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Status of June Sucker in Utah Lake and Refuges

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ABSTRACT The June sucker *Chasmistes liorus* is endemic to Utah Lake, Utah. Abundant when first described in the 19th century, the species declined precipitously in the 20th century, leading to it being listed as endangered in 1986. The wild population size at time of listing was estimated to be less than 1,000 and may be even smaller at present. A multi-partner cooperative program was formally established in 2002 with the dual goals of recovering the June sucker and allowing continued operation of water facilities for human use. One recovery action of the program has been collection and artificial propagation of June sucker, yielding more than 46,000 June sucker of varying ages currently being held outside of Utah Lake. Mature fish held in captivity are beginning to contribute to recovery as they and their offspring are released into the lake. Dwindling numbers of wild fish combined with the increasing proportions of stocked fish returning to spawn in the Provo River indicates barriers to recruitment that are being addressed by other program recovery actions. While actions being taken to address environmental threats to June sucker, especially controlling nonnative fishes and habitat alteration, must continue if artificially and naturally produced June sucker are to survive in Utah Lake, the ability of this species to thrive and reproduce in habitats outside of Utah Lake will likely be important to its persistence. Habitat recovery and conservation efforts will be critical for maintaining a diverse environment where both June sucker and Utah sucker *Catostomus ardens* can survive. Environmental influences in Utah Lake appear to have been important for the evolution of sucker feeding habits and the observed morphologies of the two species. June sucker have been kept from going extinct, but should remain listed as endangered. The goal of this paper is to present information regarding the current status of June sucker and the status of actions to recover this endangered species, currently dominated by the captive propagation efforts.

The June sucker *Chasmistes liorus* is one of four extant species of lakesuckers in North America. The three other species are the cui-ui *C. cujus* of Pyramid Lake, Nevada and shortnose sucker *C. brevirostris* and Lost River sucker *Deltistes luxatus* of the Klamath lakes and Lost River system of Oregon and California (Scoppettone and Vinyard 1991). The Snake River sucker *C. muriei*, a presumed fifth lakesucker species from the upper Snake River system of Wyoming, was described by Miller and Smith (1981) after its extinction in the 20th century. The June sucker was federally listed as endangered with critical habitat in 1986 (USOFR 1986). Designated critical habitat

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is the lower 7.8 km of the Provo River (Figure 1). A June sucker recovery plan was approved in 1999 (USFWS 1999).

June sucker were first collected from Utah Lake by scientists of the Wheeler expedition of the 1870s (Cope and Yarrow 1875) and were formally described by Jordan (1878). The species is endemic to Utah Lake and its tributaries. Some first accounts of June sucker described a very large spawning population (Jordan 1878; Jordan and Evermann 1903; Carter 1969; Heckmann et al. 1981) that supported large harvests of the fish by aboriginal humans as well as settlers of European descent from the east (Carter 1969). The annual spawning run of this species is known today only from the Provo River.

June sucker was one of 12 native fish species found in Utah Lake at the end of the 19th century. The historic ichthyofauna of Utah Lake also included Utah chub *Gila atraria*, leatherside chub *Snyderichthys copei*, speckled dace *Rhinichthys osculus*, longnose dace *R. cataractae*, Bonneville redside shiner *Richardsonius balteatus hydroflox*, least chub *Iotichthys phlegethontis*, Utah sucker *Catostomus ardens*, Bonneville cutthroat trout *Oncorhyncus clarkii utah*, mountain whitefish *Prosopium williamsoni*, mottled sculpin *Cottus beldingii*, and Utah Lake sculpin *Cottus echinatus*. Miller and Smith (1981) suggested that contemporary suckers of Utah Lake resulted from hybridization events between Utah sucker and June sucker within the past 80 years, especially during drought conditions of the 1930s. Hybridization between June and Utah suckers has been noted by modern workers, though the timing of the initiation of hybridization is uncertain (Li 1999). Recent molecular analysis suggests that June and Utah sucker share a common evolutionary history, having diverged into the modern forms from a common progenitor in recent geologic history (Mock et al. 2006). The two sucker species recognized as occurring in Utah Lake today are June sucker and

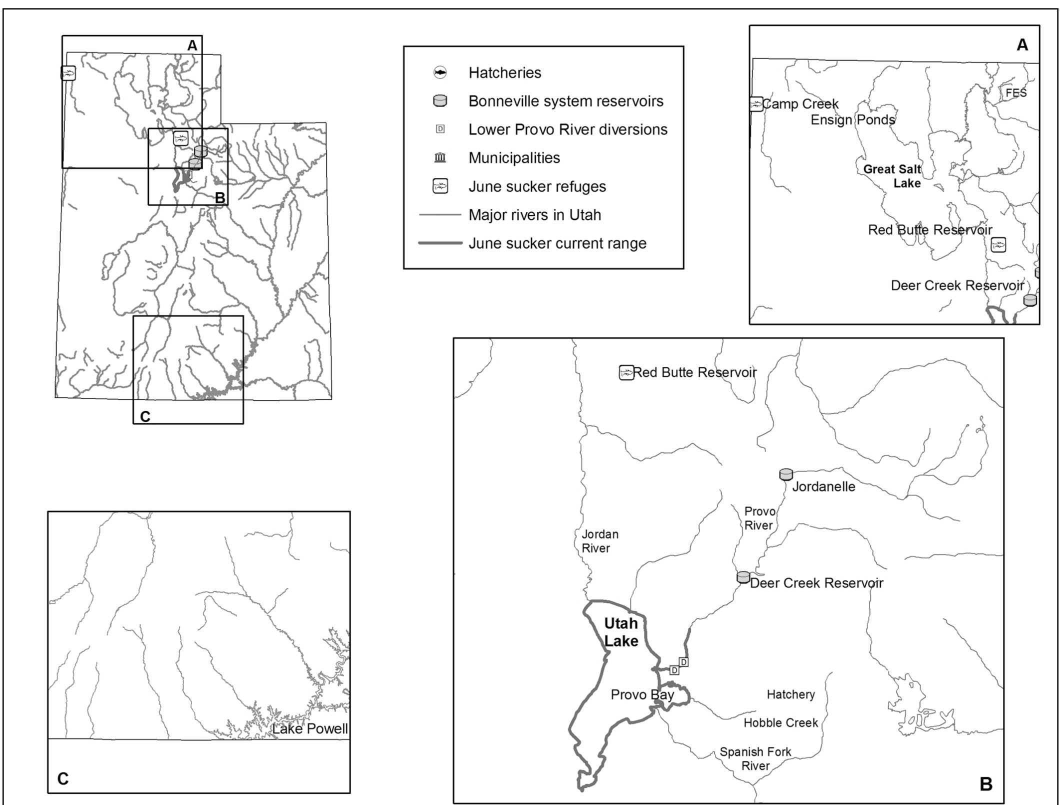

Figure 1. Selected localities throughout Utah.

Utah sucker (USFWS 1999; Belk et al. 2001; SWCA 2002).

June sucker are so named because their annual spawning run often occurred in June (Miller and Smith 1981; Shirley 1983; Radant et al. 1987). Recent information suggests that spawning runs now occur from mid-April to early May (Utah Division of Wildlife Resources, unpublished data) perhaps in response to altered hydrologic conditions resulting from water development (Figure 2). Wild June sucker mature in about their fifth year of life, based on opercles taken from spawning June sucker accidentally killed (Belk 1998). Evidence from a small number of individuals suggests a potential life span of more than 40 years (Scoppettone and Vinyard 1991; Belk 1998).

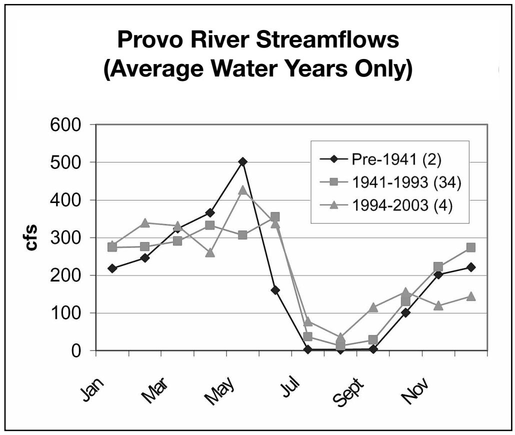

Figure 2. Provo River stream flows (in cubic feet per second) for average water years. Number in parentheses in legend refers to the number of average water years included in that time period. Deer Creek Reservoir was constructed in 1941, and the June sucker flow work group began meeting in 1994.

Water Development History

In March 1849, settlers established the first colony along the Provo River, called Fort Utah, and constructed the first water diversion structure on the river. The "Bean Ditch" irrigation canal provided water for more than 80 ha of crops (USBR 1989). By 1850, several larger diversions were constructed near the mouth of Provo Canyon approximately 17 km upstream from Utah Lake. Water-propelled industry, such as sawmills, became common. In 1853, the first irrigation company was formed and was allowed to remove up to half the water of the Provo River.

The average annual inflow (1951–1990) to Utah Lake from all sources is about 898 million cubic meters (898×10^6 m^3). Of this, 428×10^6 m^3 is discharged to the Jordan River (only natural outlet of Utah Lake; Figure 1) and about 470×10^6 m^3 is lost to evaporation. In 1872, a low dam was placed across the lake outflow to the Jordan River, changing the function of Utah Lake to a storage reservoir. A pumping plant was built in 1902 so that the lake could be lowered below the outlet elevation. The pumping plant has been modified and enlarged several times. Its present capacity is about 31.5 m^3/s, and it can lower the lake level 2.4–3 m below the "compromise elevation" of 1,368.26 m mean sea level (msl; Utah Division of Water Resources 1997). The compromise elevation is a target managed lake elevation that the interested water authorities have agreed to try to maintain. The surface elevation of Utah Lake fluctuates, on average, about 1.2–1.5 m in a given year. Over several years, the surface elevation can fluctuate approximately 3.4 m. At compromise elevation, the lake has an average depth of 2.9 m and a maximum depth of 4.2 m (Fuhriman et al. 1981). Approximately 2,590 m of the lower Provo River is influenced by the lake level when it is at compromise elevation (Keleher et al. 1999).

Deer Creek Reservoir, the principle feature of the Provo River Project, was constructed by the Bureau of Reclamation in 1941 about 25 km upstream of Utah Lake (Figure 1). It has an active storage capacity of 188×10^6 m^3 and is operated by the Provo River Water Users Association. Approximately 149×10^6 m^3 of Provo River water is stored in Deer Creek Reservoir. The reservoir also stores water imported from adjacent Weber and Duchesne River drainages (Utah Division of Water Resources 1997).

Jordanelle Reservoir, approximately 17 km upstream from Deer Creek Reservoir, was first filled to capacity in 1996 (Figure 1). It has a storage capacity of 460×10^6 m^3 and is operated by the Central Utah Water Conservancy District as a component of the Bonneville Unit of the Central Utah Project (Utah Division of Water Resources 1997).

Historic use of Provo River water in Utah Valley for agriculture and municipal purposes by increasing numbers of settlers resulted in the loss of an extensive wetland at the confluence of the river and the lake (Wakefield 1933), channelization of the river, and armoring of the banks. Extended drought in the 1930s decreased the area and volume of Utah Lake (Miller and Smith 1981). Altered flow regimes in the lower Provo River, along with decreased available spawning habitat as a result of river channelization and installation of diversion dams that block migration, increase the potential for hybridization with Utah sucker. Lowest flows of the lower Provo River in recent times were observed in the early 1980s. The natural spring runoff peak has been altered due to upstream reservoir storage (Radant et al. 1987). A cooperative effort is underway among water authorities and providers to restore the timing and duration of a more natural hydrograph by acquiring and releasing water to mimic historic flows. Agencies continue to refine flow recommendations and acquire necessary water to maximize habitat for June sucker spawning.

Threats to June Sucker

Nonnative fish species

Nonnative fish were introduced into Utah Lake, starting with black bullhead *Ameiurus melas* in 1871 and common carp *Cyprinus carpio* in 1881, as food sources in part because overharvest had so dramatically reduced the supply of native fish species (Popov 1949). Sport species were also introduced throughout much of the 20th century, and although not all species have persisted, a large suite of nonnative fish species is now present in Utah Lake. Most are thought to directly or indirectly impact June sucker, including goldfish *Carassius auratus*, common carp, red shiner *Cyprinella lutrensis*, fathead minnow *Pimephales promelas*, black bullhead, channel catfish *Ictalurus punctatus*, western mosquitofish *Gambusia affinis*, white bass *Morone chrysops*, green sunfish *Lepomis cyanellus*, bluegill *L. macrochirus*, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, yellow perch *Perca flavescens*, and walleye *Sander vitreus* (SWCA 2002). The most recent thorough inventory of the Utah Lake fish community was conducted in 1978 and 1979 (Radant and Sakaguchi 1981; Table 1). Of 17 species sampled, common carp were the most abundant fish collected, representing 66.2% of the catch by number and 90.9% by weight. Common carp were followed by white bass (26.7% by number, 4.2% by weight), walleye (2.0% by number, 2.6% by weight), and black bullhead (1.4% by number, 0.7% by weight). All other fish species collected represented less than 1% both in number and weight of total catch. The only native species collected, excluding a single Utah chub, were June sucker and Utah sucker that combined represented 0.4% of the total number captured and 0.5% of weight (Table 1). White bass and common carp have the greatest negative impacts through direct and indirect effects on June sucker (SWCA 2002).

Population declines

Habitat losses from natural (Miller and Smith 1981) and anthropogenic (Wakefield 1933; Radant et al. 1987) causes, introduction of nonnative fish (Table 1), and overharvest (Carter 1969) appear to have initiated large-scale population declines of the June sucker (Modde and Muirhead 1994; USFWS 1999; Belk et al. 2001). Modde and Muirhead (1994) concluded that recruitment failure of June sucker in Utah Lake was not attributable to poor reproductive success. June sucker raised in protected locations and released into Utah Lake return to spawn in the Provo River thereby providing further evidence that the major impediment to recruitment and eventual recovery of the species is low survival of early life stages.

June sucker numbers, counted during the annual spawning run, were estimated at below 1,000 adults in 1986 when the species was listed as endangered (USFWS 1999). As the need for federal listing became apparent, the threat of extinction of June sucker seemed imminent. Scoppettone and Vinyard (1991) stated in their review of the life history and management of the four endangered lakesuckers "…the June sucker population may have declined so low that extraordinary efforts will be required to avert extinction." Initial efforts to prevent extinction included streamside in vitro spawning and taking of fertilized eggs into a hatchery for hatching and rearing (UDWR 2004). Opportunistic actions to rear June sucker were

Table 1.
Relative abundance by number and weight of adult fish collected in 1978 and 1979 inventory of Utah Lake (Randant and Sakaguchi 1981).

Species	*Total number*	*Percent by number*	*Percent by weight*
Common carp	22,717	66.2	90.9
White bass	9,163	26.7	4.2
Walleye	687	2.0	2.6
Black bullhead	484	1.4	0.7
Channel catfish	274	0.8	0.7
Largemouth bass	48	0.1	0.2
Bluegill	109	0.3	0.1
Yellow perch	102	0.3	0.1
Fathead minnow	553	1.6	T
June sucker and Utah sucker	126	0.4	0.5
Black crappie	5	T	T
Golden shiner *Notemigonus crysoleucas*	14	T	T
Brown trout *Salmo trutta*	3	T	T
Rainbow trout *Oncorhynchus mykiss*	2	T	T
Green sunfish	3	T	T
Redside shiner	1	T	T
Utah chub	1	T	T

T = less than 0.1%.

taken as additional protected locations became available. Research was initiated in an effort to better understand the ecology and life history of the species and threats to its continued existence.

Recovery Activities

Recovery implementation program

A multi-partner June Sucker Recovery Implementation Program (Program) was organized and finalized in 2002 to address recovery actions described in the 1999 Recovery Plan. The Program partners have agreed to pursue recovery of June sucker while allowing for continued water use to benefit humans. Actions being implemented by the Program address the following recovery elements:

a. Nonnative and sportfish management,
b. Habitat development and maintenance,
c. Water management and protection,
d. Genetic integrity and augmentation,
e. Research, monitoring, and data management,
f. Information and education.

The Program has conducted feasibility studies to improve habitat and address nonnative species control. Concepts for addressing these concerns have been developed and habitat enhancement, along with control of problematic nonnative fish, are expected to reduce or eliminate the recruitment bottleneck. Improving conditions that promote survival of larvae and young-of-year (YOY) fish is an effort to complete the life cycle within the Utah Lake system so that natural production can augment the wild population. The transition from conceptual plans to implementation requires addressing multiple challenges, including securing sufficient funds, identifying willing landowners to facilitate habitat modifications and/or purchases, the logistical and economic challenges associated with controlling nonnative fish, and resolving conflicts with sportfishing interests.

Hatchery production, stocking, and research

To date, captive propagation has been the most visible and active recovery action and is the primary source of June sucker released into the wild. June sucker produced by in vitro spawning of running ripe adults in the Provo River have been brought to the Utah Division of Wildlife Resources' Fisheries Experiment Station (FES) for rearing. Human-mediated propagation has also been conducted at FES. The original FES facility for June sucker was small, 72 m^2, had only cool water of 15.6°C, and had become increasingly crowded. Standard trout feeds readily available at the station were initially fed to these fish. Though the exact cause or causes were not known, the condition of these captive fish deteriorated, as indicated by the presence of visible deformities and as quantified by calculation of the health condition profile (HCP) of Goede and Barton (1990). A new facility for June sucker at FES was completed in 2001, providing additional space (252 m^2) and warmer water (18.5°C). Survival of June sucker hatched in the new facility has improved as compared to the original facility. Artificial feed development and artificial propagation experiments have been initiated in the new facility. An additional June sucker facility at FES initiated operation in 2006.

While other recovery actions are being researched and implemented, the Program continues to spawn and/or rear June sucker in refuges for release into Utah Lake to augment the wild spawning population, support survival in native habitat, and provide fish for research and monitoring efforts. A management plan for June sucker in captivity was completed in 2004 (UDWR 2004). This plan, intended to support genetic management decisions, including maintaining available genetic diversity, is being revised with newly available molecular data in 2006. The Program has funded research on the genetic make-up of the wild June sucker and Utah sucker populations in the wild and the June sucker held in refugia (Mock et al. 2006). Additional research includes investigating ecological needs of young June sucker, responses of June sucker to habitat variables, ecological and morphologic differences of suckers from Utah Lake, and heritability of morphologic traits. Propagation and augmentation, the recovery actions with the longest record of implementation at this time, are beginning to exhibit measurable results. The goal of this paper is to describe the current status of June sucker and the status of actions to recover this endangered species, currently dominated by the captive propagation efforts.

Study Sites

Natural habitats

Utah Lake.—Utah Lake covers approximately 38,400 ha and is located in Utah County, Utah, about 65 km south of the Great Salt Lake (Figure 1). The lake has an average depth of only 2.8 m and a maximum depth of 4.2 m at the compromise elevation of 1,368 msl. It is approximately 38 km long and 21 km wide. Utah Lake has a large area to depth ratio and frequent winds prevent thermal stratification. Scouts from the expedition of Father Escalante in 1776 described a shoreline that included broad pastures, marsh communities with reeds and marsh grasses, and abundant swamps. Settlement of the territory by humans of European descent started in 1847, and over time, nearshore areas were diked, drained, and filled to provide land for agricultural production and grazing, recreational facilities, and a municipal airport. Historically, the lake had relatively stable water levels and was likely less turbid with a deeper littoral zone. Stable lake levels along with clear water and a lake perimeter of productive wetland habitats and macrophyte beds provided nursery habitat commonly used by native fishes (USFWS 1999). Increased nutrient loading from urbanization, increased lake level fluctuations from downstream water demands and upstream storage, and introduction and establishment of common carp, which uproot aquatic vegetation and resuspend bottom sediments through foraging, have contributed to the homogeneous, turbid lake devoid of aquatic vegetation that exists today.

Provo River.—Riverine habitat used by spawning adult June sucker and developing larvae was probably more extensive historically than today (Radant and Sakaguchi 1981). Prior to settlement of Utah Valley, several large tributaries, including the Provo and Spanish Fork rivers and Hobble Creek (Figure 1), provided diverse habitats in braided, slow, meandering channels. The natural river systems provided warm, slow water pools and marsh habitats suitable for enhanced larval development and refuges from predation by larger fishes (historically Bonneville cutthroat trout). River channelization, dredging, irrigation depletions, and upstream water storage have severely impacted these tributaries, resulting in significantly reduced, less complex habitats. Currently, the only habitat used by spawning June sucker is the lower approximately 4.8 km of the Provo River up to an irrigation diversion that is a barrier to upstream fish movement in all but wet years. In very high water years, an additional 3 km above this diversion becomes accessible (USFWS 1999; Figure 1).

Captive Rearing Sites

Springville State Fish Hatchery

The Utah Division of Wildlife Resources (UDWR) operates a state fish hatchery at Springville, Utah County, Utah, approximately 10 km from the confluence of the Provo River and Utah Lake (Figure 1). The facility is primarily for rainbow trout production and includes indoor tanks and outdoor concrete raceways. Fertilized June sucker eggs were first brought to this facility in 1982 (Shirley 1983), and larvae were raised in a wetland pond on the hatchery complex, then were transferred to Camp Creek Reservoir in 1987.

Utah Correctional Institution

Temporary tanks were used for rearing June sucker at the Utah Correctional Institution (UCI) in Draper, Salt Lake County, Utah from 1987 to 1993. The UCI offered a natural groundwater supply and a protected rearing area in which to raise fish, although care and survival of fish were variable at this facility. Remaining June sucker were removed from the UCI in 1993 and transferred to the Fisheries Experiment Station (FES).

Brigham Young University

Laboratories in the Widstoe Building at Brigham Young University in Provo, Utah County, Utah (Figure 1) received and hatched fertilized June sucker eggs from 1986 to 1991. All surviving fish were transferred to FES.

Utah State University; Natural Resources Building and Millville

Utah State University (USU) in Logan, Cache County, Utah has a laboratory in the Natural Resources Building (NR 111) where June sucker have been hatched, reared, and held. No June sucker are held in this laboratory today. June sucker have also been held in an outdoor research facility with man-made ponds maintained by USU in the nearby town of Millville (Figure 1). A small number of June sucker are held at the Millville ponds today.

Wahweap State Fish Hatchery

Wahweap State Fish Hatchery (Wahweap) is a UDWR facility located on Wahweap Creek, an ephemeral tributary to the Colorado River, now dammed immediately below the confluence by the Glen Canyon Dam to form Lake Powell. This facility is 3.3 km northwest of Big Water, Kane County, Utah and approximately 50 km northwest of Page, Arizona (Figure 1). The hatchery sits on 107 ha of UDWR land with 35 ponds, including 27 lined and 8 earthen ponds. Surface area of the ponds ranges from 0.1 to 0.16 ha. The facility has a patented right to 0.102 m^3/s of water from two wells located on the hatchery property.

Fisheries Experiment Station

June sucker have been held at the UDWR Fisheries Experiment Station (FES) in Logan, Utah since August 1991 (Figure 1). The FES is used for sport and native fish production, research, and fish health management in addition to June sucker research and production. The site is on 35 ha and is supplied by 16 artesian wells with a total flow of 127.4 L/s and water temperature range of 12–18.5°C. June sucker have been held in fiberglass circular tanks and rectangular troughs in a 6 x 12 m Quonset hut since 1991. The tanks are fed by a well with 15.6°C water that is passed through degassing columns that utilize Koch-Glitsch cascade mini-rings to remove nitrogen gas and increase dissolved oxygen. In December 2001, an additional facility was constructed to meet increased production requirements. The building is a 12 x 21 m metal structure housing 37 fiberglass circular tanks of various sizes for holding family lots, eight fiberglass troughs for hatching eggs and initial rearing, and 15 fiberglass troughs for conducting research. The facility utilizes a 2 x 2 m quarantine building housing 10 aquaria. During construction, the water source was switched to a well with 18.5°C water that incorporated a low-head oxygenation system (Water Management

Technology, Inc., Baton Rouge, Louisiana) with a liquid oxygen supply. This system replaced the degassing columns in the Quonset hut. The need for additional rearing space for June sucker has been identified, especially to provide fish for release into Utah Lake. National Environmental Policy Act compliance efforts identified FES as the preferred alternative for this additional facility, which initiated operation in 2006. The new facility utilizes recirculation technology to raise water temperatures in an effort to improve growth rates, reduce susceptibility to disease, increase longevity, and produce progeny lots for release into Utah Lake or other locations as needed.

Refuge Sites

Arrowhead and Teal ponds

Arrowhead and Teal ponds at the Ogden Nature Center are located in Ogden, Utah, approximately 63 km north of Salt Lake City (Figure 1). Surface area of both ponds is approximately 0.2 ha, and maximum depth is less than 2 m. The level of the ponds is maintained by groundwater that prevents complete winter freezing. Approximately 20 June sucker are held at this site as an emergency back-up stock. The site's limited size restricts the number of fish that can be held there.

Red Butte Reservoir

Red Butte Reservoir is located on Red Butte Creek, approximately 2.5 km northeast of Salt Lake City (Figure 1). Red Butte Reservoir has a surface area of approximately 5.2 ha and a maximum depth of 10 m. The reservoir was constructed in 1930 to supply water for Fort Douglas, a U.S. Army base that was decommissioned in 1991. The federal government retained ownership of the dam and reservoir following decommmissioning, and lands around Red Butte Reservoir are managed by the U.S. Forest Service as a research natural area. Because the surrounding land management provided increased security for the reservoir with no competing fishery issues, captive June sucker were introduced for holding in 1992. Bonneville cutthroat trout live and reproduce upstream of the reservoir in Red Butte Creek and can occasionally be found in the reservoir. The introduced population of June sucker unexpectedly reproduced in the reservoir and recruited several year-classes starting in approximately 1995. This site has potential to serve as a long-term refuge for June sucker, so efforts to secure the area for this purpose and to repair the dam to meet State of Utah safety standards were initiated (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service 2003). The Central Utah Water Conservation District assumed ownership and operation of Red Butte Reservoir in 2004. In 2005, as the reservoir was being drained to allow for dam repairs, approximately 9,000 June sucker greater than 150 mm were transferred to Utah Lake. Salvaged June sucker smaller than 150 mm were taken to holding ponds constructed in 2004 on the Ensign Ranch in Box Elder County, Utah until they can attain lengths greater than 150 mm thought to help them avoid predation.

Ensign ponds

Three 0.4-ha ponds were constructed on a private ranch, the Ensign Ranch, in 2004 to benefit June sucker and other native fishes. These ponds are fed by mountain springs piped approximately 1 km to a valley depression. They were first used to receive June sucker transferred from Red Butte Reservoir in 2005.

Camp Creek Reservoir

Camp Creek Reservoir is located in western Box Elder County, Utah, near the town of Etna, approximately 358 km northwest of Salt Lake City. The reservoir is located on Camp Creek, which originates in Nevada and flows east into Utah. The surface area of the reservoir is approximately 2 ha, and maximum water depth is 5 m. It is privately owned and used for irrigation (Thompson 2001). A variety of age-classes of June sucker have been introduced here, beginning in 1987, and they have reproduced. In order to maintain healthy fish in Camp Creek Reservoir and to support recovery efforts the June sucker population is thinned every 1 to 2 years, and they are transferred to and released in Utah Lake. Approximately 1,000 June sucker were captured in Camp Creek Reservoir, passive integrated transponder (PIT)-tagged, transported, and released in Utah Lake in 2004 and 2005.

Methods

Emergency actions

The primary goal of biologists who first engaged in conservation actions to protect June sucker was to prevent immediate extinction. Resource agencies, with limited funds and facilities, initiated salvage operations in 1982 by in vitro spawning of ripe adults from the spawning run and taking of fertilized eggs into protected locations. The Springville Hatchery was the first facility to receive fertilized eggs for hatching and rearing. Between 1982 and 1993, June sucker were either taken as fertilized eggs from the Provo River or transferred from Springville as juveniles and held at Utah State University, Brigham Young University, Utah Correctional Institution, Camp Creek Reservoir, and Arrowhead and Teal ponds. Disease considerations, the availability of only cool water, and low percentage hatching and larval survival led to the search for alternatives to Springville Hatchery. This search gradually focused increasing attention on the potential for rearing June sucker at FES where additional facilities and full-time staff were available. Fish were first transferred to FES in 1991 (Table 2). Streamside matings were conducted for a few years during the 1980s, then reinitiated in 1994 with transfer of fertilized eggs to FES for hatching and rearing. Consistent annual monitoring of the June sucker spawning run was also initiated in 1994.

Refuges

Multiple populations currently provide refuges for the species in case of catastrophic loss in the wild. Today, captive June sucker are held at FES, Camp Creek Reservoir, Ensign Ponds, Arrowhead Pond, and USU Millville (Table 3). Dam repairs were completed, and June sucker were re-introduced into Red Butte Reservoir in October 2006.

Habitat enhancement and nonnative control

The Program is developing approaches for habitat enhancement by targeting areas believed important to early life stages of June sucker, associated primarily with historic tributary flood plains and their deltaic interface with the lake. Most areas currently targeted are privately owned, and the Program is committed to working with willing sellers. The Program is also developing approaches for nonnative fish control, including removal of target species, especially common carp and white bass (SWCA 2002).

Broodstock development

The new native fish facility at FES was completed in 2001 and now holds some of the old June sucker stock and all of the newly received stock. June sucker currently held at Camp Creek Reservoir may also prove to be of desirable genetic background and used as broodstock for artificial crosses. Fish reared in excess of minimum numbers needed to maintain broodstock are released from FES either into Utah Lake or into other refuges.

June sucker held at FES are segregated into lots, each the result of a cross of two individual fish. Individuals in the oldest lots have all been PIT-tagged and are held together. They are identified by the year in which they were produced, except for those fish that were captured as drifting larvae and are likely the result of more than one fertilization event. Collectively, these lots are the brood lots (i.e., parent fish crossed to yield progeny lots; UDWR 2004). Progeny lots are the offspring destined for release into Utah Lake and/or protected rearing locations. Progeny lots will be held until they reach a size, currently thought to be 150 mm, which allows them to avoid the majority of the predatory fish present in Utah Lake. After reaching 150 mm, the progeny lots will be released into Utah Lake. Current research is investigating the available genetic diversity of brood lots and will be used to help identify the most appropriate fish for progeny lot production.

Propagation research

Crosses of broodstock at FES to produce progeny lots were initiated in 1998 (Table 2). A release of 20 June sucker progeny fish (offspring spawned in 2000 from two fish captured as adults, one in 1989, one in 1991) from FES was made in 2003. Since molecular markers are not yet available, biologists attempt to maximize available genetic diversity by conducting crosses using individuals from two different year-classes (UDWR 2004). The genetic diversity of fish held in other refuges

Table 2.
June sucker lots held at Fisheries Experiment Station as of October 1, 2005.

Lot number		*Number on hand*	*Fish/lb*	*Length (in)*	*Gram/fish*	*Length (mm)*
89SKJNUSU	Brood lot	17	0.72	15.38	629.99	390.65
91SKJNBYU	Brood lot	27	0.72	15.38	629.99	390.65
91SKJNUSU	Brood lot	19	0.72	15.38	629.99	390.65
92SKJN	Brood lot	8	0.72	15.38	629.99	390.65
93SKJNlot2	Brood lot	20	0.72	15.38	629.99	390.65
94SKJNLot-4	Brood lot	87	0.72	15.38	629.99	390.65
94SKJNLot-6	Brood lot	34	0.72	15.38	629.99	390.65
94SKJNlot8	Brood lot	12	0.72	15.38	629.99	390.65
94SKJNLot-11	Brood lot	44	0.72	15.38	629.99	390.65
95SKJNlot4	Brood lot	22	0.72	15.38	629.99	390.65
Mixed lot	Lost tags, lot unknown	6	0.72	15.38	629.99	390.65
Totals	10	296	0.72	15.38	629.99	390.65
990618SKJNPR01	Brood lot larval fish from Provo River 1999	37	1.19	14.10	381.17	358.14
000509SKJNPR01	Brood lot	245	1.41	12.57	321.70	319.28
000525SKJNPR04	Brood lot	84	1.59	11.82	285.28	300.23
000525SKJNPR05	Brood lot	155	2.70	9.99	168.00	253.75
000601SKJNPR07	Half sib hatchery male	273	1.06	14.05	427.92	356.87
000527SKJNFE01	Progeny lot 89SKJNUSU female 91SKJNUSU male C16	8	1.19	14.10	381.17	358.14
Totals	5	765	1.59	12.51	316.81	317.65
010424SKJNPR01	Brood lot	141	1.21	14.02	374.87	356.11
010426SKJNPR02	Brood lot	53	1.77	12.35	256.27	313.69
010502SKJNPR03	Brood lot (Feed Study #1)	276	2.23	11.10	203.40	281.94
010516SKJNPR05	Brood lot	305	2.25	11.40	201.60	289.56
010516SKJNPR06	Brood lot	352	1.19	14.10	381.17	358.14
Totals	5	1,127	1.73	12.59	283.46	319.89
020430SKJNPR01	Brood lot	23	4.14	9.58	109.56	243.33
020501SKJNPR02	Brood lot	4	2.15	11.91	210.97	302.51
020506SKJNPR03	Brood lot	90	5.64	8.64	80.42	219.46
020520SKJNPR04	Brood lot (Feed Study #2)	295	1.63	11.98	278.28	304.29
020521SKJNPR06	Brood lot	401	1.63	13.07	278.28	331.98
020521SKJNPR07	Brood lot	410	2.14	11.93	211.96	303.02
020528SKJNPR08	Brood lot	305	2.18	11.86	208.07	301.24
020604SKJNPR10	Brood lot larval fish from Provo River 2002	319	2.72	11.02	166.76	279.91
Totals	8	1,847	2.78	11.25	193.04	285.72

(continued)

Table 2. (continued)

Lot number		Number on hand	Fish/lb	Length (in)	Gram/fish	Length (mm)
030528SKJNPR21	Brood lot (Feed Study #3)	644	10.90	7.38	41.61	187.45
030528SKJNPR22	Brood lot	438	9.82	7.18	46.19	182.37
030604SKJNPR25	Brood lot	47	6.96	8.05	65.17	204.47
030616SKJNFE01	Progeny lot	337	6.26	8.34	72.46	211.84
030617SKJNFE02	Progeny lot	305	5.38	8.78	84.31	223.01
030617SKJNFE03	Progeny lot	590	6.95	8.06	65.26	204.72
Totals	6	2,361	7.71	7.97	62.50	202.31
040507SKJNPR01	Brood lot	4	24.78	5.27	18.30	133.86
040612SKJNFE01	Progeny lot*	852	61.52	3.90	7.37	99.06
040613SKJNFE03	Progeny lot (Feed Study #4)*	256	23.78	4.42	19.07	112.27
040613SKJNFE04	Progeny lot* (Temperature Study #1)	983	26.83	5.14	16.91	130.56
040627SKJNFE06	Progeny lot	69	136.61	2.99	3.32	75.95
Totals	7	2,164	54.70	4.34	13.00	110.34
Tag retention	Mixed lot	86	2.13	11.95	212.95	303.53
050620SKJNFE26	Progeny lot ~	3,529	1,624.68	1.31	0.28	33.27
050620SKJNFE27	Progeny lot ~	1,132	1,520.37	1.34	0.30	34.04
050621SKJNFE29	Progeny lot ~	120	1,556.64	1.33	0.29	33.78
050620SKJNFE30	Progeny lot ~	3,523	2,112.77	1.20	0.21	30.48
050620SKJNFE28	Progeny lot ~	3,400	1,368.46	1.38	0.33	35.05
050605SKJNFE07	Progeny lot ~	667	1,377.89	1.38	0.33	35.05
050605SKJNFE13	Progeny lot ~	828	1,204.36	1.45	0.38	36.83
050606SKJNFE20	Progeny lot ~	453	2,608.80	1.12	0.17	28.45
050506SKJNFE08	Progeny lot ~	3,593	1,691.77	1.29	0.27	32.77
050605SKJNFE17	Progeny lot ~	395	1,694.99	1.29	0.27	32.77
050605SKJNFE05	Progeny lot ~	4,116	2,054.50	1.21	0.22	30.73
050605SKJNFE07	Progeny lot ~	3,955	1,240.70	1.43	0.37	36.32
050605SKJNFE09	Progeny lot ~	1,442	1,872.51	1.25	0.24	31.75
050605SKJNFE21	Progeny lot ~	3,311	1,170.90	1.46	0.39	37.08
050605SKJNFE10	Progeny lot ~	2,424	1,451.49	1.36	0.31	34.54
050504SKJNFE02	Progeny lot ~	5,396	1,264.26	1.42	0.36	36.07
Totals	16	38,284	1,613.44	1.33	0.29	33.69
Grand totals	42	46,967	168.60	9.14	209.32	232.19

~ Numbers estimated by percentage at last passive integrated transponder tag reading.

* Estimate no total inventories taken to date.

Table 3.
June sucker stocked out from the Fisheries Experiment Station.

Date	*Lot number*	*Number stocked*	*Kilograms stocked*	*Fish/kg*	*Grams/fish*	*Stocking/transfer location*
1992–1993	89SKJN-USU	1,487	–	–	–	UCI, USU, Red Butte
1992–1993	91SKJN-BYU	13	–	–	–	USU
04/26/94	89SKJN-USU	76	7.85	9.68	103.25	Ogden Nature Park
04/26/94	89SKJN-USU	544	55.70	9.77	102.39	Ogden Nature Park
04/26/94	910523SKJNUL01	707	34.02	20.78	48.12	Ogden Nature Park
10/11/94	89SKJN-USU	146	21.29	6.86	145.84	Utah Lake
10/11/94	89SKJN-USU	614	65.32	9.40	106.38	Utah Lake
10/11/94	91SKJN-BYU	797	47.82	16.67	60.00	Utah Lake
10/24/95	89SKJN-USU	118	26.11	4.52	221.26	Utah Lake
10/24/95	89SKJN-USU	76	16.81	4.52	221.25	Provo River (section 1)
10/24/95	91SKJN-BYU	177	25.32	6.99	143.08	Utah Lake
10/24/95	91SKJN-BYU	199	28.48	6.99	143.10	Provo River (section 1)
10/24/95	91SKJN-USU	309	34.19	9.04	110.64	Utah Lake
10/24/95	91SKJN-USU	342	37.83	9.04	110.63	Provo River (section 1)
06/21/96	89SKJN-USU	63	12.84	4.91	203.76	Provo River (section 2)
06/21/96	91SKJN-BYU	155	31.53	4.92	203.39	Provo River (section 2)
06/21/96	91SKJN-USU	94	19.14	4.91	203.64	Provo River (section 2)
11/14/98	94SKJN Lot-4	352	36.79	9.57	104.51	Millville Ponds (USU)
11/14/98	94SKJN Lot-6	250	44.82	5.58	179.26	Millville Ponds (USU)
11/14/98	94SKJN Lot-8	100	8.45	11.84	84.46	Millville Ponds (USU)
08/99	94SKJN Lot-4	370	69.40	5.33	187.57	Provo River
08/30/99	990531SKJNFE01	13,532	4.05	3,340.70	0.30	Millville Ponds (USU)
09/10/99	94SKJN Lot-11	156	34.18	4.56	219.12	Millville Ponds (USU)
04/09/01	000601SKJNPR07	8,364	7.58	1,102.82	0.91	Wahweap SFH
06/21/01	000601SKJNPR07	40	0.04	928.25	1.08	Mona Reservoir (USU)
07/06/01	000601SKJNPR07	132	0.14	938.73	1.07	Mona Reservoir (USU)
07/12/01	000601SKJNPR07	542	0.59	926.27	1.08	Goshen (USGS), Utah Lake (BYU)
07/19/01	010426SKJNPR01	80	0.01	1,0374.52	0.10	Utah Lake (BYU)
07/19/01	010502SKJNPR03	85	0.01	8,923.32	0.11	Utah Lake (BYU)

(continued)

is also not well known at this time. Additional molecular and morphologic analyses are being conducted to quantify diversity available in captivity and to describe genetic structuring of the known population, including wild and captive June sucker.

Studies to evaluate feed regimes for rearing captive June sucker are continuing (Hansen 2002, 2003a). Experiments are also being conducted to increase gamete yield from hatchery fish (Table 4). Attempts to induce spawning in FES June sucker broodstock using hormones have occurred since 1998, although success in spawning female June sucker has been limited. In 2002, a study to evaluate human chorionic gonadotropin dosage levels resulted in no injected females ovulating. Possible causes for lack of ovulation were increased water temperature 5 months prior and a diet change 4 months prior to hormone injection. In 2003, a study was initiated to evaluate temperature requirements and an additional hormone,

Table 3. (continued)

Date	*Lot number*	*Number stocked*	*Kilograms stocked*	*Fish/kg*	*Grams/fish*	*Stocking/transfer location*
07/19/01	010515SKJNPR04	85	0.01	12,492.65	0.08	Utah Lake (BYU)
07/19/01	010516SKJNPR05	180	0.01	12,800.82	0.08	Utah Lake (BYU)
07/19/01	010516SKJNPR06	84	0.01	12,345.68	0.08	Utah Lake (BYU)
07/02/02	020521SKJNPR07	220	0.01	23,095.66	0.04	USU
07/10/02	020521SKJNPR07	4,000	0.80	4,982.11	0.20	USU
09/02	990618SKJNPR01	8	1.21	6.63	150.82	Utah Lake (used in state fair)
07/10/03	030513SKUTPR01	1,302	0.12	11,039.89	0.09	BYU
07/10/03	030513SKUTxNPR02	861	0.09	9,990.25	0.10	BYU
07/10/03	030515SKJNPR03	8,754	0.78	11,220.31	0.09	BYU
07/10/03	030515SKJNxUTPR04	9,297	0.63	14,852.20	0.07	BYU
07/10/03	030520SKJNPR11	1,432	0.06	24,284.36	0.04	BYU
07/10/03	030521SKJNPR13	2,965	0.10	28,419.98	0.04	BYU
07/10/03	030523SKUTPR15	2,097	0.07	30,820.11	0.03	BYU
07/10/03	030528SKJNPR19	3,274	0.09	36,089.07	0.03	BYU
07/11/03	030520SKJNxUTPR12	2,391	0.08	31,006.85	0.03	BYU
07/11/03	030520SKUTPR09	2,057	0.14	15,116.11	0.07	BYU
07/11/03	030520SKUTxJNPR10	2,137	0.15	14,722.50	0.07	BYU
07/11/03	030521SKJNxUTPR14	3,935	0.24	16,064.90	0.06	BYU
07/11/03	030523SKUTxJNPR16	3,027	0.10	30,333.09	0.03	BYU
07/11/03	030528SKJNxUTPR20	2,954	0.09	32,561.73	0.03	BYU
07/17/03	00527SKJNFE01	19	3.27	5.82	171.89	Utah Lake
07/17/03	000523SKJNPR02	2	1.11	1.80	555.66	Utah Lake (lots were combined)
07/17/03	000601SKJNPR06	3				
07/17/03	000602SKJNPR08	2				
07/17/03	010518SKJNPR08	1				
08/19/03	030520SKJNPR11	733	0.06	11,542.58	0.09	USU
08/19/03	030523SKUTPR15	333	0.04	9,176.59	0.11	USU
11/24/03	020521SKJNPR07	400	3.81	105.11	9.51	USU
12/02/03	020521SKJNPR07	67	0.66	101.17	9.88	USU
01/21/04	020521SKJNPR07	30	0.37	80.66	12.37	USU

Ovaprim. Ovaprim is an analog of salmon gonadotropin releasing hormone with a dopamine blocker (Hansen 2003b). Success with artificial hatchery spawning has improved, with three crosses yielding tens of thousands of fertile eggs each in 2004 and again in 2005. Improving yield and viability from artificial hatchery crosses of June sucker is being studied further by U.S. Fish and Wildlife Service personnel at the Bozeman (Montana) Fish Health and Technology Center.

Stocking

Approximately 5,400 June sucker in excess of broodstock needs at FES were implanted with passive integrated transponders (PIT) tags and released into Utah Lake and the Provo River in 1994, 1995, 1996, and 1999 (Table 3). Subsequent monitoring determines if June sucker raised in a protected location will participate in wild spawning runs. This information has been used to help develop stocking protocols that are still being refined.

Adult and juvenile June sucker in excess of

Table 4.

Percent survival to swim up compared for three June sucker hatchery crosses and three crosses received from wild stock in 2003.

Cross number	*Number of eggs*	*Number of fish on feed (swim up)*	*Percent survival to swim up*
Hatchery Cross 1	6,875	3,855	56.07
Hatchery Cross 2	7,497	2,219	29.60
Hatchery Cross 3	8,162	5,281	64.70
Wild Cross 1	23,750	9,371	39.46
Wild Cross 2	32,487	17,391	53.53
Wild Cross 3	31,529	1,832	5.81

** Two lots received from wild stock were not included in this comparison since they were discarded prior to projected hatch date due to poor egg quality and condition.*

those needed to maintain respective populations were removed from Red Butte and Camp Creek reservoirs in 2001, and 1,600 (approximately 700 and 900, respectively) were released into Utah Lake (Table 3). Condition of sampled fish indicated stunting, possibly due to lower water levels and/or density, in Camp Creek Reservoir (Thompson 2001). Fish released were intended to augment the wild population of older fish. Stocked fish were hatched and raised in the hatchery with no attempt to imprint them to Utah Lake tributary water, and it was unknown if stocked fish would participate in spawning events in the Provo River.

Approximately 8,300 YOY June sucker from FES, originally collected as eggs from a streamside cross on the Provo River, were taken to the Wahweap State Fish Hatchery in April 2001. The fish were held at Wahweap until August 2002, at which time 2,474 individuals that survived and grew were implanted with PIT tags and transported to Utah Lake. A subset of the same June sucker lot was held at FES throughout the study period.

Results

Emergency actions

The emergency efforts implemented to save June sucker have been effective in that the species still exists, albeit in low numbers, in the wild. The adult population was estimated at less than 1,000 in 1999 (USFWS 1999). Less than 300 June sucker adults have been captured each year during the annual spawning run up the Provo River in the first years of the 21st century (UDWR, unpublished data).

Refuges

The June sucker stocked in Red Butte and Camp Creek reservoirs are spawning, as demonstrated by the presence of multiple year-classes younger than those originally introduced (UDWR field data, Thompson 2001). In 2003, June sucker eggs were collected in traps and nets along the perimeter of Red Butte Reservoir and the face of the dam. Adult fish were observed spawning on the face of the dam and a digital video record of the activity was collected. Vertebral and opercular deformities have not been seen in June sucker from these habitats, although high densities are apparently stunting growth rates. June sucker have been spawning in Arrowhead Pond in the presence of green sunfish. The Red Butte Dam is being repaired, and June sucker will be reintroduced into the reservoir as it refills in 2006. Camp Creek Reservoir continues to hold June sucker and to produce excess fish that are transferred to Utah Lake.

Habitat enhancement and nonnative control

The June sucker program has acquired lands at the mouth of Hobble Creek, one of the primary inflows to Utah Lake's Provo Bay (Figure 1). Following habitat enhancement this location could prove to be favorable for June sucker during spawning, rearing, or other life stages. Attempts by the June sucker program partners to purchase lands along the Provo River near the mouth have been largely unsuccessful to date. The Program is pursuing easements on lands just north of the mouth of the Provo River that may provide temporary habitat for June sucker (e.g., to be used as grow out ponds for YOY fish).

The carp control feasibility study initiated by the Program has completed two seasons. The current estimate of the carp population in Utah Lake is 7 million (c.i. 6–10 million). The Program is now assessing how a continuous removal project might be made effective and affordable.

Because some of the nonnative fishes in Utah Lake and its tributaries are sport species, the desires of Utah Lake anglers are being considered as nonnative fish management actions are developed. A creel survey is being conducted to assess angler desires and habits.

Broodstock development

The largest number of June sucker in captivity is held at FES. About 1% of these fish are mature and the remainder are juveniles. The oldest June sucker in captivity, up to 16 years old (Table 2), now held at FES, are showing signs of stress, including osteologic and opercular deformities. Condition of the FES population as a whole has improved, however, in the new June sucker facility with warmer water. At this time, FES is holding 10 mature brood lots, each made up of less than 50 individuals, 23 immature lots ranging in number from 4 to more than 400 individuals, and 23 progeny lots of from 8 to more than 5,000 individuals. As of 1 October 2005 the facility was holding more than 46,000 individual June suckers (Table 2).

Propagation research

Captive feeding studies have concluded that a feed regime of brine shrimp and the Razorback Diet (formulated by the U.S. Fish and Wildlife Service Bozeman Fish Health and Technology Center and manufactured by Nelson & Sons, Inc., Bozeman, Montana) is the most suitable diet for June sucker compared to the other diets evaluated. Other diets fed to June sucker prior to the feed study were two of the more inferior diets tested. The switch to the preferred diets has improved overall fish condition and reduced the occurrence of deformities (Hansen 2002; Hansen 2003a).

Artificial crosses between select individuals from brood lots to produce progeny for release have resulted in variable production and survival. Induced spawning trials with Ovaprim and variable water temperatures showed that a significantly higher number of fish ovulated when held in 13°C water for 4 months, compared to 13°C for 1 week and 18°C for more than a year. Human chorionic gonadotropin effectively increased the amount of milt extruded by males. In 2003, there was no significant difference in percent of eggs hatched from the wild stock versus progeny of induced captive broodstock; however, an order of magnitude fewer eggs were produced from hatchery crosses, compared to those received from streamside crosses (Table 4; Hansen 2003b).

The 8,300 June sucker held at Wahweap from 2001 to 2002, fed the diet used at FES in the 1990s, grew an average of 0.2 mm/d. Individuals from the same lot at FES grew an average of 0.12 mm/d. Survival rates during the study period were 35% at Wahweap and 73% at FES. Biologists implanted 2,474 June sucker with PIT tags at Wahweap; of these, 200 (7%) expired during tagging, and of these, 140 (70%) were noticeably deformed. No mortalities were incurred during transport from Wahweap to Utah Lake.

Stocking monitoring

Ripe hatchery and/or refuge-reared June sucker began to appear in spawning runs in 1995 (Keleher et al. 1999; Utah Division of Wildlife Resources, unpublished data), and the first returns from the augmentation program begun in 1994. Of approximately 6,000 PIT-tagged June sucker stocked into Utah Lake and the Provo River from FES, Red Butte Reservoir, and Camp Creek Reservoir, 253 have been captured during the spawn in the Provo River along with wild fish (Table 5). This number may not be a true indicator of survival of stocked fish. Some stocked fish may have not yet reached sexual maturity, and monitoring does not sample all fish in the spawning run. Largest numbers of returning stocked fish have come from Red Butte Reservoir, but individuals from FES and Camp Creek have also been recorded (Table 5). From 1997 through 2003, June sucker returned to spawn in the Provo River between 20 April and 1 July. Estimated onset of June sucker spawning activity was late May in 1997 and 1998, the first week of June in 1999, and late April during 2000–2004. It was difficult to sample for June sucker in the Provo River in 2005 due to unseasonably high spring flows. The proportion of fish in

Table 5.
Stocked June sucker recaptured in the Provo River.

Date	*Stocked*	*Returned*	*Source*
10/05/94	760		FES
10/11/94	791		FES
06/01/95		19	FES
08/16/95	235		FES
08/18/95	256		FES
08/23/95	259		FES
08/24/95	180		FES
10/05/95	173		FES
10/05/95	370		FES
10/06/95	194		FES
10/18/95	474		FES
10/18/95	460		FES
10/23/95	129		FES
10/23/95	145		FES
06/01/96		2	FES
06/21/96	295		FES
06/01/97		6	FES
06/01/98		1	FES
06/01/99		6	FES
09/01/99	692		FES
06/01/00		21	FES
05/01/01	479		RB
06/01/01		12	FES
10/04/01	222		RB
10/09/01	587		CC
10/10/01	315		CC
06/01/02		36	FES
06/01/02		65	RB
06/01/02		9	CC
06/01/03		35	FES
06/01/03		97	RB
06/01/03		2	CC

FES = Fisheries Experiment Station.
RB = Red Butte Reservoir.
CC = Camp Creek Reservoir.

the spawning run made up of fish reared in captivity has been increasing and consisted of 75% of the fish captured in the 2003 spawning run (Utah Division of Wildlife Resources, unpublished data).

Fish in recent Provo River spawning runs exhibit morphologies consistent with June sucker, Utah sucker, and hybrids of the two species. Currently available data indicate that there is measurable diversity within the existing June sucker genome (Mock et al. 2004, 2006). The heritability of morphologic traits observed in suckers from Utah Lake is being investigated, as are environmental influences on morphology.

Discussion

Emergency actions

Those interested in the persistence of the June sucker should be encouraged that the emergency actions taken on behalf of June sucker beginning in 1982 have supported survival of the species to date. Time will tell whether these actions were in time (i.e., whether sufficient genomic diversity has been maintained to eventually support a self-sustaining population of June sucker in Utah Lake).

Because the June sucker in the wild do not appear to be successfully reproducing in sufficient numbers, a network of hatcheries and refuges will be maintained with June sucker for the foreseeable future. Hatcheries and refuges continue to be managed to produce large numbers of June sucker for release into Utah Lake.

Refuges

The ability of June sucker to spawn in lentic habitats (i.e., Red Butte and Camp Creek reservoirs, and Arrowhead Pond) suggests that they may be able to spawn in Utah Lake, and possibly spawned in the lake historically. This reproductive strategy has been observed in other lakesuckers. In-lake spawning was observed in native lakesuckers of Upper Klamath Lake in association with subsurface groundwater discharge areas (Buettner and Scoppettone 1990; Perkins et al. 2000). June sucker spawning in Utah Lake, if it occurs, will be difficult to observe and document until the numbers of June suckers in the lake are increased. Lentic spawning in the reservoir sites has been, and likely will continue to be, an important source of June sucker that can be stocked into Utah Lake to help support species survival until natural reproduction and environmental remediation are sufficient to support a self-sustaining population. Refuges are likely to continue to be important for conservation of the species. Newly emerging genetic data will help maximize the available genetic diversity in these managed habitats.

Habitat enhancement and nonnative control

Environmental threats to June sucker, especially (1) nonnative fishes that prey on young June sucker and alter habitats, and (2) habitat alteration, must be reduced if artificially and naturally produced June sucker are to survive in Utah Lake and its tributaries. Increasing the survival of wild-produced larvae to recruitment will be necessary to establishing a self-sustaining June sucker population. Additional predator avoidance locations and/or mechanisms are needed. Predator avoidance locations may include more complex habitats where wild-produced larvae can find cover from predators. Selective passage gates and other structures may be the mechanisms necessary to help young June sucker survive to recruitment.

The ability of June sucker to recruit in habitats other than Utah Lake (e.g., Camp Creek and Red Butte reservoirs) indicates that current conditions in the lake are limiting to recovery, especially degraded habitat and the presence of nonnative fish species. At least some habitat restoration and nonnative fish population reduction will be necessary to reestablish June sucker recruitment. The loss of historic flows on the Provo River has negatively impacted spawning adults (Radant et al. 1987). Efforts by Program participants to acquire water and mimic a natural hydrograph during the spawning period are ongoing and will continue. Channelization and land development have limited habitat complexity at the mouth of river and reduced available cover for drifting larvae. Habitat investigations suggest that increased vegetative cover permits increased survival of larvae (Petersen 1996; T. A. Crowl and M. C. Belk, June Sucker Recovery Implementation Program, unpublished data). Efforts to increase the complexity of the river mouth and provide conditions that allow for restoration of aquatic macrophytes in key areas will continue but may be limited by lack of access to privately held lands. Many investigators have documented the negative effects of predation by nonnative fish on June sucker, especially drifting larvae (Modde and Muirhead 1994; Petersen 1996; Belk et al. 2001; SWCA 2002). Successful June sucker spawning and recruitment in Arrowhead Pond in the presence of green sunfish offers additional evidence of the importance of cover for larvae. Habitat modification by common carp reduces emergent macrophytes that serve as cover for drifting larvae, increasing their exposure to predation (SWCA 2002). Efforts by Program participants to develop strategies to reduce and control nonnative fish species, especially white bass and common carp, should continue.

Cooperative efforts to provide minimum flows in the Provo River to benefit June sucker have largely been effective, even in drought years. Program partners are investigating the potential value of pulsing flows to help distribute larval June sucker out of the Provo River where a limited amount of cover is available.

June and Utah suckers probably have a shared evolutionary history. The observed morphologic differences between the two species may be the result of recent ecological selection (Mock et al., 2006). More diverse habitats that have some of the physical features of the historic Utah Lake habitat will be necessary for maintaining the environment driving the evolutionary trajectory that has maintained the two sucker forms to date. The traditional timing of June sucker spawning, early to mid-June, on the descending limb of the hydrograph (Jordan 1878, Radant and Sakaguchi 1981; Shirley 1983) before water temperatures had warmed (Shirley 1983) may have been a method for maintaining a spawning run distinct from the Utah sucker who spawned in April (Radant et al. 1987). Personnel from UDWR now capture June sucker, Utah sucker, and hybrids ascending the Provo River to spawn as early as March. Maintenance of two distinct species, June sucker and Utah sucker, may require that a more natural hydrograph is reestablished so that these species may experience their traditional spawning cues of flow and temperature.

Broodstock development

Studies are currently under way to investigate the degree of relatedness between morphologies and genomes in suckers ascending the Provo River to spawn. A study is underway investigating heritability of the observed morphologic traits. Investigators are studying the genetic structure and diversity of captive June sucker and those captured in the annual spawning run. Results of these investigations will help to direct production of additional fish in refuges, including hatchery crosses. Possibly, the majority of genetic diversity available in wild fish is already well represented in captivity. Alternatively, captive fish may represent a fraction of the diversity evident in wild spawning fish, and development of additional brood lots may be needed to maximize the diversity present in the brood lots and resulting progeny lots destined for release into Utah Lake. The advancing age of the oldest brood lot fish in captivity is also of concern, as some of these fish may senesce before they can contribute to brood lots, an outcome that may also require the collection of additional wild fish for brood lots. In the absence of clear genetic markers, broodstock has been selected based on June sucker morphologic characteristics, but continued research in genetics, morphology, ecology, and heritability is needed to support or modify this approach. Research into all of these areas has been underway for years (e.g., Belk and Benson 2005; Belk et al. 2005; Mock et al. 2004, 2006). Data and recommendation from the research are providing increasingly specific information to help guide management actions, especially propagation.

Propagation research

Warmer water and specifically formulated sucker feeds appear important for June sucker growth and survival in the hatchery. The June sucker indoor facility completed at FES in 2001 has been an important tool for increasing water and ambient air temperatures, increasing captive June sucker survival rates, lowering crippling rates, and providing space for research needs such as feeding and spawning hormone studies. An interim hatchery at FES is planned for completion in 2006 in order to provide additional space, take advantage of a limited water supply, and further increase water temperatures by circulating water in a closed system.

Producing young June sucker by spawning captive fish in standing water bodies (i.e., extensive culture) appears to produce superior quality fish on average, compared to those reared in indoor hatchery tanks (i.e., intensive culture), as illustrated by the comparison of fish from the same lot reared at FES and Wahweap. Lower survival rates and higher growth rates of fish in extensive culture compared to intensive culture have been documented by Cushing (1981). Findings suggest that June sucker may be more fit for the wild if appropriate exterior rearing locations can be secured (e.g., Belk and Benson 2005; Belk et al. 2005). However, production numbers are currently limited by available space. Evaluation of extensive culture areas must include review of water quality, dependable water supply, and site security. Current stocking and study demands require maintaining both culture types. A warmwater fish hatchery, incorporating intensive and extensive methods at two locations, has been planned, based on initial estimates of producing more than 3 million June sucker for release into Utah Lake to support recovery. If producing these large numbers of June sucker are ultimately reviewed and approved by Program participants, additional facilities will be needed. An additional protocol of spawning June sucker streamside, hatching them in protected locations (e.g., FES) and holding them in protected locations (e.g., Red Butte and Camp Creek reservoirs) or protected nearshore areas, will likely be necessary until they can successfully avoid predation. Artificial propagation will be directed by the captive management plan now being reviewed and revised by Program participants. The Program partners and FES personnel are working closely with the U.S. Fish and Wildlife Service Bozeman Fish Health and Technology Center to improve captive reproduction of June sucker.

Stocking

The presence of recently stocked June sucker in annual spawning runs in the Provo River indicates that initial efforts to artificially increase the spawning population have been successful. Not all fish participating in the spawning runs are captured, and more stocked fish probably participate in runs. Additionally, it is likely that some stocked fish have not reached sexual maturity and will contribute to spawning runs in future years, or some fish may skip spawning in some years. Propagation and stocking need to continue until other threats limiting natural reproduction and recruitment, especially habitat loss and effects due to nonnative fish, have been reduced or eliminated. Propagation and stocking protocols need additional refinement so as to introduce the most robust and genetically diverse individuals possible.

Both remaining native fish species of Utah Lake, June sucker and Utah sucker, stand to benefit from the ecosystem approach of the Program, especially the efforts to improve habitat, control nonnative fish, and provide instream flows. Maximizing available genetic diversity should ensure, to the extent possible, that the population of June sucker in Utah Lake has the greatest possible tolerance for future environmental variation. Increasing the wild population size by augmentation with genetically diverse June sucker should increase survival potential and recruitment.

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