abundance of fall-run chinook salmon in the site 18a pond. On April 3, approximately 2,050 juvenile chinook salmon were captured in the small borrow pond adjacent to the site 18a pond. Five of the 2,050 fish were adipose clipped, giving a ratio of 0.0025 for clipped to unclipped fish. For the 17 acre site 18a pond, 117 adipose clipped juvenile chinook salmon were captured in the hoop net. Initial abundance of juvenile fall-run sized chinook salmon in the site 18a pond, therefore, may have exceeded 50,000 fish (i.e., 117 ÷ 0.0025). [Note: This estimate assumes an equal ratio of clipped to unclipped fish in both ponds and should be considered as illustrative because of the very small ratio of marked to unmarked fish (i.e., 0.0025) and the availability of only a single sample.]

Although the loss of 50,000 juvenile chinook salmon may be small relative to total production of juveniles in the system, given other factors, the loss warrants consideration. There are thousands of acres of ponds that are isolated throughout the Sacramento River system following flood events, including several hundred acres of ponds on the lower American River floodplain. If similar numbers of fish are lost per acre, loss in all ponds may have exceeded millions of juvenile salmon. Also, given that over 100 smolt-sized winter-run chinook salmon were captured this year, expanded losses of coded wire tagged winter run potentially totaled several thousand, a large number considering that only about 150,000 tagged juvenile winter-run were initially released at Redding.

Factors Affecting Stranding

For juvenile chinook salmon, the magnitude of stranding is determined by floodplain structure and habitat use. As flood flows recede, juvenile chinook salmon and other fish species will move from drained areas. Stranding may occur when fish move into ponded areas that loose connection from the river system. If the timing, frequency, and duration of floodplain availability encompasses the necessary period of use, juvenile chinook salmon will return to the river prior to loss of connection. Return of juvenile chinook salmon to river habitats seems to be determined by size and readiness to migrate downstream that is likely associated with smoltification, the physiological change that occurs prior to movement to sea water.

Size related movement is supported by data collected throughout the study. On April 7, the opportunity for movement out of the site 18a pond and into the NEMDC was provided through the open gated culvert. Capture of juvenile winter- and spring-run sized chinook salmon in the hoop net, and their physical appearance, indicated their readiness to migrate downstream. The length of juvenile chinook salmon was consistent with California Department of Fish and Game observations that the average size of winter-run chinook salmon at saltwater entry is about 118mm (Niemela pers. comm.). Juvenile chinook salmon that moved through the gated culvert draining the site 18a pond on April 7 averaged 122 mm in fork length and had apparently undergone smoltification, as indicated by the absence of parr marks, deciduous scales, and a silvery appearance.

Juvenile chinook salmon that remained in the site 18a pond during beach seine sampling on April 11 through April 23 averaged about 87 mm fork length and displayed parr marks, characteristic of the freshwater residence life stage. The juvenile chinook salmon were observed actively feeding at the surface of the site 18a pond throughout the study, especially during the evenings. Fall-run sized juveniles appeared to avoid moving through the gated culvert because they had apparently not grown to a size ready to move to salt water. Warm water temperature also did not cause substantial movement of juvenile chinook salmon from the pond. After the gated culvert was opened to the NEMDC on April 15, bottom water temperature in the pond exceeded 70°F, but substantial numbers of juvenile chinook salmon remained in the pond up through April 23.

On April 27, it appears that juvenile chinook salmon and other fish left the pond prior to complete isolation from the NEMDC. This conclusion, however, is based on the absence of fish in the residual water remaining in the pond and movement out of the pond was not directly observed. Chinook salmon and other species were abundant in the site 18a pond on April 23 (Table 3), but few fish and no chinook salmon were present in the pond on April 27. It is possible that the depth of the water, primarily less than 1 foot, stimulated final movement through the culvert.

Nightfall is another factor affecting movement. During drainage of the site 18a pond through the hoop net, juvenile chinook salmon did not initially move through the gated culvert until night. A pulse of juvenile movement at nightfall was apparent for all hoop net sampling of the pond drainage. During the second day of pond drainage, however, the highest pulse of juvenile salmon movement occurred at about 3:00 p.m. Movement at this time of day may have been associated with reduced pond depth and increasing water temperature, but the actual cause of movement is unknown.

Fish Growth

Growth of juvenile chinook salmon in floodplain habitat of the Yolo Bypass has been shown to be substantially greater than growth of salmon remaining in the Sacramento River (California Department of Water Resources 1999). Growth of juvenile chinook salmon during this study provides additional confirmation of the potential benefits provided by rearing in floodplain habitat. Growth for fall-run sized chinook salmon is illustrated in Figure 2, where the increase in length appeared to exceed 1 mm each day from April 3 to April 11.

Growth for juvenile winter-run chinook salmon is also indicated. The average size of coded wire tagged winter run released in the Sacramento River near Redding was approximately 80 mm in fork length on January 28, 1999 (Niemela pers. comm.). Two months later during the sampling on April 3, the average size of the 8 winter- and spring-run sized fish captured was 93 mm and the maximum size was 103 mm. On April 7 and 8, the average size of juvenile winter-run exiting the pond was about 122 mm. Although the increase in juvenile size may reflect substantial growth, the size of fish captured is potentially biased because only small fish from the original release may have moved into floodplain habitat, fish captured in the small borrow pond may have been stunted because of the high fish density, predation may have eliminated smaller juveniles during pond residence, and only larger juveniles left the site 18a pond and were captured in the hoop net.

Juvenile steelhead also appeared to grow over the April sampling period, illustrating the potential value of floodplain habitat to juvenile steelhead. The number of fish captured, however, was small and did not permit any definitive conclusions. Also, the presence of only hatchery fish is puzzling, potentially indicating a relationship to release location or hatchery fish behavior.

Predation

Based on an initial rough estimate of 50,000 chinook salmon and an abundance of about 10,000 juvenile chinook salmon estimated in the pond about 2 weeks later (± 5,000, $\propto$=0.05), mortality may have approached 80%. Although the mortality estimate is based on minimal statistics, mortality in the pond was potentially high and is partially attributable to predation by fish, birds, and otters. Black and white crappie, as indicated by stomach contents, were the primary predatory fish species. Large mouth bass and other sunfish species may also prey on juvenile chinook salmon, although the stomach contents examined did not reflect substantial predation. Juvenile steelhead may also prey on juvenile chinook salmon, but all steelhead were released immediately to the NEMDC and stomach contents were not examined. Fish-eating bird species observed in the site 18a pond included great egrets, snowy egrets, great blue herons, pied-billed grebes, western grebe, and double-crested cormorants. Herons and egrets were observed to capture juvenile chinook salmon. Otters were sighted in the NEMDC but were not observed feeding in the site 18a pond.

Several factors may affect predation on the floodplain. Perennial pond habitat that supports substantial populations of crappie and other predatory fish species may lead to high predation on juvenile chinook salmon, especially as juveniles are concentrated in ponds as flood flow recedes. In addition, the relatively low amount of vegetative cover in the site 18a pond may have increased vulnerability of juvenile chinook salmon to predation by birds.

Recommendations for Floodplain Restoration

Available information on floodplain habitat use by juvenile chinook salmon and stranding in isolated ponds, including information developed by this study, indicates the potential benefits of the following floodplain restoration actions:

1. Remove material from the perched floodplain along the lower American River to increase frequency and duration of floodplain inundation, subsequently increasing habitat availability for juvenile chinook salmon.

2. Design floodplain restoration projects to drain completely and minimize ponding following receding flows.

3. Connect existing ponds to the NEMDC or the American River.

4. Provide vegetative cover in inundated areas consistent with riparian and marsh restoration objectives.

Increasing floodplain habitat availability could have substantial benefits to juvenile chinook salmon. Existing floodplain habitat in the Sacramento River system is limited relative to historic availability primarily because levees have reduced the active floodplain to less than 5% of its pre-1850 extent (CALFED Bay-Delta Program 1998). Along the Sacramento River and the lower American River, the active floodplain is even more constricted. In addition to levees, hydraulic mining debris introduced into the channels of the American and Sacramento Rivers during the mid- to late-1800s has resulted in the remaining floodplain perched several meters above the existing river channel (U.S. Army Corps of Engineers and State of California Reclamation Board 1998). The combination of levees and perched floodplain has reduced inundation frequency and duration and, therefore, seasonal availability of floodplain habitat to juvenile chinook salmon. Removing material from the bench in the lower American River would increase the frequency and duration of floodplain inundation.

As discussed above, stranding is potentially significant source of mortality following flood events. Floodplain restoration projects must be designed to drain completely and minimize ponding following receding flows. This study showed that the gated culvert on the site 18a pond, in combination with pond structure, allowed egress of stranded fish to the NEMDC. If the gated culvert had not been installed, juvenile chinook salmon, steelhead, and other fish species stranded in the isolated pond would have died during the ensuing warmer months. Although the residual ponds remaining after the site 18a pond drainage did not contain substantial numbers of stranded fish, additional contouring to allow complete drainage would avoid stranding that might occur during cooler weather or when connection with the NEMDC is rapidly severed.

The site 18a pond represents 17 acres out of several hundred acres of ponds on the American River floodplain. The magnitude of stranding for juvenile chinook salmon, including winter-run chinook salmon, indicates potential benefits of improved connections that allow fish to exit existing ponds and complete downstream migration. In ephemeral ponds, stranding losses could be reduced by recontouring the ponds so that they drain completely to the NEMDC or the American River. For perennial ponds, habitat values for wood ducks, pond turtles, otters, and other species need to be considered. Connections to the NEMDC may be appropriate, either through permanent sloughs or through gated culverts that may be operated consistent with multiple species needs. Management of perennial ponds should also consider factors that could reduce predation by non-native fish species, especially crappie, largemouth bass, and other predators on juvenile chinook salmon.

Riparian and marsh vegetation may provide cover that could benefit rearing chinook salmon. Riparian vegetation provides velocity refuge during high flow events. As flows recede, vegetative cover provides shade that may minimize water temperature fluctuation and maintain conditions that improve growth and survival. Vegetative cover may also increase food availability and provide refuge from predators, especially from birds.

Additional Information Needs

Future studies are needed to provide information for improved floodplain management for fish species, including design and prioritization of restoration actions. Improved connectivity of the floodplain would increase use and reduce stranding losses. Recording the timing, frequency, and duration of floodplain inundation and the location, elevation, and size of existing ephemeral and perennial ponds would improve understanding of the potential use and extent of stranding. Restoration actions could then be prioritized based on cost of improving connectivity, species affected, and frequency of potential stranding.

Although benefits of riparian and marsh restoration are recognized for many species, the benefits of vegetative cover to fish species in floodplain habitats is relatively undocumented. Comparison of juvenile chinook salmon survival and growth in ponded areas with and without vegetative cover, along with measurement of water temperature and other water quality parameters, would provide additional support and direction for riparian and marsh restoration actions.

Substantial numbers of juvenile chinook salmon are known to use floodplain habitat and become stranded in floodplain ponds, but potential effects on population abundance have not been determined. Population effects are difficult to determine because annual abundance varies by orders of magnitude and the importance of floodplain habitat is largely dependent on weather. Relatively simple and inexpensive tagging studies could provide information on the magnitude of habitat use and stranding in any given year. Studies to determine population effects, however, would be costly and require a long-term commitment.

Studies are needed to better understand the types of connections that will allow movement from ponded areas. Unanswered questions include:

- Must ponded areas drain completely or is there a minimum depth that will result in fish movement?
- Are there advantages of open channels over culverts?
- What is the minimum size of a connection required for fish movement?
- Is a static connection sufficient, or is tidal or net flow needed to stimulate movement of fish?
- What effect does water quality, such as water temperature, water clarity, and dissolved oxygen, have on fish movement?

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A relatively simple study quickly became complex because of endangered species issues and unexpected capture of adipose clipped chinook salmon. The help and cooperation of Mr. Dan Logan of the National Marine Fisheries Service, Ms Stephanie Brady of the U.S. Fish and

Wildlife Service, Ms Deborah McKee of the California Department of Fish and Game, and Ted Sommer of California Department of Water Resources enabled quick resolution of endangered species issues and subsequent implementation of the study within a very short window of opportunity. Erin Sauls (U.S. Fish and Wildlife Service), Kevin Niemela (U.S. Fish and Wildlife Service), and Jerry Big Eagle (Big Eagle and Associates) took time out of their busy schedules to furnish information on coded wire tags.

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Shaul, Warren. Fish Biologist. Jones & Stokes Associates, Sacramento, CA. Personal records of fish sampling in the Sacramento and Sutter Bypasses and on the Feather River floodplain. E-Mail: warrens@jsanet.com.   Phone: 916 737 3000.

Sommer, Ted. Fish Biologist. California Department of Water Resources, Sacramento, CA. E-Mail communication and phone conversations about use of Bismarck brown and inclusion on scientific research take permit for winter-run chinook salmon: March 25, April 2, and April 7, 1999. E-Mail: tsommer@water.ca.gov. Phone: 916 227 7537.

Table 1. Species and Number of Fish Captured in the Borrow Pond by Beach Seine on April 3, 1999

Species	**Number**	**Comment**
chinook salmon[1] *Oncorhynchus tshawytschya*	2,051	includes juveniles of all runs
steelhead[1] *Oncorhynchus mykiss*	9	all adipose clipped hatchery fish
golden shiner *Notemigonus crysoleucas*	80	adult, spawning condition
Sacramento pikeminnow[1] *Ptychocheilus grandis*	35	juveniles, most less than 100 mm
Sacramento blackfish[1] *Orthodon microlepidotus*	2	juveniles, about 100 mm in length
Sacramento sucker[1] *Catostomus occidentalis*	2	juveniles <60 mm
threadfin shad *Dorosoma petenense*	32	adult
inland silverside *Menidia beryllina*	28	adult
bluegill *Lepomis macrochirus*	30	adults and juveniles
black crappie *Pomoxis nigromaculatus*	10	adults (170 - 200 mm)
white crappie *Pomoxis annularis*	1	adult
largemouth bass *Micropterus salmoides*	7	adult (300 - 420 mm) and juveniles
redear sunfish *Lepomis microlophus*	2	adult

[1]Native species

Table 2. Species and Number of Fish Captured in the Site 18a Pond by Beach Seine

Species	Number by Sampling Date April 1999					Comment
	11	13	17	23	27	
chinook salmon[1] *Oncorhynchus tshawytschya*	495	49	310			includes juveniles of all runs
steelhead[1] *Oncorhynchus mykiss*	1					adipose clipped hatchery fish
golden shiner *Notemigonus crysoleucas*	18	5	4	12		adults
fathead minnow *Pimephales promelas*	1					adult
goldfish *Carassius auratus*		2			1	adult
carp *Cyprinus carpio*			1			juvenile
red shiner *Notropis lutrensis*		1		1	1	
Sacramento pikeminnow[1] *Ptychocheilus grandis*	9	5	7	2		juveniles (<100 mm)
Sacramento sucker[1] *Catostomus occidentalis*	1	1				juveniles (<100 mm)
threadfin shad *Dorosoma petenense*	11	80	76	120	4	adult
inland silverside *Menidia beryllina*	1	1	16		6	adult
bluegill *Lepomis macrochirus*			4			adults and juveniles
pumpkinseed *Lepomis gibbosus*			1			
black crappie *Pomoxis nigromaculatus*			1			adult
white crappie *Pomoxis annularis*		2	1	1		adult
redear sunfish						

Species	Number by Sampling Date April 1999					Comment
	11	**13**	**17**	**23**	**27**	
Lepomis microlophus			2	25		adults and juveniles
logperch *Percina macrolepida*			5	2		adult
black bullhead *Ictalurus melas*			6	32		adult and juvenile
brown bullhead *Ictalurus nebulosus*			1			adult
white catfish *Ictalurus catus*				1		adult
mosquitofish *Gambusia affinis*					1	adult

[1]Native species

Table 3. Species and Number of Fish Captured in a Hoop Net on a Gated Culvert between the NEMDC and the Site 18a Pond

Species	Number by Sample Date - April 1999		Comment
	7-8	12	
chinook salmon[1] *Oncorhynchus tshawytschya*	237	17	winter-run sized juveniles except for 4 fall-run sized
steelhead[1] *Oncorhynchus mykiss*	11	9	adipose clipped hatchery fish
golden shiner *Notemigonus crysoleucas*	5		adults
fathead minnow *Pimephales promelas*	2		adult
goldfish *Carassius auratus*	1	4	juveniles
carp *Cyprinus carpio*		1	juvenile
Sacramento pikeminnow[1] *Ptychocheilus grandis*	1		juveniles (<100 mm)
Sacramento sucker[1] *Catostomus occidentalis*	19		juveniles (<100 mm)
bluegill *Lepomis macrochirus*	4		adults and juveniles
black crappie *Pomoxis nigromaculatus*	4		adult
white crappie *Pomoxis annularis*	16	11	adult
redear sunfish *Lepomis microlophus*	3		adults and juveniles
black bullhead *Ictalurus melas*	98	9	adult and juvenile
riffle sculpin[1] *Cottus gulosus*	1		

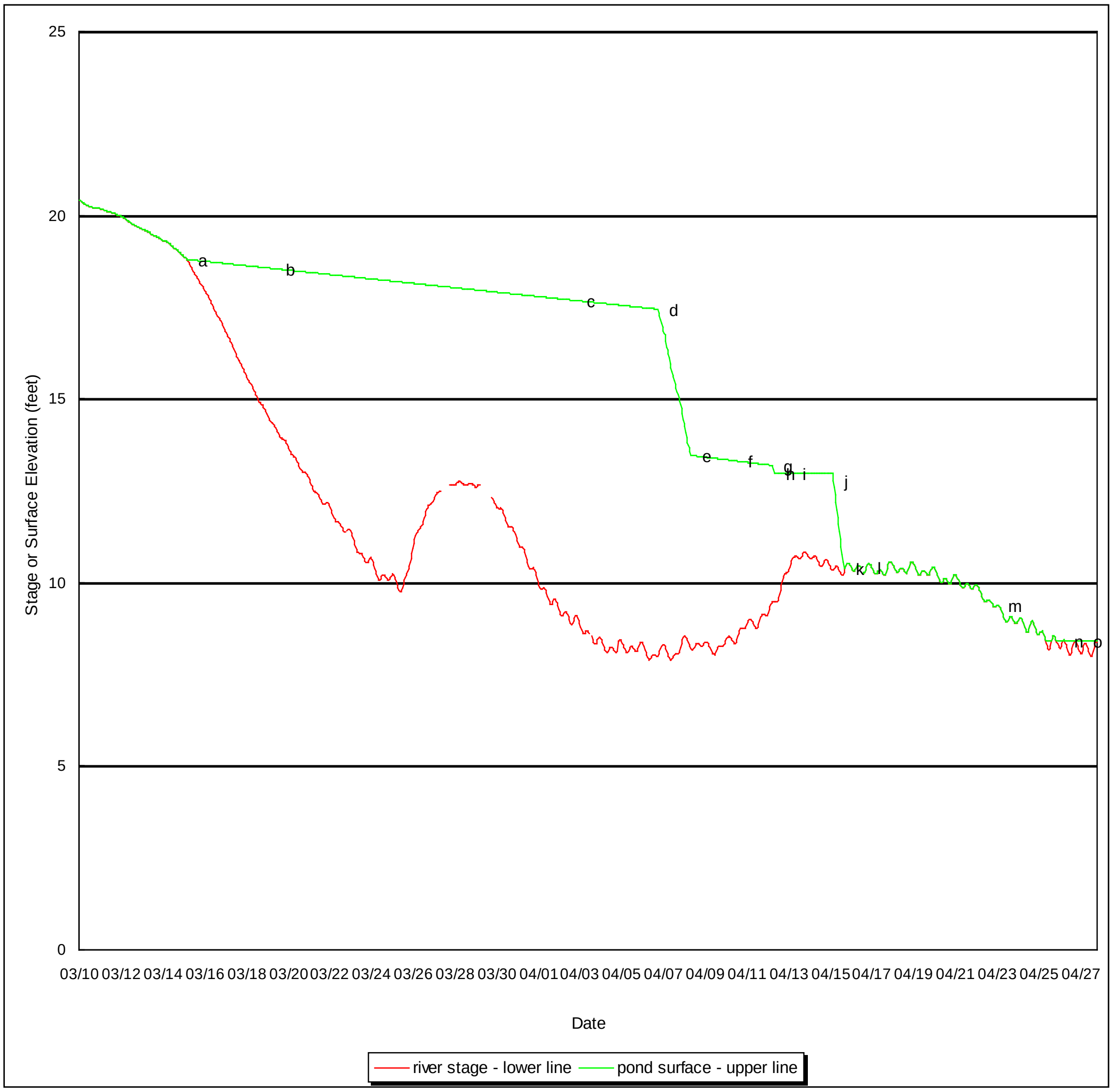
[1]Native species

Table 4. Coded Wire Tagged Chinook Salmon Recovered At Site 18A Pond, April 1999

Number	Date	Fork Length	Tag Code	Run
1	04/07	126 mm	05-01-02-08-11	winter
2	04/07	122 mm	No Tag	
3	04/07	114 mm	05-01-02-09-02	winter
4	04/07	128 mm	05-01-02-08-11	winter
5	04/07	105 mm	No Tag	
6	04/07	130 mm	05-01-02-08-15	winter
7	04/08	118 mm	No Tag	
8	04/08	109 mm	05-01-02-09-08	winter
9	04/08	120 mm	05-01-02-09-08	winter
10	04/08	121 mm	05-01-02-09-03	winter
11	04/08	121 mm	05-01-02-09-06	winter
12	04/08	125 mm	05-01-02-09-09	winter
13	04/08	119 mm	05-01-02-09-02	winter
14	04/08	128 mm	05-01-02-09-07	winter
15	04/08	124 mm	05-01-02-09-08	winter
16	04/08	118 mm	05-01-02-09-12	winter
17	04/08	113 mm	05-01-02-08-12	winter
18	04/08	135 mm	05-01-02-09-06	winter
19	04/08	130 mm	05-01-02-09-08	winter
20	04/08	125 mm	06-01-06-07-08	fall

Note: All of these fish (except 06-01-06-07-08) were from Coleman NFH. They were all released at Caldwell Park on the Sacramento River near Redding on January 28, 1999. Mean fork lengths for each group ranged from 70 mm to 84 mm. Tag 06-01-06-07-08 is from the Feather River Hatchery and was released on the Sacramento River at Elkhorn boat ramp on February 11, 1999. (Sauls, Sommer, and Niemela pers.comm.).

Figure 1. Sacramento River Stage at I Street and Approximate Site 18a Pond Surface Elevation during March and April 1999



Key Dates:

a - site 18a pond disconnects from NEMDC
b - small borrow pond disconnects from NEMDC
c - sample and mark fish from small borrow pond
d - begin first drainage of site 18a pond through hoop net
e - end first drainage of site 18a pond through hoop net
f - seine and fin clip fish in site 18a pond
g - begin second drainage of site 18a pond through hoop net
h - end second drainage of site 18a pond through hoop net
i - seine site 18a pond
j - open gated culvert
k - site 18a pond reaches equilibrium with NEMDC
l - seine site 18a pond
m - seine site 18a pond
n - site 18a pond drainage is complete
o - seine residual ponds within site 18a pond

Figure 2. Fork Length of Juvenile Chinook Salmon Captured by Beach Seine during April 1999

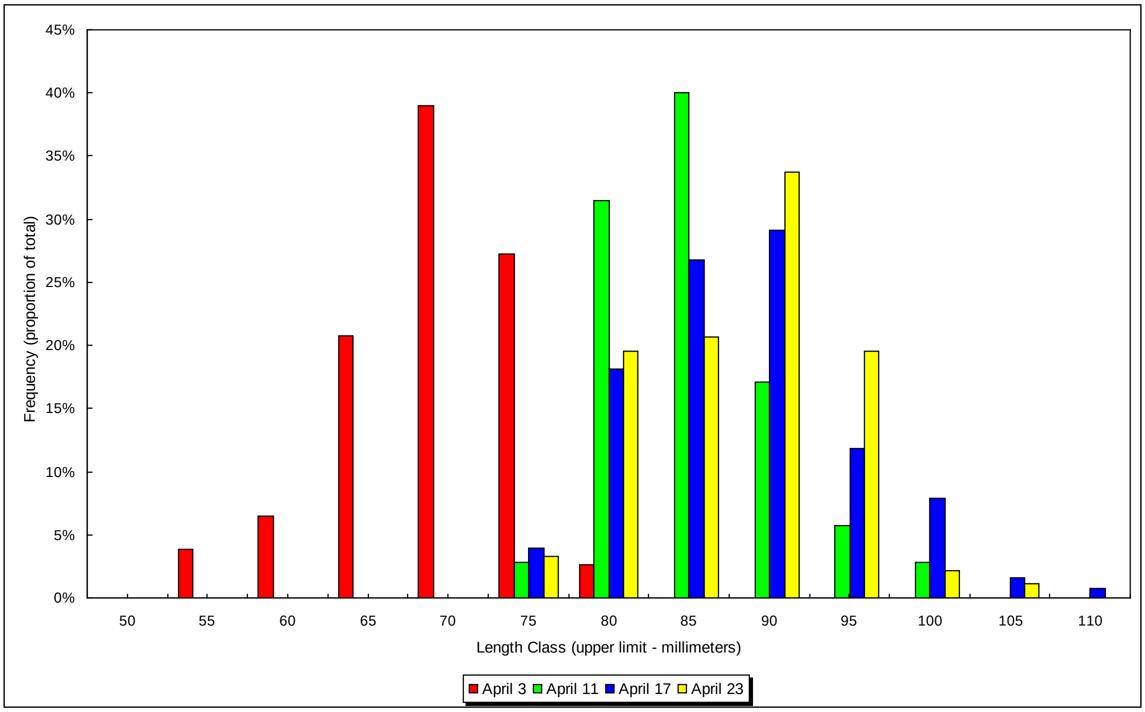


Figure 3. Comparison of Fork Length of Juvenile Chinook Salmon for Beach Seine and Hoop Net Catches from the Site 18a Pond during April 1999

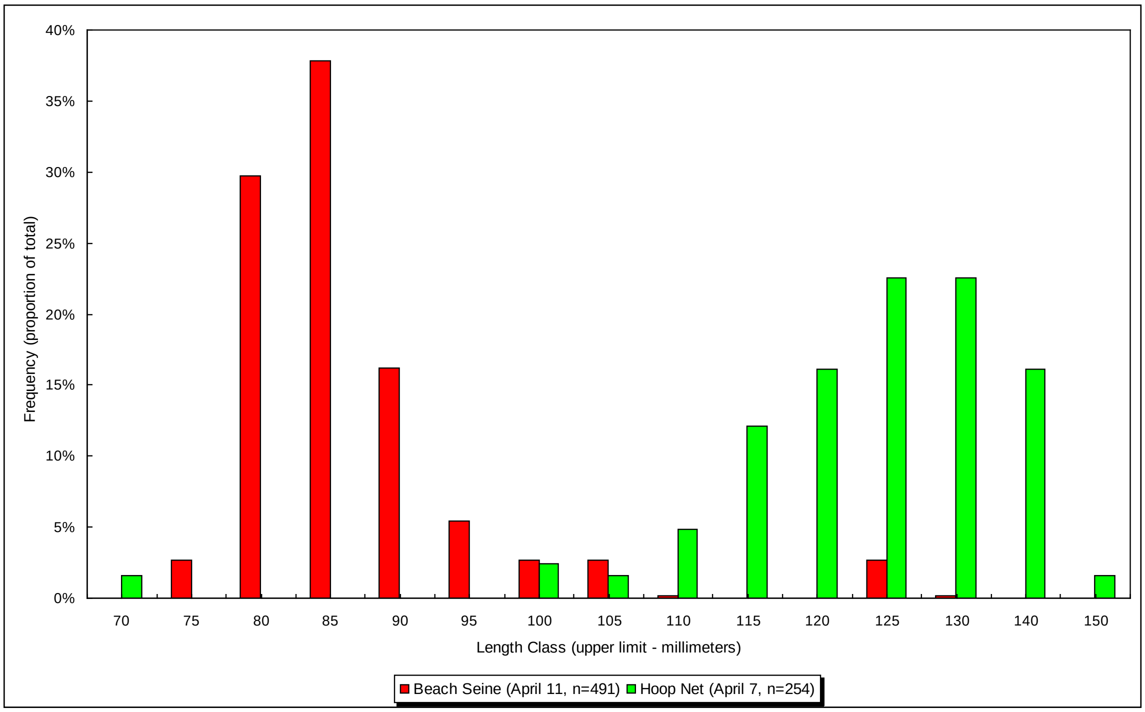
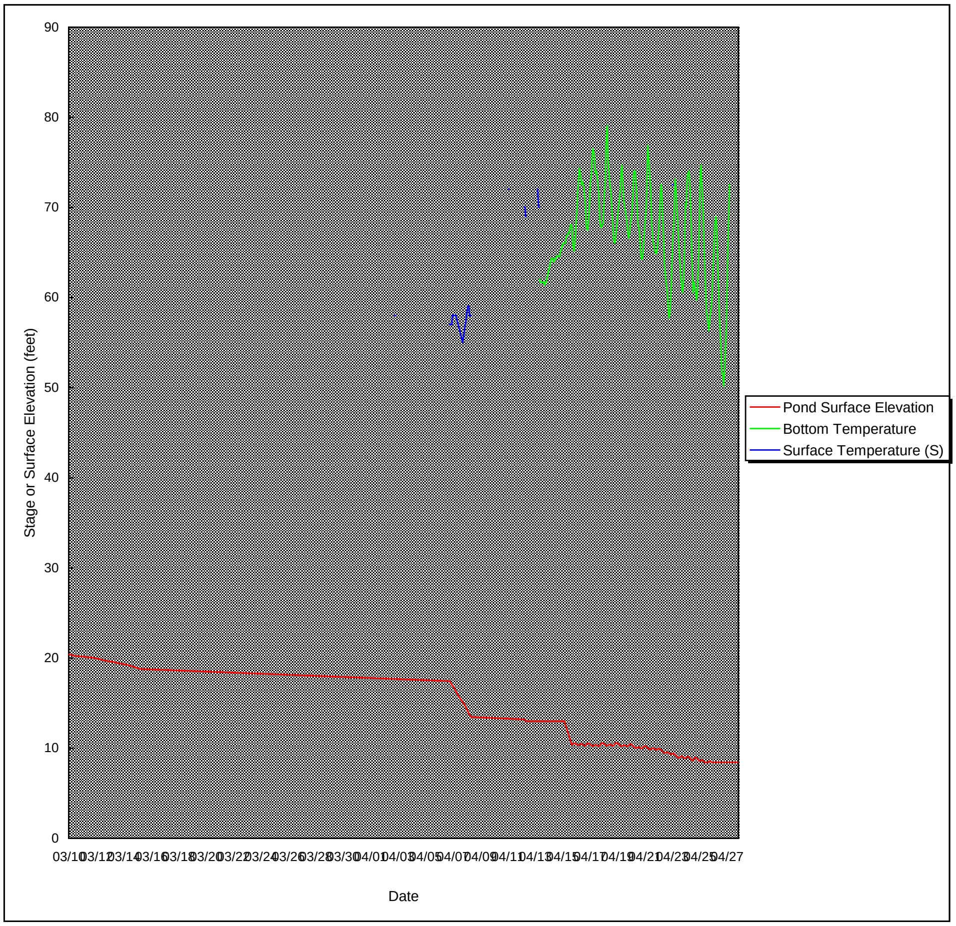


Figure 4. Site 18a Pond Surface Elevation and Water Temperature during March and April 1999



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m - seine site 18a pond
n - site 18a pond drainage is complete
o - seine residual ponds within site 18a pond