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Water Quality Assessment of Razorback Sucker Grow-out Ponds Grand Valley, Colorado

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EXECUTIVE SUMMARY

The lower Gunnison River and the upper Colorado River in the Grand Valley of western Colorado are designated critical habitat for two federally listed endangered fish species: the Colorado pikeminnow (*Ptychocheilus lucius*) and the razorback sucker (*Xyrauchen texanus*). Because wild stocks of razorback sucker were declining rapidly, with little or no recruitment, the Upper Colorado River Basin Recovery Program (CRRP) determined that captive propagation and stocking was necessary to restore and augment populations. Razorback suckers are reared in tanks at a Fish & Wildlife Service hatchery in Grand Junction, CO, and distributed to local grow-out ponds in the spring after the first year when fish are about 100 mm long. Razorback suckers are held in grow-out ponds until they are large enough (300 mm in length) to be stocked into the river.

Water quality parameters had never been assessed in these grow-out ponds. Historically growth, condition, and survival of razorback suckers have been variable between ponds. Because of elevated selenium concentrations previously found in many Grand Valley ponds and wetlands, we had concerns of elevated selenium in grow-out ponds. The purpose of this study was to describe water quality conditions and food supplies in 16 grow-out ponds in western Colorado that are currently being used by the CRRP to propagate juvenile endangered razorback suckers, and to identify any water quality parameters which may limit growth, condition, and survival of razorback suckers in both the grow-out ponds and after stocking into the Colorado and Gunnison rivers.

Specific conductance in each pond was reflective of the source water, with highest conductivities found in ponds which receive primarily ground water. Specific conductance fluctuated seasonally; higher levels in most of the ponds occurred during August. In general, the ponds seemed to be well mixed throughout the summer, as characterized by depth profiles of field measurements of dissolved oxygen concentrations, pH, and conductivity. During August, low dissolved oxygen concentrations became a concern in a few ponds. Low dissolved oxygen

conditions corresponded to elevated nutrient concentrations. Calculated trophic-state-index (TSI) values indicate most grow-out ponds were eutrophic throughout the growing season.

Biomass of dietary items for razorback suckers was variable among ponds. Body condition of razorback suckers was highest at ponds with the greatest zooplankton biomass, although supplementary feeding also occurred in these same ponds. Parasitic infestations of anchor worm (*Lernaea spp.*) were found in large numbers at four ponds receiving water from the Gunnison River.

Selenium was the trace element of greatest concern, and toxicity guidelines were exceeded in water, sediment, dietary items, and razorback sucker muscle plugs from several ponds (most notably Maggio and Clymers ponds), indicating increased risk of reproductive impairment (Lemly 1996). Stocked razorback suckers recaptured from the rivers at least 8 months post-stocking still retained high selenium tissue residues acquired from the grow-out ponds. River-stocked razorback suckers had significantly higher selenium concentrations than native bluehead suckers (*Catostomus discobolus*) and native flannelmouth suckers (*Catostomus latipinnis*) collected in the Colorado and Gunnison Rivers in the Grand Valley. The levels of selenium we found in razorback suckers are likely reproductively problematic (Lemly 1996). Management recommendations for grow-out ponds are presented to improve survival and condition of razorback suckers.

INTRODUCTION

Studies funded by the U.S. Department of the Interior (DOI) National Irrigation Water Quality Program (NIWQP) revealed elevated selenium concentrations in water, sediment, and biota samples collected from the Gunnison and Colorado rivers, various tributaries, and ponds and wetlands within the Uncompahgre Project Area and Grand Valley Project Area in western Colorado (Butler *et al*. 1994 and 1996, Butler and Osmundson 2000). The Gunnison/Grand Valley Project area, plus the Middle Green River Project area in Utah, (including Ouray National Wildlife Refuge) were chosen out of 600 sites evaluated, as having serious irrigation and drainage-related water quality problems in need of remediation (Engberg *et al.* 1998). In addition, several stream segments in western Colorado, including the Gunnison River between Delta, CO and the Colorado River confluence, plus associated tributaries, and the Colorado River below the Gunnison River confluence to the Colorado-Utah Stateline plus all Grand Valley tributaries, are now listed on the Clean Water Act (CWA) 303(d) list of impaired water-bodies for the state of Colorado because of elevated selenium concentrations (Colorado Department of Public Health and Environment (CDPHE 2008a); http://www.cdphe.state.co.us/op/wqcc/Special Topics/303(d)/303dtmdlpro.html).

The lower Gunnison River and the Colorado River (including the 100-year floodplain) in western Colorado are designated critical habitat for two federally listed endangered fish species: the Colorado pikeminnow (*Ptychocheilus lucius*) and the razorback sucker (*Xyrauchen texanus*) (USFWS 1994). The Colorado River Recovery Program (CRRP) began in 1988, with the goal of establishing self-sustaining populations of the endangered fish while providing for new water development (http://www.r6.fws.gov/coloradoriverrecovery) (Wydoski and Hamill 1991). Because of inadequate natural recruitment for the endangered fish species, the CRRP determined that captive propagation and stocking was necessary to restore and augment wild populations (Wydoski 1994). The razorback sucker was assigned the highest priority because wild stocks were declining rapidly, and little or no recruitment was found in the Upper Colorado River basin. Populations of wild razorback sucker are been estimated to be nearly extirpated in the Gunnison and upper Colorado River reaches (Burdick 2003).

Three propagation facilities for endangered fish were built within the Grand Valley near Grand Junction, Colorado from 1992-1996 (Montagne 1998); Horsethief Refugia Ponds, the 24 Road Hatchery, and Clymers grow-out pond. Horsethief Refugia Ponds are six artificial ponds located within Horsethief State Wildlife Area near Fruita, Colorado, and hold razorback suckers captured from the wild for brood stock. These ponds are filled with water pumped from the Colorado River. An aerator runs continuously in each pond to add oxygen and remove nitrogen from the water. The 24 Road Hatchery rears razorback suckers produced from the brood stock held at Horsethief Refugia Ponds. The hatchery is an indoor facility which consists of 4-foot and 8-foot diameter tanks, which are filled with de-chlorinated domestic water (from the Kannah Creek watershed) and operated with a water reuse system. Juvenile razorback suckers are reared in tanks at the 24 Road Hatchery for the first season after hatching, and the following spring are distributed to grow-out ponds (Czapla 2002). The year-old fish are on average approximately 100 millimeters (mm) total length, when stocked into grow-out ponds. Razorback suckers are reared in grow-out ponds for approximately six months, to allow for growth and decrease risk of predation upon release to the Colorado and Gunnison rivers. Clymers pond was the first grow-out pond developed for the razorback suckers produced at 24 Road Hatchery. Clymers pond is located near the confluence of the Gunnison and Colorado rivers, and water diverted from the Gunnison River is used to fill the pond. Researchers have identified riverside ponds as a preferred option for rearing fish, because they provide relatively predator-free and nutrient-rich environments (Osmundson & Kaeding 1989).

With the development of endangered fish recovery goals for the states of Utah and Colorado (USFWS 2002a & 2002b), the original stocking plans developed in the late 1990s were modified to achieve the target numbers for each species which were necessary to secure self-sustaining populations and achieve recovery goals in a more efficient and timely manner (Czapla 2002). To produce numbers of razorback suckers of total length of $\geq$ 300mm specified in the State of Colorado stocking plan (Nesler 1998), it was determined that 18.1 acres of grow-out ponds were needed. A total of 98 acres of potential grow-out ponds were determined to be available for use by the Grand Valley facility (Czapla 2002). Both the Grand Junction Endangered Fish Facility

and the Ouray National Fish Hatchery in Vernal, Utah are dedicated to the production of razorback suckers. The modified stocking plan specifies that the Grand Junction facility will annually produce 9,930 razorback suckers for Colorado waters, and 4,965 for the lower Green River in Utah. Ouray National Fish Hatchery will produce razorback suckers for stocking in the middle and lower Green River. Thus, the Grand Junction Facility will augment razorback numbers produced at Ouray National Fish Hatchery for the purpose of stocking in the lower Green River. The primary goal identified in the current stocking plan is to establish at least one to three minimum viable razorback sucker populations in the Upper Colorado and Gunnison rivers to complement the existing population in the lower Green River in Utah.
Water quality parameters have not yet been assessed in these grow-out ponds. Growth, condition, and survival of stocked razorback suckers have been variable between ponds (R. Smaniotto, pers. com., 2004). The variability in survival and growth of fish in grow-out ponds was suspected to be, in part a result of elevated selenium levels. Elevated selenium concentrations have been found in many Grand Valley ponds and wetlands (Butler et al. 1991, 1994, 1996; Butler & Osmundson 2000). Recovery goals for the razorback sucker and Colorado pikeminnow acknowledge that selenium is a factor that may inhibit recovery by adversely affecting reproduction and recruitment (USFWS 2002a, 2002b). In addition to selenium, other factors may also be inhibiting growth and survival: differences in zooplankton biomass, dissolved oxygen levels, trophic status of ponds, parasites, and artificial fertilization and feeding within ponds.

Lemly (1993) found that elevated selenium in combination with low water temperature caused reduced activity and feeding in juvenile bluegill, with a significant reduction in fat supplies and associated mortality. If razorback suckers accumulate elevated selenium concentrations from any of the grow-out ponds, it is possible that they may be less able to survive metabolic stress from upcoming winter conditions; especially considering that they are stocked from grow-out ponds (relatively nutrient rich) to the Colorado and Gunnison rivers (relatively nutrient poor) in the fall.

There have also been documented adverse reproductive effects associated with high selenium concentrations in fish tissues (Lemly 1996b; Hamilton *et al*. 2001a, 2001b). Research has shown that the most critical time of selenium exposure associated with deformities in fish is when there is maternal deposition of selenium into eggs (Ohlendorf 2002, Hamilton *et al*. 2001a & 2001b). Osmundson *et al*. (2000) found selenium concentrations in Colorado pikeminnow captured in the Upper Colorado River may be conserved in muscle tissue from year to year. This selenium retention was possibly because Colorado pikeminnow have a tendency to maintain fidelity to a home feeding range (Osmundson & Kaeding 1989). However, in another study, Hamilton *et al.* (2001b) found a loss of only 14-21 % of selenium from muscle tissue during a depuration period of 86 days from a selenium-rich to a selenium-poor environment, also suggesting a slow loss of selenium from muscle tissues. Thus, it is possible that if razorback suckers accumulate selenium from grow-out ponds, selenium could be conserved in muscle tissue and later transferred to eggs after they have been stocked in the Upper Colorado and Gunnison rivers and become sexually mature. This selenium accumulation and retention may be especially true for razorbacks stocked from multi-year ponds, which would be older when released into the rivers. To date, no sample collections have been conducted to document the concentrations of selenium bioaccumulated by razorback sucker prior to or after being stocked in the upper Colorado and Gunnison rivers.

Purpose and Scope

The purpose of this investigation is to describe water quality conditions and food supplies in 16 grow-out ponds that are currently being used by the CRRP to propagate juvenile endangered razorback suckers, and to identify water quality conditions which may limit growth, condition, and survival of razorback suckers in grow-out ponds. Additionally, this investigation looks at the role selenium may be playing in growth, condition and survival of razorback suckers pre-, and post-stocking into the Colorado and Gunnison Rivers. Analysis for chemical and physical water quality parameters are reported (e.g. dissolved oxygen, pH, nutrients, anion/ions, chlorophyll a, and trace elements), and a trophic state index is calculated for each grow-out pond. Selenium concentrations in water, sediment, zooplankton and benthic invertebrate food-chain items, and in razorback suckers reared in grow-out ponds are reported and compared to concentrations found by other researchers to be associated with adverse effects. Selenium concentrations which are accumulated by stocked razorback suckers in residence for at least eight months within the Upper Colorado and Gunnison rivers, as well as wild Colorado pikeminnow, will also be compared with selenium toxicity threshold guidelines to assess risk to endangered Colorado River fish. The change in selenium residues in razorback suckers between the hatchery, each grow-out pond, and those stocked in Gunnison and Colorado rivers will be assessed. Growth and body condition of razorback suckers will be compared between the 15 currently used grow-out ponds.

METHODS

Description of the Study Area

Grow-out Pond Location and Water Source

Fourteen of the 15 razorback sucker grow-out ponds studied in this investigation are located within the Grand Valley of western Colorado (Figure 1). The Colorado Department of Transportation Pond is located approximately 30 miles east of the Grand Valley near the town of Debeque, CO (Figure 1). Grow-out ponds range in size from 0.5 to 15 surface acres (Table 1). Some of the grow-out ponds receive Gunnison River water directly from an irrigation canal, some receive groundwater discharge, and some receive irrigation tail-water along with groundwater discharge (Table 1).

Some of the grow-out ponds are currently leased by the Colorado River Recovery Program (Table 1), with the Bureau of Reclamation administering the lease. Some of the grow-out ponds are on State property, and some have been temporarily donated by private entities. Some ponds (such as Beswick and CDOT ponds) were created after gravel was mined from the site. All ponds are currently managed by the Colorado River Fisheries Project staff. For single-year use ponds, juvenile fish are typically transferred from the hatchery to grow-out ponds in March-April and captured in September to be stocked in the rivers. For multi-year use ponds, fish may occupy the pond for 2-3 successive years if they are not captured after the first growing season. Fish feed on naturally occurring food items in the ponds. An exception occurred in 2005. Silvercup® food pellets containing 0.05 mg/Kg selenium, were provided in PETERS 1-4 ponds (B. Scheer, pers. comm. 2006).

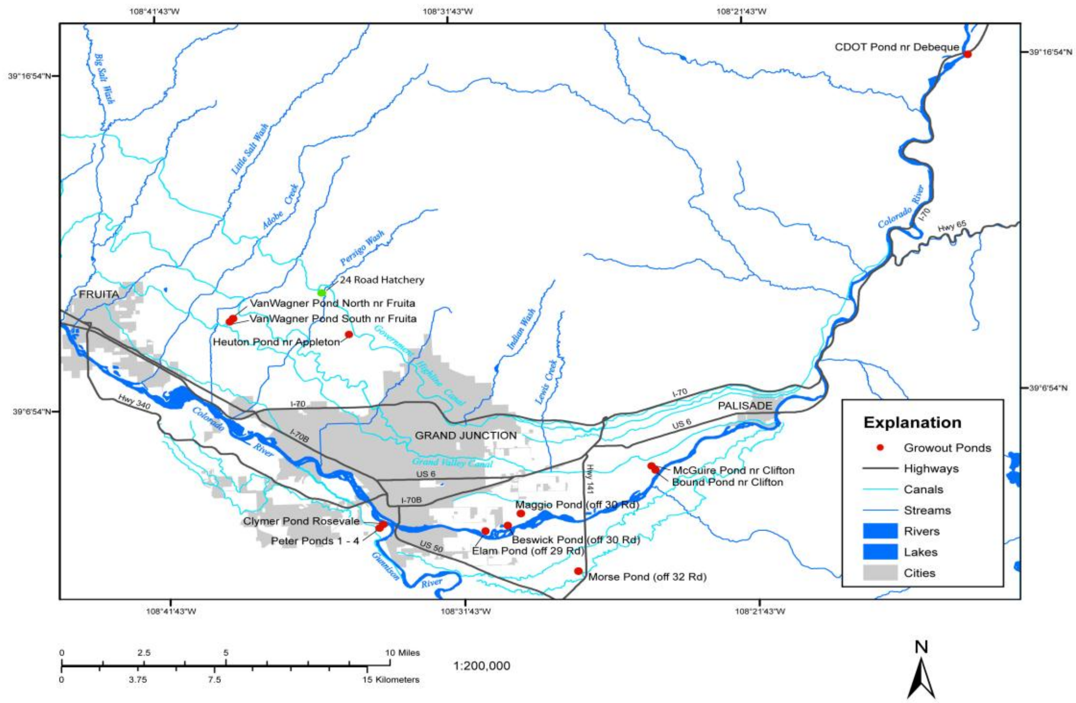


Figure 1. Map of razorback sucker grow-out ponds in the Grand Valley of western Colorado.

Irrigation, Climate and Soils

Approximately 70,000 acres of irrigated lands in the Grand Valley are provided water by Federal and private irrigation systems (Butler *et al.* 1996). These irrigated areas are located along the Colorado River in the Grand Valley, centered around Grand Junction in Mesa county, CO. The majority of irrigated acres are located on soils derived from Mancos shale or from alluvium

Table 1. Description of razorback sucker grow-out ponds in the Grand Valley of western Colorado.

Grow-out Pond Name and nearby town in CO	Latitude Degrees, minutes and seconds	Longitude Degrees, minutes and seconds	Pond Schedule for fish	Approx. Max. Depth (feet)	Surface Acres	Water Source	Ownership*
CDOT Pond near Debeque	39 16 52 N	108 14 01 W	Multi-year	19	5.0	Ground water	AC
MCGUIRE Pond near Clifton	39 04 50 N	108 25 08 W	Multi-year	16	6.0	Ground water & irrigation water	L
BOUNDS Pond near Clifton	39 04 49 N	108 25 06 W	Multi-year	6	7.5	Ground water	AS
MORSE Pond (off 32 Road)	39 01 47 N	108 27 49 W	Multi-year	10.4	3.4	Ground & Irrigation canal water	
MAGGIO Pond (off 30 Road)	39 03 33 N	108 29 44 W	Multi-year	17	15.0	Ground water	L
ELAM Pond (off 29 Road)	39 03 05 N	108 30 53 W	Multi-year	7	4.6	Ground water	L
BESWICK Pond (off 30 Road)	39 03 12 N	108 30 05 W	Single-year	7.5	3.0	Ground water	AS
CLYMER Pond Rosevale	39 03 19 N	108 34 25 W	Single-year	4	5.0	Gunn. R. via Redlands Canal-drains in winter	BR
PETERS Pond 1 Rosevale (furthest N)	39 03 13 N	108 34 33 W	Single-year	9.3	1.0	Gunn. R. via Redlands Canal-drains in winter	BR
PETERS Pond 2	39 03 14 N	108 34 33 W	Single-year	8.2	1.0	Gunn. R. via Redlands Canal-drains in winter	BR
PETERS Pond 3	39 03 15 N	108 34 33 W	Single-year	7.6	1.0	Gunn. R. via Redlands Canal-drains in winter	BR
PETERS Pond 4 (furthest south)	39 03 16 N	108 34 33 W	Single-year	6	1.0	Gunn. R. via Redlands Canal-drains in winter	BR
HEUTON Pond near Appleton	39 09 00 N	108 35 23 W	Single-year	5	0.5	Ditch water-drains in winter	L
VANWAGNER Pond North near Fruita	39 09 33 N	108 39 19 W	Single-year	12.1	1.3	Irrigation canal water	
VANWAGNER Pond South near Fruita	39 09 27 N	108 39 25 W	Single-year	10	6.5	Irrigation canal water	L

*L=Lease between private entity and USFWS; BR=Bureau of Reclamation fee title;

overlying Mancos shale (Figure 1). Numerous small streams and washes dissect the Grand Valley and capture discharged irrigation return water before discharging into the Colorado River. The confluence of the Gunnison and Colorado rivers is also located near the center of Grand Junction, CO. The Grand Valley has an arid to semi-arid climate and is characterized by cool winters and hot summers (Butler *et al.* 1996). The mean annual precipitation in this area is only 8.7 inches. Given this combination of an arid climate and soils rich in selenium, the Grand Valley has been identified as an area susceptible to irrigation-induced selenium contamination (Seiler 1998, Seiler et al. 2003).

Data Collection and Analysis

Grow-out Pond Surface Water Samples

Surface water samples were collected and processed using techniques described in the USGS field-methods manual (USGS 1998). Water samples and depth-profile measurements were collected from late March to late August, 2005, to characterize and monitor temporal changes in water quality. Samples were first collected in March-May (depending upon when ponds were filled with water), then again in June-July, and a lastly again in late August (Table 2).

Generally, samples were collected at the midpoint of a pond's surface and along a single vertical within the photic zone. A Secchi-disk was used at each sample visit. Depth of the photic zone was approximated at twice the Secchi-disk depth (Goldman and Horne 1983, pg 15). Specific water sample depths were selected after stratification patterns at the site were evaluated using equal increment depth-profile measurements (e.g., temperature, dissolved oxygen, pH, and specific conductance). A hand-held water sampling device (US DH-81) was used to collect a vertically-composited sample when sampling depths were $\leq$ 4 feet. An open-tube sampling device (Van Dorn) was used when photic zone depths exceeded 4 feet. The sampler was lowered and remotely triggered to collect two depth-specific water samples within the photic zone; one sample collected at a depth of approximately 1/3 the photic-zone depth, and the other sample

Table 2. List of field measurements and water quality analyses conducted for each sampling visit in 2005.

Site name	Major Ions[1]	Trace Elements[2]	Nutrients[3]	Alkalinity[4]	Turbidity[5]	Chlorophyll-a[6]	Total Nitrogen[7]	Quality Assurance
CDOT	M, J, A[a]	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	Blank (J), 2 Replicates Chlorophyll-a (A)
MCGUIRE	J, A	J, A	J, A	J, A	J, A	J, A	A	Blank (A)
BOUNDS	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	
MORSE	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	
MAGGIO	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	
ELAM	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	Blank (M), 2 Replicates Chlorophyll-a (A)
BESWICK	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	Replicated all & 2 Replicates Chlorophyll-a (J)
CLYMERS	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	Replicates all (J)
INFLOW P3	J, A	J, A	J, A	J, A	J, A	J, A	A	Replicate Chlorophyll-a (J)
PETERS 1	M, J, A	J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	Replicated all, 2 locations (J)
PETERS 2	M, A	M, A	M, A	M, A	M, A	M, A	A	2 Replicates Chlorophyll-a (A)
PETERS 3	M, J	M, J	M, J	M, J	M, J	M, J		
PETERS 4	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	
HEUTON	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	Blank (M)
VANWAG N	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	2 Replicates Chlorophyll-a (M), 2 Replicates (J)
VANWAG S	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	M, J, A	A	2 Replicates Chlorophyll-a (A)

[1]Major ions, filtered 0.45 micron filter, Analytes: Calcium, Chloride, Fluoride, Magnesium, Potassium, Silica, Sodium, and Sulfate. Analytical method references: Fishman (1993), Fishman and Friedman (1989), Fishman et al. 1994 American Public Health Association (1998).
[2]Trace elements (dissolved samples), filtered 0.45 micron filter, Analytes: Cadmium, Copper, Iron, Lead, Manganese, Selenium, Silver, Zinc. Analytical method references: Faires (1993), Hoffman *et al*. (1996), Garbarino and Struzeski (1998), (Garbarino et al. (2006)
[3]Nutrients, filtered 0.45 micron filter, Analytes: Nitrogen, ammonia; Nitrogen, ammonia + organic nitrogen; Nitrogen, nitrite; Nitrogen, nitrite + nitrate; Phosphorus; Phosphorus, orthophosphate. Nutrients, unfiltered, Analytes: Nitrogen, ammonia + organic nitrogen; Phosphorus. Analytical method references: (USEPA 1993, method 365.1), Fishman (1993), Patton and Truitt (2000).
[4]Alkalinity, filtered 0.45 micron filter, Analyte: Alkalinity. Analytical method references: Fishman and Friedman (1989).
[5]Turbidity, unfiltered, Analyte: Turbidity. Analytical method references: (Fishman and Friedman (1989).
[6]Chlorophyll-a, filtered onto glass-fiber filter 47mm, Analytes: chlorophyll-a; Phytoplankton, fluorometric. Analytical method reference: Arar and Collins (1997).
[7]Total Nitrogen, unfiltered, Analyte: Total Nitrogen, ammonia + nitrite + nitrate + organic nitrogen. Analytical method references: Patton and Kryskalla (2003)
[a]M = March-May, J = June-July, A = August

collected at approximately 2/3 the photic-zone depth. The two depth-specific samples were then composited into a laboratory-cleaned and field-rinsed plastic 3-L bottle.

After collection, all water samples were immediately placed on ice. All samples were transported to the USGS laboratory in Grand Junction, CO, for processing after the last sample was collected each day. Typically, sample processing was completed within 3 to 6 hours of the sample collection. Sample processing was as follows: water collected for analysis of turbidity was unfiltered; water collected for analysis of total nitrogen - unfiltered and preserved using sulfuric acid; major ions - filtered through a 0.45 micron filter in an enclosed filter chamber using a peristaltic pump and preserved as needed using trace-element grade nitric acid; trace elements - both filtered and unfiltered and preserved as needed using trace-element grade nitric acid; and nutrients - filtered and unfiltered and preserved as needed using sulfuric acid. All samples were stored on ice at 4°C prior to delivery to the laboratory for analysis. Water collected for analysis of chlorophyll-a was filtered through glass-filter membranes, and the filters were placed in a plastic Petri dish, wrapped in foil, and frozen. Chlorophyll-a samples were transported on dry ice as recommended in the USGS field-methods manual (USGS, variously dated).

Processed samples were delivered to the USGS National Water Quality Laboratory in Lakewood, Colorado for parameter specific analysis (Table 2). All field measurements and water-quality data were entered into the USGS National Water Information System data base. Water-quality data analyzed as part of this report can be obtained from the Webpage at the URL http://waterdata.usgs.gov/co/nwis/qwdata (search for data using the USGS site number).

Quality-assurance samples consisted of randomly selected field blanks and replicate samples (Table 2). A field blank consisted of a collection of organic-free rinse water from laboratory- or field-cleaned sampling equipment. The blanks were processed in a manner consistent with procedures listed previously in this section. Three replicate samples were collected to determine the variability of the results of the chemical analyses; and 16 replicate samples were collected to determine the variability of the chlorophyll-a and pheophyte-a results, due to the potential for greater inherent variability of results.

A multi-parameter field meter that measures water temperature, pH, dissolved oxygen, and specific conductance was calibrated at the first site prior to depth profiling. Calibration procedures were documented on field forms, and routine maintenance was done by the sampling team as needed (Wilde and Radtke 1998). Following the collection of the last sample, a calibration check was done to determine if the meter was still operating within calibration limits.

Water quality parameters were evaluated and compared among ponds, and compared to Colorado water quality standards for the protection of aquatic life (CDPHE 2008b).

Trophic Status Index

Three trophic status index (TSI) equations were used to assess the degree of eutrophication in the grow-out ponds. The TSI is calculated from chlorophyll-a concentrations (algae biomass), secchi-disk depth (water clarity), and total-phosphorus concentrations by using a distinct formula, below, for each parameter (Ortiz 2004). The TSI scale ranges from 0 to 110, with TSI values less than 40 indicative of oligotrophic conditions; values 40-50 indicative of mesotrophic conditions; and values greater than 50 indicative of eutrophic conditions. Nitrogen to phosphorus (N:P) ratios were also determined to assess nutrient limitation related to phytoplankton growth in each grow-out pond.

The TSI formula for total phosphorus (TP) in micrograms per liter (ug/L) is:

$$TSI_{TP}=(14.42*(\log TP) + 4.15) \qquad \text{Equation 1}$$

The TSI formula for chlorophyll-a (CHLa) in ug/L is:

$$TSI_{chla}=(9.81*(\log CHLa) + 30.6) \qquad \text{Equation 2}$$

The TSI formula for Secchi Disc (SD) water clarity in meters (m) is:

$$TSI_{SD}=60 - (14.41*(\log SD)) \qquad \text{Equation 3}$$

Sediment Samples

Two composite sediment samples were taken during mid-summer from each of 16 currently used grow-out ponds (n=32). Sediment samples were collected by USFWS personnel using a BMH-53 sampler (Ward and Harr 1990). The top 3-5 cm of several cores were placed into a stain-less-steel bucket and mixed using a stainless-steel spoon. Composite sediment samples were stored in chemically clean containers at $4^{O}C$ (held < 4 months), until shipment to Trace Element Research Laboratory, Texas A & M University for metals analysis. Sampling equipment was cleaned between sites with distilled water.

Invertebrate Samples

Two zooplankton samples were collected at each of the 15 currently used grow-out ponds, in both spring and in mid-to late-summer (n=64). Spring zooplankton samples were analyzed for trace elements at Trace Element Research Laboratory (TERL) at Texas A&M University in College Station, Texas. Summer samples were analyzed only for selenium. Zooplankton samples were collected by using modified light traps (Espinosa and Clark 1972). These light traps consisted of flashlights and 3.8-liter plastic containers with attached funnels. Light traps were set overnight, and the trapped zooplankton collected the next morning. The contents of each light trap was concentrated by filtering the samples through the basket of a 153 µm plankton net, and the contents were placed into a chemically clean glass jar and frozen. Samples were shipped on dry ice to the laboratory for metals analysis. Zooplankton biomass from each light trap was used as a crude measure of productivity of potential razorback sucker dietary items among the 16 grow-out ponds (McAda 1977, Muth et al. 1998, U.S. Fish and Wildlife Service 2002b).

Two benthic invertebrate samples were collected per pond site (n=32), using a hand-net and forceps during mid-summer. Benthic invertebrates were collected until individual samples provided at least 2 grams for laboratory analyses. Thus, biomass estimates should be considered crude estimates of productivity. Invertebrate groups were identified to orders and composited to provide at least 2 grams of biomass for metals analysis. Samples were placed into chemically clean containers and placed on ice in the field, until they could be frozen and eventually shipped to the lab within a few months. Sampling equipment was cleaned with soap and water and rinsed with distilled water between sites.

Sediment and invertebrate samples were shipped to TERL for trace element analyses. Samples were analyzed for selenium and selected trace elements (aluminum, arsenic, beryllium, boron, calcium, cadmium, chromium, cobalt, copper, iron, lead, manganese, magnesium, molybdenum, phosphorous, potassium, silicon, silver, sodium, strontium, sulfur, titanium, vanadium, and zinc) using inductively coupled argon-plasma atomic-absorption spectrometry after complete digestion of the sample in strong acids. Analyses for arsenic and selenium were done using hydride-generation atomic absorption, and analyses for mercury were done by flameless cold-vapor atomic absorption. All analytical data were reviewed by the Service's Analytical Control Facility (ACF), Shepherdstown, WV. Quality-control procedures associated with trace element analyses included sample spikes, duplicates, and blanks (available upon request).

Muscle Plug Biopsy Collection

Muscle plug biopsy samples were collected from 20 young-of-year hatchery-raised razorback suckers (approx. 100 mm length) before they were stocked into grow-out ponds (late March to May), to determine a baseline selenium concentration. Muscle plug samples were taken with clean, sterile, disposable 4 or 5-mm biopsy punches according to procedures specified by Williamson (1992). Using a new punch for each sample, muscle plugs were taken 1-2 cm to either side of the dorsal fin. The plug samples were placed in chemically-cleaned cryotubes and stored on wet ice, until they could be frozen and eventually shipped to the Columbia Environmental Research Center (CERC) for sample preparation prior to selenium analysis.

Prepared samples were then transported to the University of Missouri Research Reactor (MURR), Columbia, Missouri, for analysis of the radionuclide Se^{77m} by neutron activation using methods described in McKown and Morris (1978). The use of this method for selenium analysis in fish muscle plugs has been previously described by Waddell and May (1995).

Muscle plugs for selenium analysis were also taken from 10 randomly selected razorback suckers per each of the 16 currently used grow-out ponds (only six from Van Wagner S pond.). These plugs were taken during August through October, when razorback suckers were harvested from ponds for stocking into the Upper Colorado and Gunnison rivers. Razorback suckers from the hatchery were stocked in single-year use ponds in late March to May and had been in the grow-out ponds for 4 to 6 months (some had over-wintered from the previous year's stocking). Razorback suckers in multi-year ponds had been in ponds for at least six months before they were harvested for release into the rivers (some for 1-2 years), although total time in ponds could not be determined.

Muscle plug samples were taken from recaptured razorback suckers that had been at large in the Colorado and Gunnison rivers for at least 8 months after stocking in previous years (n=16 during 2004, n=34 during 2005). Muscle plugs were also taken from captured wild Colorado pikeminnow (n=19 during 2004, n=26 during 2005). These fish were captured in the Colorado and Gunnison rivers by Colorado River Fisheries Project staff while conducting Colorado pikeminnow population surveys.

<u>Statistical Analysis and Data Interpretation</u>

Unpaired T-tests with an alpha of 0.05 were used to compare mean selenium concentrations in razorback sucker muscle plugs between sites: 1) hatchery, 2) each of the 16 currently used grow-out ponds, and 3) the stocked fish recaptured from the Upper Colorado and Gunnison rivers (Dowdy and Wearden 1983). To improve normality and stabilize treatment variance, selenium concentrations were log-transformed before analysis (Singh *et al*. 1997, Ott 1990, deBruyn et al. 2008). A t-test was used to determine if selenium concentrations were significantly different in razorback suckers between each grow-out pond, and also within critical habitat within the Colorado and Gunnison rivers compared to baseline concentrations in fish in the 24 Road Hatchery. Analyses were used to determine if fish accumulate or eliminate selenium after release into the rivers from the grow-out ponds and if stocked razorback suckers contain higher or lower selenium residues than wild Colorado pikeminnow. Selenium concentrations in razorback sucker muscle plug samples were compared to selenium concentrations in muscle plug samples taken from three other sucker species: including the non-native white sucker (n=23), the native bluehead sucker (n=9), and the native flannelmouth sucker (n=12). These fish were collected from the Colorado River in the Grand Valley below the Gunnison River confluence (unpublished data, B.Osmundson).

<u>Selenium Hazard Assessment</u>

Selenium concentrations in water, sediment, zooplankton, benthic invertebrates, and fish muscle plug samples were used to calculate a selenium hazard for each grow-out pond. We used a modified version (i.e. without the collection and analysis of avian eggs) of Lemly's (1995) hazard assessment protocol. Lemly (1995) developed this protocol to evaluate different ecosystem components to address the potential risk of food-chain bioaccumulation of selenium and associated reproductive impairment in fish and birds. This technique was used previously by Hamilton et al. (2002b) to assess selenium hazard to razorback suckers at other sites in the Colorado River basin, including Horsethief State Wildlife Area near Fruita, CO, where razorback sucker brood stock are kept. In our investigation, we further modified the selenium hazard assessment protocol by projecting the potential fish egg concentrations by using a conversion factor applied to the selenium concentrations in muscle plugs (as in Hamilton *et al*. 2005). Selenium concentrations in all samples were compared to selenium toxicity thresholds presented in the literature (Maier & Knight 1994; Lemly 1996; Hamilton et al. 2001a, 2001b.

Body Condition of Razorback Suckers

Mean total length (mm), weight (g), and body condition of razorback suckers was determined at the time when fish were harvested from each grow-out pond for pond to pond comparisons. The relative condition (k_n) of razorback suckers was determined using the following equation from (Osmundson *et al.*1998):

k_n=100xM_o/M_e____Equation 4

where M_o is the observed mass (g) and M_e is the expected mass (g) as calculated from the following equation:

$\log_{10}(M_e)=\log_{10}(\text{length})*m + b$_______________________________Equation 5.

And M_e is calculated from combined fish measured and collected for muscle plug samples from all the grow-out ponds, with (m) as the slope and (b) as the y-intercept. The relative condition of razorback suckers is compared among the grow-out ponds.

RESULTS & DISCUSSION

Water Quality Results

Quality Assurance/Quality Control

More than 90 percent of the analyte concentrations in field blanks were less than detection limits. In the small number of samples where concentrations in field blanks were higher than might be expected, the values were compared to the environmental data to assess the effect on data interpretation. Nearly all environmental samples had concentrations an order of magnitude higher than the field blank and all were within the range of acceptable values. This magnitude of difference from the field blank and range of environmental sample concentrations indicated little likelihood the environmental data were compromised by cross-contamination between sites. No adjustments were made to the original data to account for field-blank results. Quality assurance/quality control results accompanying analytical results for this investigation all fell within U.S. Geological Survey guidelines.

Depth Profile measurements

Specific Conductance

To account for seasonal stratification and mixing events, depth-profile measurements of water temperature, dissolved oxygen, pH, and specific conductance for each of the razorback sucker grow-out ponds are displayed in Appendix 1. Specific conductance in each pond was reflective of the source water. Highest conductivities were found in Beswick, Bounds, Maggio, and Elam ponds (Figure 2), which receive primarily ground water discharge (Butler *et al.* 1996). The CDOT pond also receives mainly groundwater, but its specific conductance was moderate compared to the other ponds receiving groundwater discharge. We suspect the reason for the difference in observed conductance is the CDOT pond is located upriver from irrigated Mancos shale soils in the Grand Valley. McGuire and Morse ponds receive both groundwater inflow of irrigation canal water, and had intermediate specific conductance measurements. Clymers, Heuton, Van Wagner N, Van Wagner S, and all the Peters ponds receive main stem river water from the Colorado and Gunnison rivers through irrigation canals, and had the lowest conductivities.

Seasonal variation in specific conductance was most pronounced in Peter ponds. During spring, snowmelt in the Gunnison River was thought to be providing dilution of salts. The highest conductivities in most of the ponds occurred during August; most likely influenced by evapo-transpiration and less dilution flows from spring runoff.

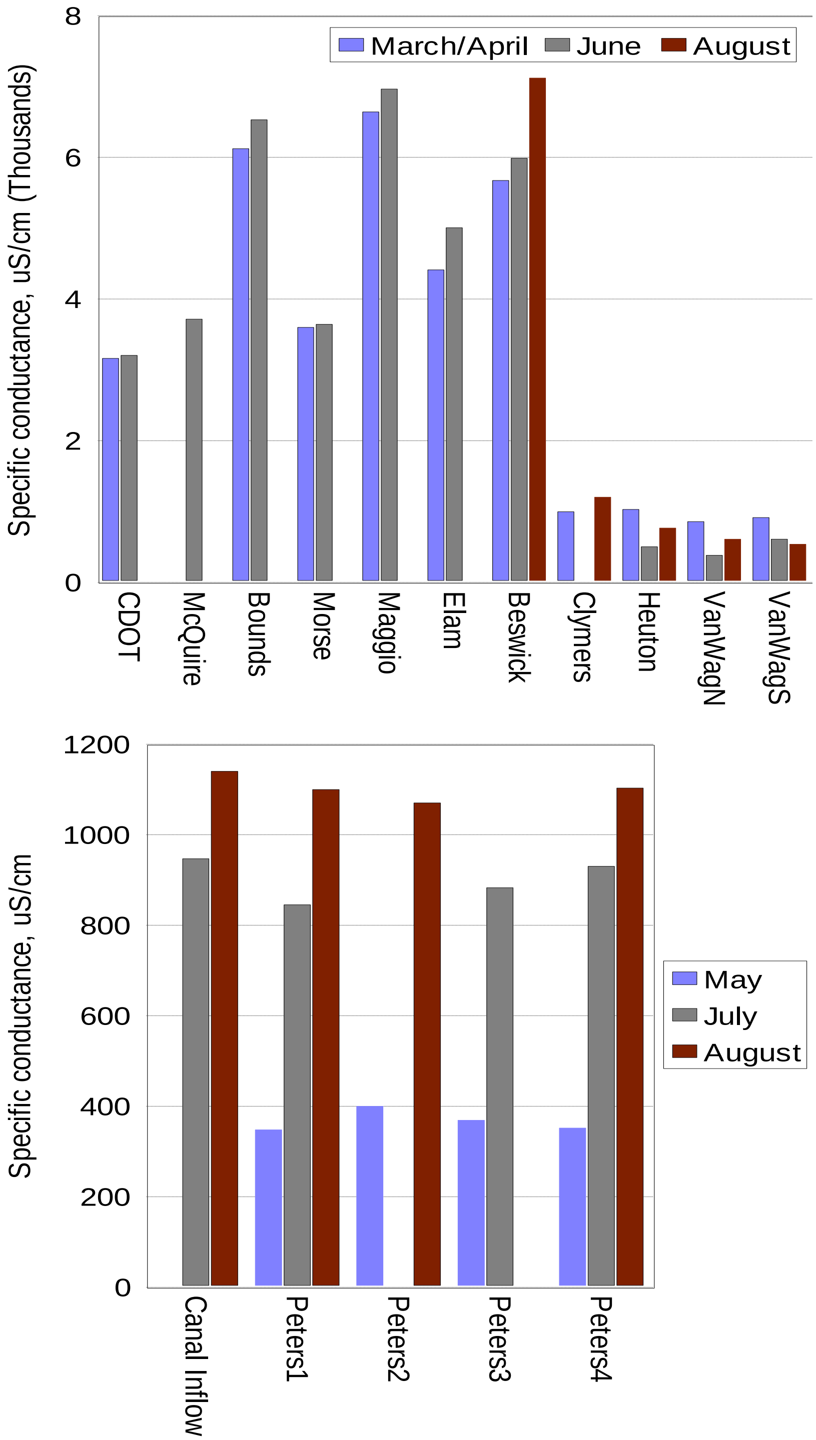


Figure 2. Specific conductance (µS/cm) in razorback sucker grow-out ponds in 2005.

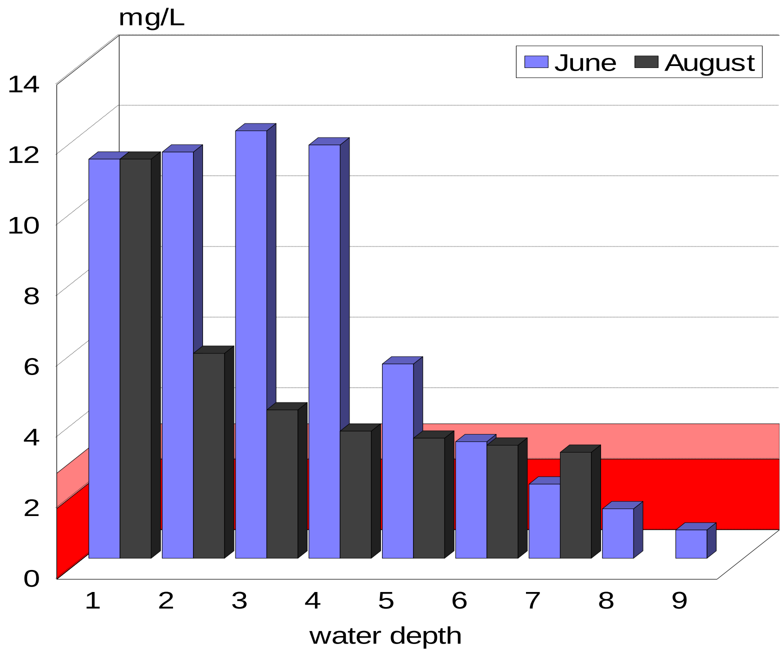
Water Temperature and Dissolved Oxygen

Water temperatures increased markedly between March and June (Appendix 1). In general, the ponds seemed to be well mixed throughout the summer, as characterized by depth profiles of field measurements of dissolved oxygen concentrations, pH, and conductivity. In deeper ponds (CDOT and Maggio), dissolved oxygen concentrations decreased with increasing depth during June and August. McGuire Pond, on the other hand, showed higher dissolved oxygen as depth increased in June, but not in August. An aerator located on the McGuire's pond bottom was most likely functioning in June, but not in August (Chuck McAda, per.com. 2007). Piper et al. (1982) discussed that negative growth effects would be seen in fish when dissolved oxygen concentrations are at 3 mg/L, and avoidance or mortality could occur after a few hours at 1-2 mg/L. During August, low dissolved oxygen concentrations were found in shallower depths compared to June in both Morse and Van Wagner N ponds (Figure 3). Low dissolved oxygen concentrations became a concern in Heuton, McGuire, Morse, and Van Wagner N ponds during the summer of 2005. Low dissolved oxygen $\leq$ 3 mg/L occurred in the deepest sections of these ponds.

pH

The pH measurements in grow-out ponds ranged from pH 7 (McGuire pond) to pH 9.4 (Elam pond) (Appendix 1). Piper *et al.* (1982) noted that excessively high pH values can occur in ponds during summer, when phytoplankton are abundant and photosynthesis is intense. Photosynthesizing plants take carbon dioxide from the water, and bicarbonate and carbonate ions bind hydrogen; acidity is reduced and pH rises. Piper *et al.* (1982) suggested that water used to rear warm water fish be in the range of 6.5 to 9.0 for optimal growth. All pH measurements in grow-out ponds fell within this range except for Elam and CDOT ponds, which had pH measurements slightly above 9.

a.



b.

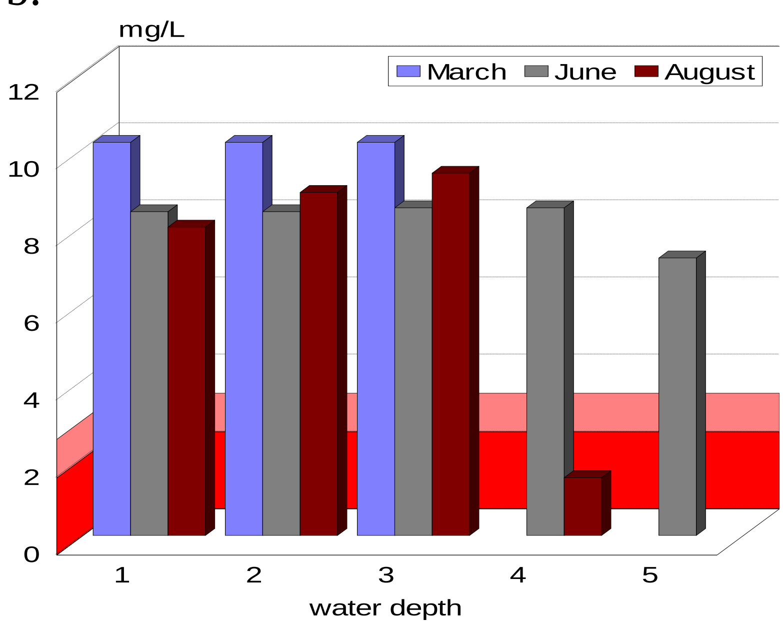
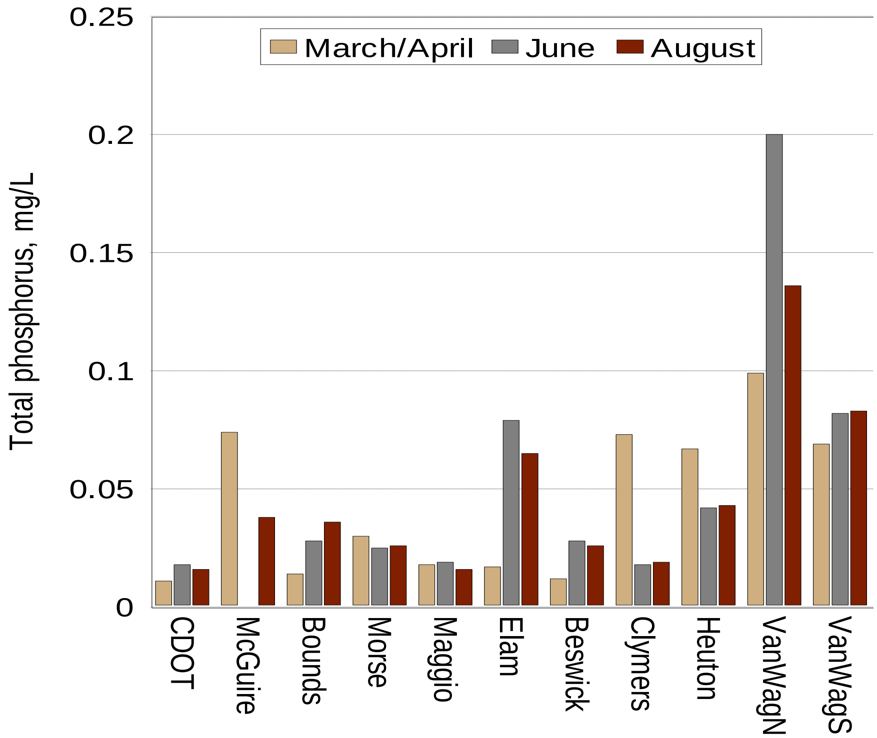


Figure 3. Dissolved oxygen (mg/L) in Van Wagner N (a) and Morse (b) ponds during 2005.

Nutrient Measurements

Total Nitrogen, Total Phosphorus, and Chlorophyll-a

Results of low-level nutrient analyses are provided in Appendix 2. Nitrogen and phosphorus compounds are required for plant growth, but excess concentrations can cause algal blooms that lead to low dissolved oxygen and result in fish kills (Carpenter et al. 1998, Mueller and Helsel 1996). Natural sources of nutrients include atmospheric deposition, precipitation, soil runoff, erosion, and biochemical mechanisms in the basin (Ortiz 2004). Manmade sources of nutrients in water include urban and agricultural fertilizer runoff, domestic and septic system effluent, livestock waste, and erosion associated with development (Mueller and Helsel 1996). Cole (1979) considered phosphorus to be the nutrient that regulates primary production in lakes, and thus a controlling factor for fish yield. Total phosphorus compounds were highest in Van Wagner N pond followed by Van Wagner S and Elam ponds (Figure 4). Total nitrogen displayed a similar pattern, with the highest concentrations (1.5-1.6 mg/L) in Van Wagner N Van Wagner S ponds (Figure 5). Additionally, Van Wagner N and S ponds also had some of the highest concentrations of chlorophyll-a (Figure 6), with Van Wagner N. and S. measuring 86.4 ug/L and 50.6 ug/L, respectively. As chlorophyll a is often the predominant type of chlorophyll in algae, it can be considered to approximate relative algal biomass (Cole 1979). With the exception of CDOT pond and Peters pond 1 and pond 4, chlorophyll-a concentrations peaked during August in grow-out ponds. These ponds had peak chlorophyll-a concentrations earlier in the spring and summer (Figure 6). There was a correlation between chlorophyll a and total nitrogen (r^2=0.52, p=0.004), and between chlorophyll-a and total phosphorus (r^2=0.19, p=0.003). This suggests that total nitrogen may have played a bigger role in affecting algal growth, as measured by chlorophyll-a, than did total phosphorus.


0.25
0.2
0.15
0.1
0.05
0
Total phosphorus, mg/L
March/April
June
August
CDOT
McGuire
Bounds
Morse
Maggio
Elam
Beswick
Clymers
Heuton
VanWagN
VanWagS

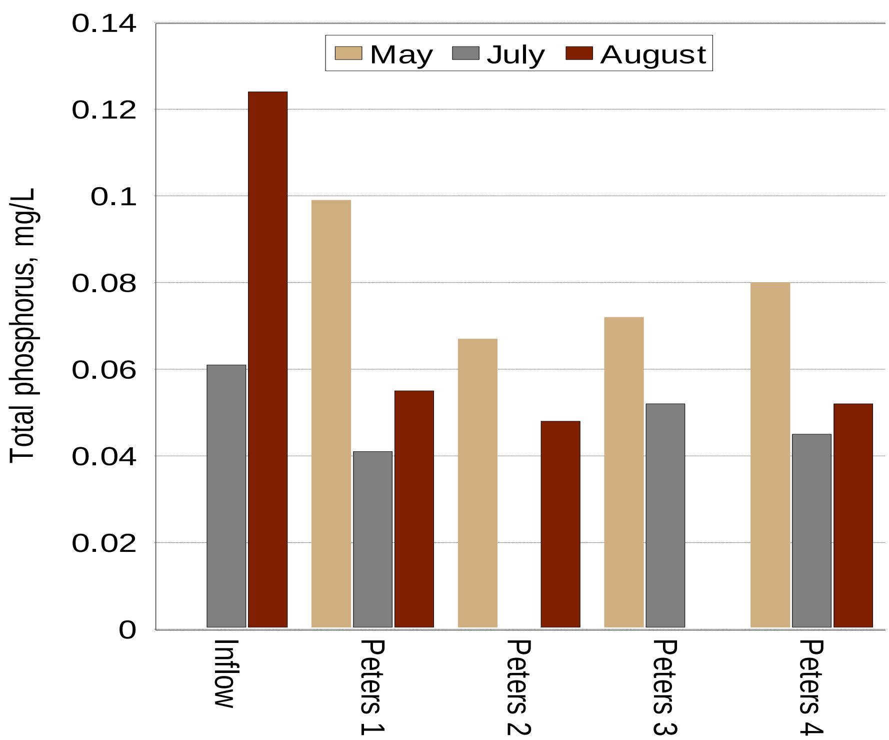

0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Total phosphorus, mg/L
May
July
August
Inflow
Peters 1
Peters 2
Peters 3
Peters 4

Figure 4. Total phosphorus (mg/L) in razorback sucker grow-out ponds during 2005.

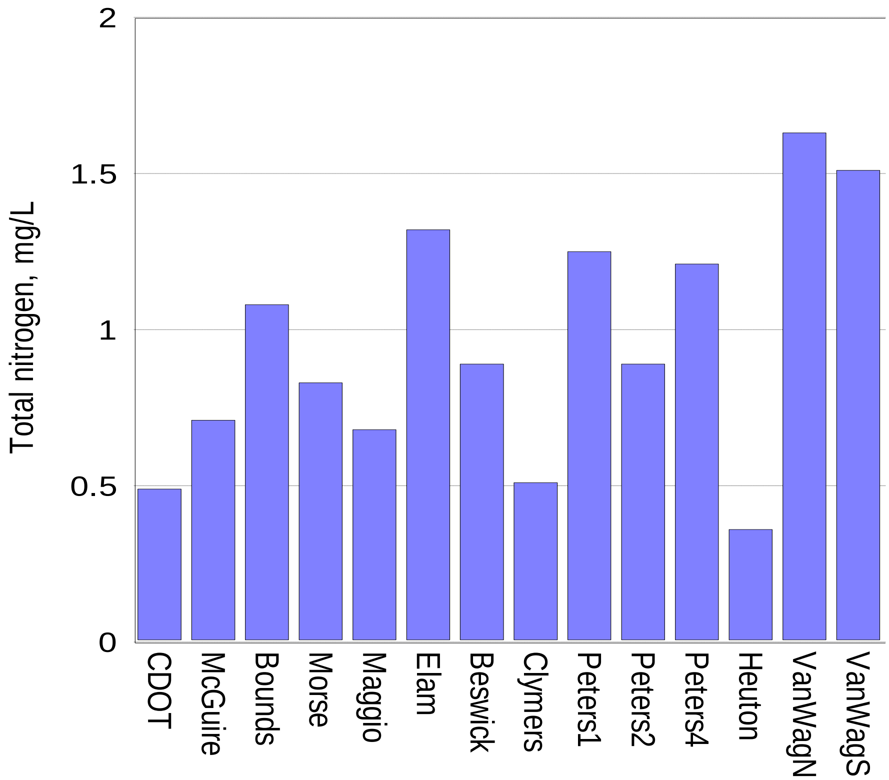
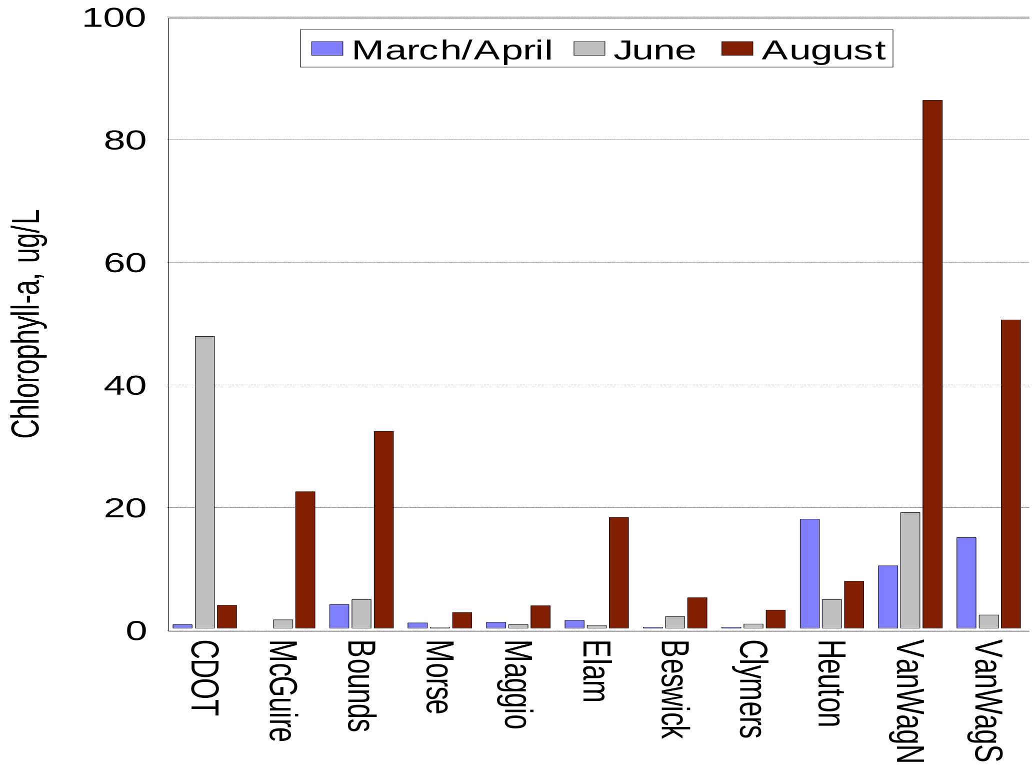
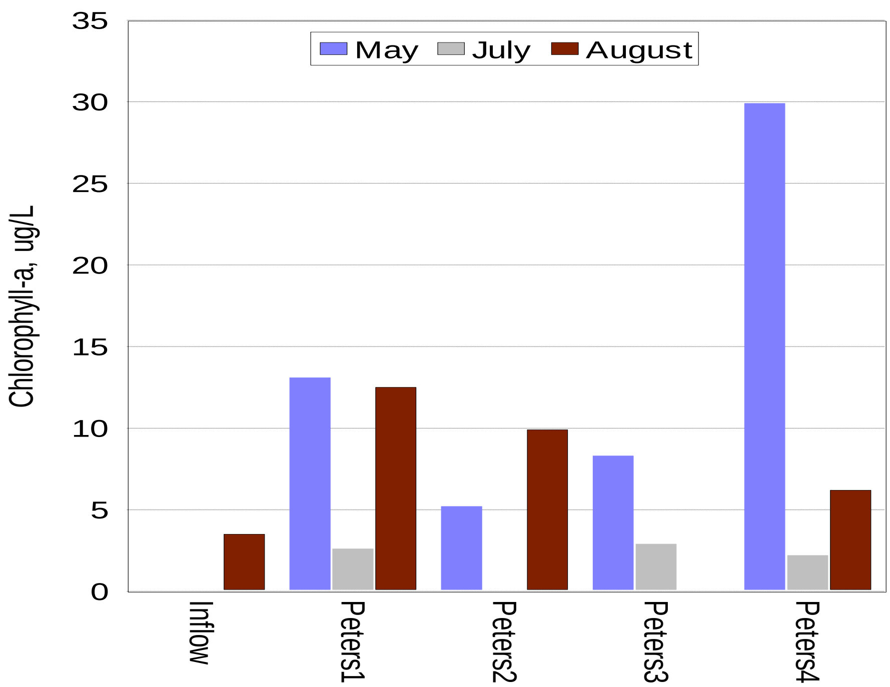


Figure 5. Total nitrogen (mg/L) in razorback sucker grow-out ponds during 2005.

During September 2006, a fish kill of razorback suckers occurred at the Van Wagner South pond and a smaller fish kill at the Van Wagner North pond. Based on our observations of elevated nutrient and chlorophyll concentrations measured during 2005, we suspect that a phytoplankton bloom occurred in 2006, and this bloom contributed to these fish kills. Bennett (1970) described two scenarios of summer-kill of fish which can occur in ponds during the summer in North America. The first summer- kill scenario described by Bennett (1970) may occur in shallow weed-filled ponds during the hot, still nights of July and August, after periods of several days of cloudy skies, with air temperatures above 80 degrees both day and night, and calm winds. While dissolved oxygen may be abundant during the daytime due to photosynthesis, during the night, respiration rates may exceed daytime oxygen surplus, leading to reduced oxygen in the water column that can suffocate and stress fish, leading to a fish kill. During these scenarios, fish are often seen at the first light of dawn, gasping for air at the water's surface. Thus, high water



Chlorophyll-a, ug/L
March/April
June
August
100
80
60
40
20
0
CDOT
McGuire
Bounds
Morse
Maggio
Elam
Beswick
Clymers
Heuton
VanWagN
VanWagS



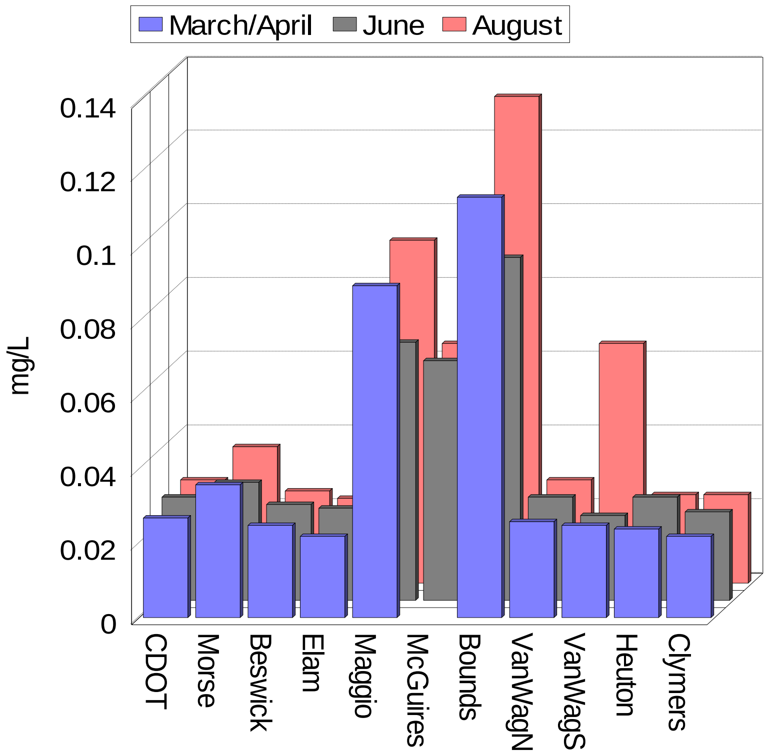
Chlorophyll-a, ug/L
May
July
August
35
30
25
20
15
10
5
0
Inflow
Peters1
Peters2
Peters3
Peters4

Figure 6. Chlorophyll-a concentrations (µg/L) in grow-out ponds during 2005.

temperatures, darkness, and rapid organic decay in shallow weed-filled ponds combine to produce summer fish kills during optimal conditions, and fish are unable to escape. The second scenario occurs when dense algae blooms occur in the upper surface layer of the pond, resulting in high surface temperatures and super-saturation of oxygen. The water column below this algal mat is shaded because of the dense algae growth, and may be devoid of oxygen, high in carbon dioxide, and 10^{o}F cooler than the surface layer, which creates a biological oxygen demand. Any upwelling of subsurface water caused by cold rain or prolonged wind action on the surface may create oxygen deficiency throughout the pond, resulting in a fish kill. Based on high nutrient concentrations and high chlorophyll-a concentrations (indicative of a phytoplankton bloom) measured during 2005, it is not unreasonable to expect that high nutrients causing a phytoplankton bloom and resulting in low dissolved oxygen concentrations occurred during 2006. Both Van Wagner ponds had considerable submergent vegetation during 2005 and 2006, relative to other ponds. Dead and gasping razorback suckers were found during the morning hours, as in Bennett's (1970) first scenario.

Inorganic Nitrogen

Inorganic nitrogen (the summation of nitrite (N03) plus nitrate (N02) plus ammonia (NH3)) concentrations were highest in Peter ponds during July and August (Figure 7, note change in scale for Peter ponds). Inflowing water to Peter ponds from the Redlands Canal (Gunnison River water) contained almost 10 times the inorganic nitrogen that was found in other grow-out ponds. This nitrogen content may be a result of nutrient input into the Gunnison River from agricultural drainage, septic tanks, or other anthropogenic sources (Spahr *et al*. 2000, Mueller & Helsel 1996). During May, high in-stream flows derived from snowmelt diluted constituents in the Gunnison River water. Although Horne and Goldman (1994) discussed that phytoplankton can readily assimilate inorganic forms of both nitrogen (nitrite, nitrate, and ammonia) and phosphorus (orthophosphate), we found that chlorophyll-a concentrations were not correlated with inorganic nitrogen concentrations (r^2=0.016, p=0.415) or inorganic phosphorus (r^2<0.002, p=0.975) in razorback sucker grow-out ponds.



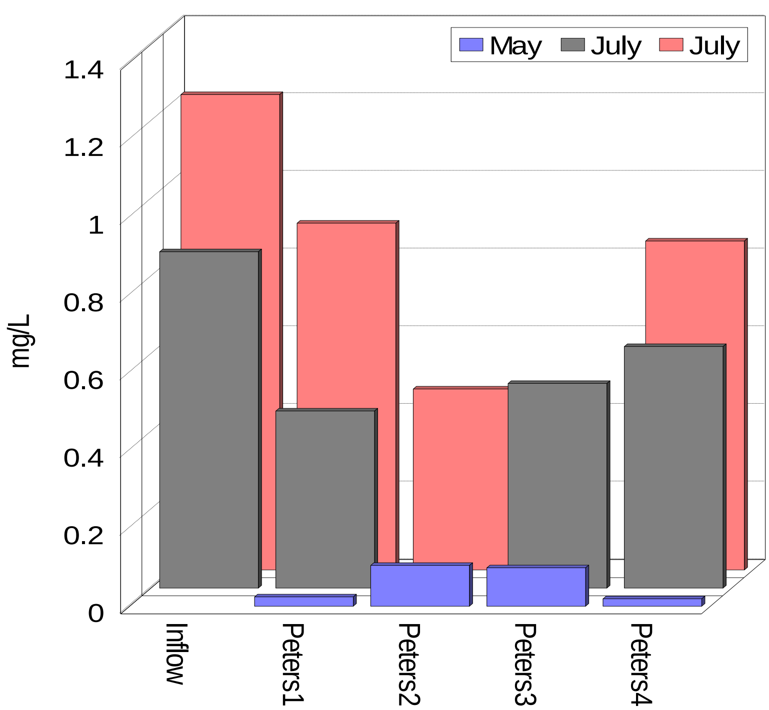


Figure 7. Inorganic nitrogen (mg/L) in razorback sucker grow-out ponds during 2005.

Total Ammonia

Concentrations of un-ionized ammonia and total ammonia (ammonia) are given herein in terms of nitrogen, that is, as milligrams nitrogen per Liter (mg N/L). The highest ammonia concentration (0.11 mg N/L) was recorded in Bounds pond. Only a small percentage of this total ammonia would be in the un-ionized form (NH3), that is potentially toxic to fish, depending on pH and temperature conditions (Hem 1985, US EPA 1999). A calculation of the unionized ammonia portion of the 0.11 mg N/L, (using a pH of 8.5 and temperature of 24^{o}C), resulted in a concentration of 0.016 mg/L un-ionized ammonia in Bounds pond. This 0.016 mg/L concentration is less than the un-ionized ammonia concentration of 25 mg/L, associated with a 1% mortality rate of razorback suckers during a 28 day exposure calculated by Fairchild et al. (2005). All water samples collected during this study were collected from the photic zone (with sunlight penetration), and ammonia concentrations can be higher towards the pond bottom where it tends to adsorb to sediment particles (Wetzel 2001). Wetzel (2001) described a process that when the sediment-water interface became anoxic, the adsorptive capacity of the sediments was reduced and a release of ammonia from the sediment into the water occurred. However, ammonia toxicity can also depend on various aspects of the ionic composition of the exposure water (USEPA 1999).

Nitrogen to Phosphorus Ratios

Nitrogen to phosphorus (N:P) ratios can be used to identify which of the two nutrients are possibly limiting plant growth and thus the primary productivity in the grow-out ponds. When a nutrient is limiting, addition of that nutrient can foster an increase in plant growth. Plant and algal growth can, be beneficial by providing food for fish or it may be detrimental and a bloom can cause fish kills (as described above). Ratios of inorganic nitrogen to inorganic phosphorus (orthophosphate) for grow-out ponds are provided in Appendix 2 and depicted in Figure 8. When the N:P ratios are smaller than five, then a nitrogen-limited (N-limited) situation is considered to exist (Britton & Gaggiani 1987, Woods 1992). Similarly, a N:P ratio greater than 10 represents a situation that is considered to be phosphorus limited. Nitrogen to phosphorus ratios from 5 to 10 could be indicative of either a nitrogen or a phosphorus limitation, or there was not a limitation of either nutrient. The N/P ratios varied between ponds and among ponds by season (Fig. 8). To maximize algal growth and fish production, we recommend the pond managers consider these results, and as appropriate, manage these conditions to maximize fish yield without exceeding nutrient amounts and maintain monitoring of nutrients to verify the pond nutrient conditions as least monthly. Excess phosphorus increases algal and macrophyte activity and the uptake of scarce nitrogen. This in turn gives an advantage to nitrogen fixing organisms such as species of blue-green algae (Carlson 1992).

Trophic State Index

Calculated trophic-state-index (TSI) values (Carlson 1977) for each grow-out pond are displayed in Appendix 3. TSI values based on total phosphorus concentrations indicate most grow-out ponds were highly productive (eutrophic) throughout the growing season. Maggio pond was consistently mesotrophic and CDOT pond ranged from oligotrophic to mesotrophic. These rankings were fairly consistent with how Vollenweider (1968) categorized trophic status by using total phosphorus: concentrations less than 0.01 mg/L were considered oligotrophic, concentrations from 0.01 to 0.02 mg/L were indicative of mesotrophic conditions, and concentrations exceeding 0.02 mg/ L were classified as eutrophic. TSI values based on chlorophyll-a were lower and less consistent than those based on total phosphorus or Secchi-disk depths, and ranged from low to high productivity. Ponds with the lowest TSI’s based on chlorophyll-a included: Morse, Beswick, Elam, Maggio, McGuire, and Clymers. Bausch and Malick (2003) reported that lower index values for chlorophyll-a could be expected when differences in laboratory analytical methods are considered. TSI values based on Secchi disk depth classified the majority of grow-out ponds as eutrophic. Use of TSI’s can give a relative indication of relative trophic status of ponds, but should not be considered as definitive (Ortiz 2005). Phosphorus is usually the nutrient that regulates productivity in ponds. Carlson and

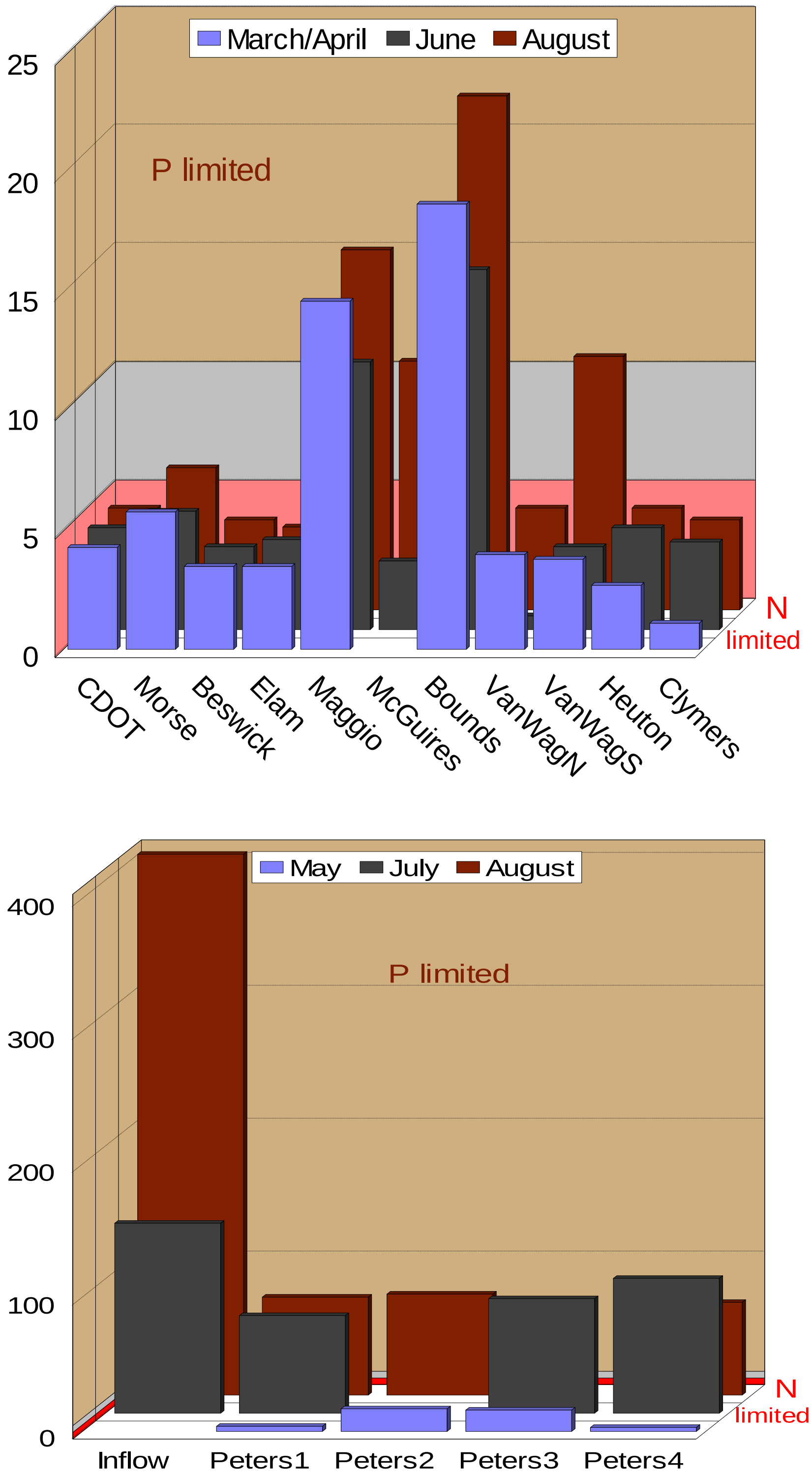


Figure 8. Nitrogen to phosphorus ratios for razorback sucker grow-out ponds.

Simpson (1996) discussed that if phosphorus and secchi disk TSI values are relatively similar and higher than the chlorophyll TSI value, then dissolved color or non-algal particulates dominate light attenuation. It follows that when secchi disk and chlorophyll TSI values are similar, then chlorophyll is dominating light attenuation. When turbidity is high, the chlorophyll index is commonly 10 to 20 units below the phosphorus or secchi depth TSI's (Carlson 1992). This was most often the case with the grow-out ponds, which suggests that light attenuation in ponds was dominated by suspended sediment and organic material.

<u>Other Water Quality Constituents including Minerals and Salts</u>

Total dissolved solid (TDS) concentrations along with associated cations and anions in razorback sucker grow-out pond water samples collected during 2005 are provided in Appendix 4. As was the case with specific conductance, those ponds with source water from groundwater resulting from subsurface irrigation drainage have the highest concentrations of total dissolved solids, cations, and anions. Maggio and Bounds ponds contained the highest concentrations of total dissolved solids (TDS), sulfate, magnesium, and calcium. Beswick and Elam ponds had the highest concentrations of potassium, sodium, and chloride. CDOT pond had the highest alkalinity and fluoride concentrations. Salinity is not precisely equivalent to TDS, but for most purposes, they can be considered equivalent (USEPA 1986). The TDS concentrations in Maggio and Bounds ponds are within the acute toxicity threshold range of 6,000-10,000 mg/L for the zooplankton *Dapnia magna*, and the fathead minnow, as well as the level of concern (LOC) of 5,500-8,900 mg/L for *Chironomus utahensis* (USDOI 1998). Both *Dapnia sp*.and *Chironomus sp*. are potential dietary items for razorback suckers (Papoulias and Minckley 1992). Piper et al. (1982) suggested that rapid changes in TDS concentrations can be stressful as fish expend energy they would otherwise use for growth or reproduction towards the maintenance of their osmotic balance in water containing excess salts. This physiological stress should be considered when moving razorback suckers from the hatchery water with relatively low TDS concentrations to ponds which receive groundwater and contain relatively high TDS concentrations, and again when fish are moved from the ponds to the Colorado and Gunnison rivers. The TDS concentrations in Maggio, Bounds, and Beswick ponds are >4000 mg/L, and in the Gunnison and Colorado rivers are <1000 mg/L.

Trace Elements

Metal concentrations found in water samples collected from razorback sucker grow-out ponds during 2005 are in Appendix 5. Because water hardness affects the toxicity of most metals, the USEPA has established water quality criteria for selected metals that are based on water hardness. Hardness is a property of water where "hard" has a high mineral content (as contrasted with "soft" water that does not). Hard water usually consists of calcium and magnesium in the form of carbonates and sulfates, and presence of these minerals can ameliorate the toxicity of metals (CDPHE 2008c).

With the exception of selenium, most of the measured concentrations of metals in the razorback sucker grow-out ponds were less than the Colorado water quality standards for the protection of aquatic life (CDPHE 2008b). The 10.2 µg/L copper concentration in Van Wagner N pond during August approaches the standard of 11.43 µg/L copper at the relatively low water hardness of 133 mg/L. The Colorado chronic aquatic life selenium standard of 4.6 µg/L (dissolved) was exceeded throughout the summer at Maggio pond (ranging from 6.5-7.9 ug/L) (Figure 9). The selenium standard was also exceeded in the inflow for all of the Peters ponds (ranging from 5.4-5.9 ug/L), which is water taken from the Redlands canal, that in turn is filled with Gunnison River water. These exceedences were not unexpected because the segment of the Gunnison River that water is diverted from to fill the Redlands canal appears on the 303(d) list of impaired waters in Colorado because of elevated selenium concentrations (CDPHE 2007). As this water was delivered to the Peters ponds 1 through 4, the selenium concentrations in Peter ponds also exceeded the selenium standard during July and August, ranging from 5.1-5.9 ug/L. Selenium concentrations in Peters ponds were below the standard during May because of dilution from snowmelt derived high in stream flows in the Gunnison River during the spring (Figure 9).

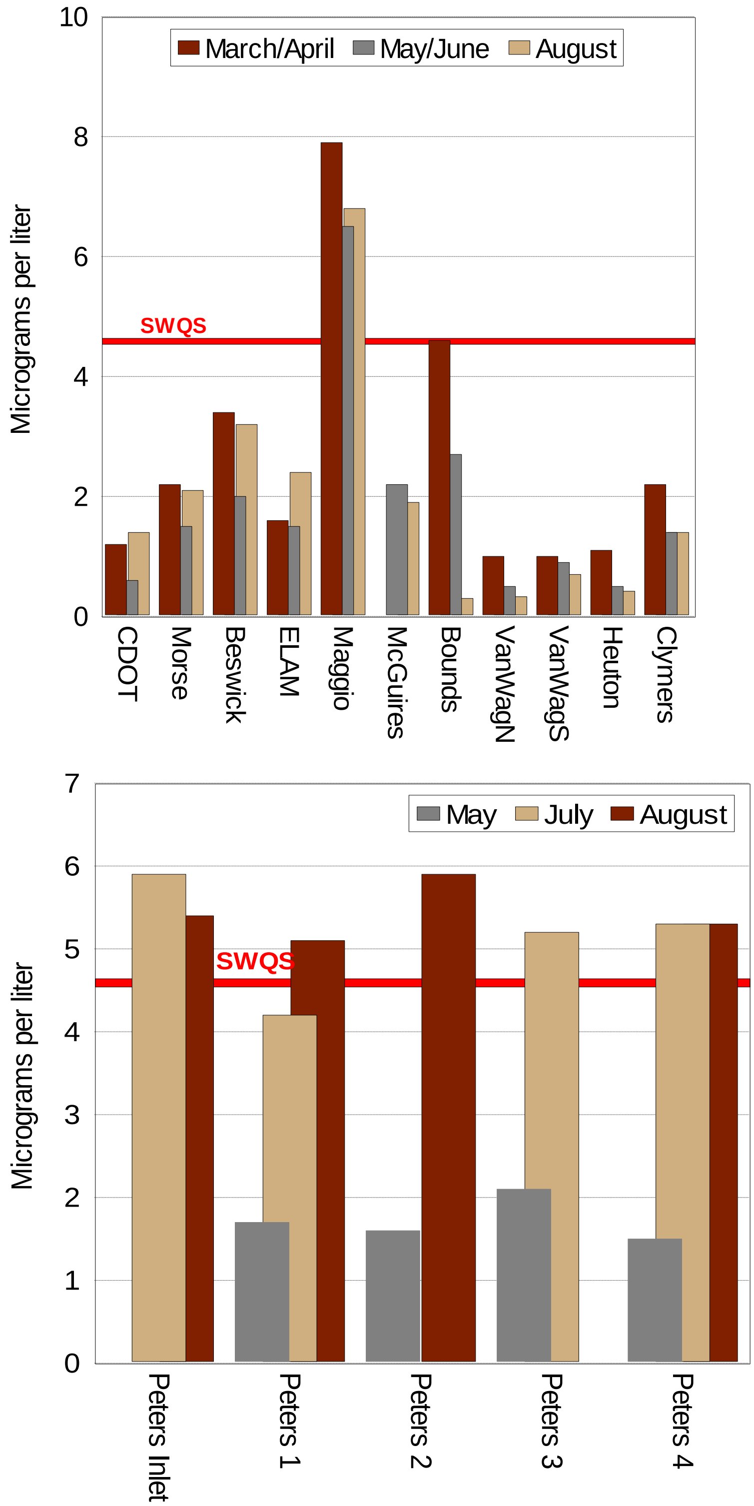


Figure 9. Selenium concentrations (µg/L) in water samples from grow-out ponds during 2005. SWQS=State Water Quality Standard.

There was a significant correlation between concentrations of nitrite and nitrate and selenium in the water (r^2=0.33, $p<0.001$). This correlation has been found in other studies (Butler et al. 1996; Hamilton et al. 2002a, Wright 1999), and reflects the nature of irrigation drain-water in the Grand Valley. Also, there were weak but significant correlations between water concentrations of selenium and sulfate (r^2=0.24, $p\leq0.001$), selenium and calcium (r^2 =0.22, p=0.002), selenium and magnesium (r^2=0.17, p=0.005), and total dissolved solids (TDS) (r^2=0.18, p=0.006). These correlations suggest that there may be a link between the selenium content of these waters (or sediment) and these other minerals that contribute to water hardness.

Sediment Results

Metal concentrations found in bottom sediment samples collected from razorback sucker grow-out ponds during July, 2005 are in Appendix 6. Promulgated criteria for sediment quality similar to water quality are generally not available. For the purposes of this report, trace element concentrations in sediment samples were compared to those found in soil data from the western U.S., as presented in Shacklette and Boerngen (1984). Also, the National Oceanic and Atmospheric Administration's (NOAA) Office of Response and Restoration has produced a set of reference tables allowing sediment metal concentrations to be compared against published sediment quality benchmarks (Buchman 2008). These tables present a spectrum of sediment metal concentrations, which have been associated with various probabilities of adverse biological effects. The threshold effects level (TEL) represents the concentration below which adverse effects are expected to occur only rarely, and the probable effects level (PEL) is the level above which adverse effects are frequently expected. The upper effects threshold (UET) relates chemical concentrations to synoptic biological indicators of injury (Buchman 2008). Freshwater TEL/PELs are based on benthic community metrics and toxicity test results (Buchman 2008). Also, Seiler et al. (2003) provided qualitative sediment guidelines that represent the upper 95^{th}-percentile values from data presented in Shacklette and Boerngen (1984). These reference values for metals in bottom sediment are provided in Table 3, along with the values which equal or exceed reference values.

Sediment concentrations were compared to these guidelines in Table 3. After comparison to these sources, the following trace elements were found to be elevated in some grow-out pond sediment samples: lead (4 ponds), molybdenum (2 ponds), manganese (1 pond), arsenic (2 ponds), cadmium (5 ponds), zinc (1 pond), and selenium (3 ponds). Buchman (2008) listed 35 µg/g dry weight (ppm) lead as a TEL and 91.3 as a PEL. Lead concentrations fell between these two guidelines in McGuire pond (49.4 and 54.9 µg/g), Beswick pond (36-41.3 µg/g), Bounds pond (43.7-56.8 µg/g), and in one sample exceeded the PEL in Van Wagner N pond at 100 µg/g. Buchman (2008) listed the sediment arsenic TEL at 5.9 µg/g and the PEL at 17 µg/g. Arsenic concentrations in sediment samples from Bounds pond were 10.2-14.8 µg/g, and from Van Wagner S pond were 7.85-15.2 µg/g. The cadmium TEL was listed as 0.596 µg/g and the PEL was 3.53 µg/g. One VanWagner N pond sediment sample contained the highest cadmium concentration at 1.99 µg/g. Cadmium concentrations in sediment samples from Van Wagner S, McGuire, Elam, Bounds, and Beswick ponds fell between the TEL and PEL listed for cadmium.

Buchman (2008) listed a UET for manganese at 1,100 µg/g related to infaunal community impacts. The manganese concentration in sediment samples collected from McGuire pond were at the UET level, and ranged from 1070 to 1140 µg/g. The qualitative guidelines for molybdenum and zinc provided in Seiler et al. (2003) were 4 µg/g and 180 µg/g, respectively. Molybdenum concentrations in sediment samples from Maggio pond (12.5-13.8 µg/g) and McGuire pond (11.8-12.2 µg/g) exceeded the qualitative guideline, as did the zinc concentration in one sample taken from Van Wagner N pond, at 181 µg/g. Lemly (2002) suggested that a concentration of 2 µg/g selenium in sediments should be considered a maximum allowable selenium concentration to protect fish and wildlife reproduction. This selenium guideline was exceeded at Maggio (4.9-5.99 µg/g), Clymers (5.74-6.27 µg/g) and Van Wagner S (3.11-3.6 µg/g) ponds (Figure 10). Selenium and strontium sediment concentrations were highly correlated (r^2=0.68, p=<0.001), and cadmium sediment concentrations were highly correlated with lead (r^2=0.89, p=<0.001) and zinc (r^2=0.88, p=<0.001). These correlations are most likely reflective

Table 3. Reference values for inorganics in bottom sediments.

Elements	TEL[1]	Sites in between TEL and PEL	PEL[1]	Sites in between PEL and UET	UET[1]	Sites over UET	QSG[2]	Sites over QSG	Lemly (1996) GL[3]	Sites over Lemly GL
As	5.9	Bound, Van Wagner S.	17		17.0		22.0			
Cd	0.596	Van Wagner S, McGuire, Elam, Bound, Beswick	3.53		3.0		---			
Cr	37.3		90.0		95.0		200.0			
Cu	28.0		35.7		197.0		90.0			
Mn	---		---		1100.0	McGuire	---			
Mo	---		---		---		4.0	Maggio, McGuire		
Ni	18.0		35.9		43.0		---			
Pb	35.0	McGuire, Beswick, Bound	91.3	Van Wagner N.	127.0		55.0			
Se	---		---		---		---		2.0	Maggio, Clymer, Van Wagner S.
Zn	123.0	Van Wagner N.	315.0		520.0		180.0			

[1]Buchman (2008), [2]Seiler et al. (2003), [3]Lemly (2002)

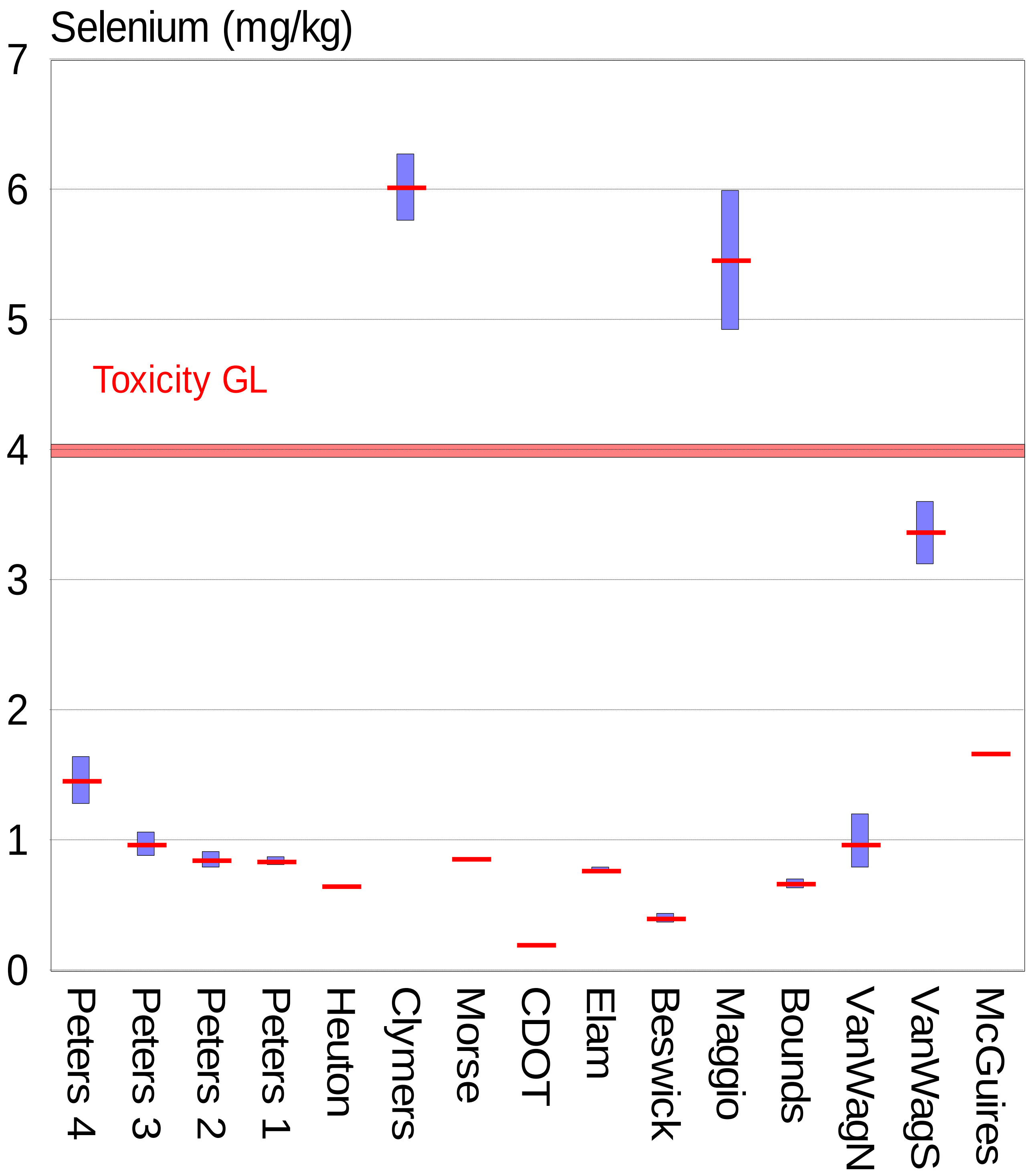


Figure 10. High, low, and mean selenium concentrations (mg/kg) in sediment samples from grow-out ponds during 2005. Toxicity guideline of 4 mg/kg from Lemly (2002).

of the underlying geology at particular ponds, but demonstrate that any potential exposures are from metal combinations. It is unknown if metals are affecting invertebrate populations.

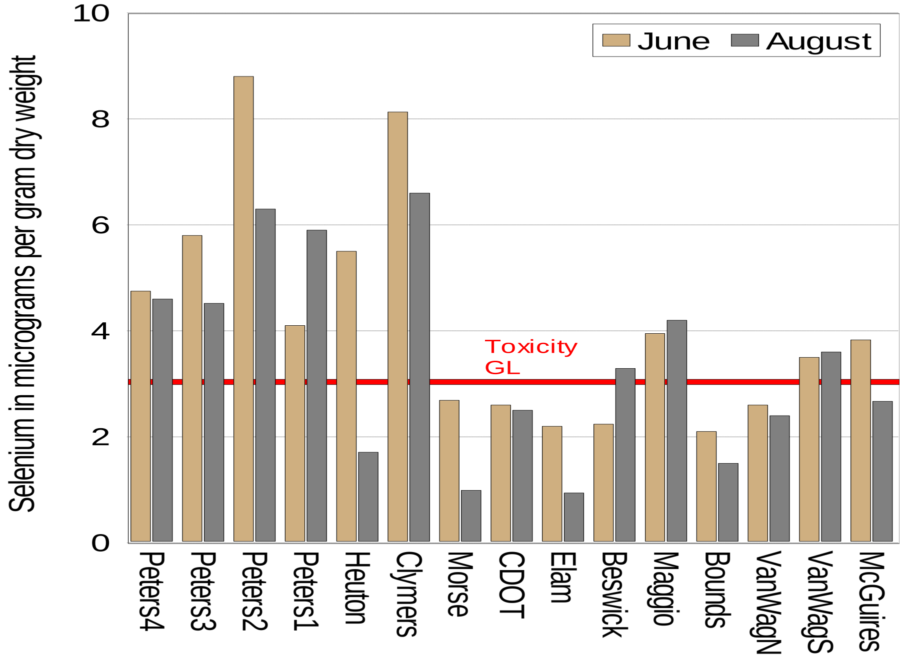
Invertebrate Results

Trace Element Concentrations in Zooplankton and Benthic Invertebrates

Wydoski and Wick (1998) reported that zooplankton and benthic invertebrates are eaten by all life stages of razorback suckers. Trace element concentrations found in zooplankton and benthic invertebrate samples are displayed in Appendix 7. In general, there was a lack of information connecting specific trace element concentrations in dietary items to negative effects in fish. Relatively elevated zinc concentrations were found in the sample set in a few zooplankton samples from Peters ponds. And relatively elevated concentrations of chromium were found in a few zooplankton and benthic invertebrate samples from various ponds (Appendix 7). These outliers are unexplained and may be artifacts of field sampling. Chromium was not measured in water, and concentrations were at background in sediment samples. Zinc concentrations in all grow-out ponds were below Colorado water quality standards, and at background concentrations in sediment samples, with the exception of one elevated zinc sediment sample collected from Van Wagner N pond. Chromium concentrations in zooplankton samples were highly correlated with nickel and molybdenum, which could be indicative of sample contamination in the field (all laboratory quality assurance/quality control was acceptable). Occasionally, there was a problem with pond water levels rising overnight and submerging zooplankton light traps, exposing the flashlight and 6-volt battery to pond water. Submerged batteries may have leaked metals and exposed zooplankton caught in submerged light traps to locally elevated metal concentrations. In chromium elevated zooplankton samples, concentrations of iron and aluminum were also relatively high as well. Elevated chromium, iron, and aluminum could also be indicative of sediment particles attached to zooplankton. The fact that chromium was found in benthic invertebrate samples as well as zooplankton samples suggests that is present in some grow-out ponds, and is incorporated into invertebrate tissue. There is still little known about the relation between concentrations of total chromium in a given environment and biological effects on the organisms living there (Eisler 2000).

Dietary exposure has been identified as the primary pathway of selenium bioaccumulation (Lemly 1996b; Maier and Knight 1994, Ohlendorf 2002). Data results from samples collected previously suggest that selenium concentrations in zooplankton may double in ponds during mid-to-late summer, responding to evapo-transpiration losses and increased selenium concentrations in water (Seiler 1998). Selenium concentrations in 17 out of 30 zooplankton samples exceeded the recommended dietary toxicity guideline of 3 µg/g DW for the protection of reproductive health in fish and wildlife (Lemly 1996b & 2002) (Figure 11a). These selenium concentrations also exceeded the dietary threshold of 4.6 ug/g DW in food found by Hamilton et al. (2005) to cause mortality in razorback sucker larvae. Selenium concentrations in zooplankton samples collected during June and August, 2005, in Peters 1-4, Clymers, Maggio, and Van Wagner S ponds were above the 3 µg/g toxicity guideline. Selenium concentrations in zooplankton were also elevated above the toxicity guideline during June in McGuire pond and during August in Beswick pond. Grow-out ponds have shallow, standing or slow-moving waters that have low flushing rates and are conducive to selenium bioaccumulation. In these systems, biological productivity is often high and selenium may be trapped through immobilization processes or through direct uptake by aquatic organisms (Lemly and Smith 1987). Ogle and Knight. (1996) found that at selenate concentrations greater than 5 ug/L, selenium uptake by daphnids was inversely related to waterborne sulfate concentrations. Maggio pond had both high selenium and sulfate water concentrations, and high selenium in zooplankton samples. There also may be a time-lag as selenium is bioaccumulated from water through intermediate trophic levels to aquatic invertebrates and fish (Beckon & Schwarzback 2001).

a.



b.

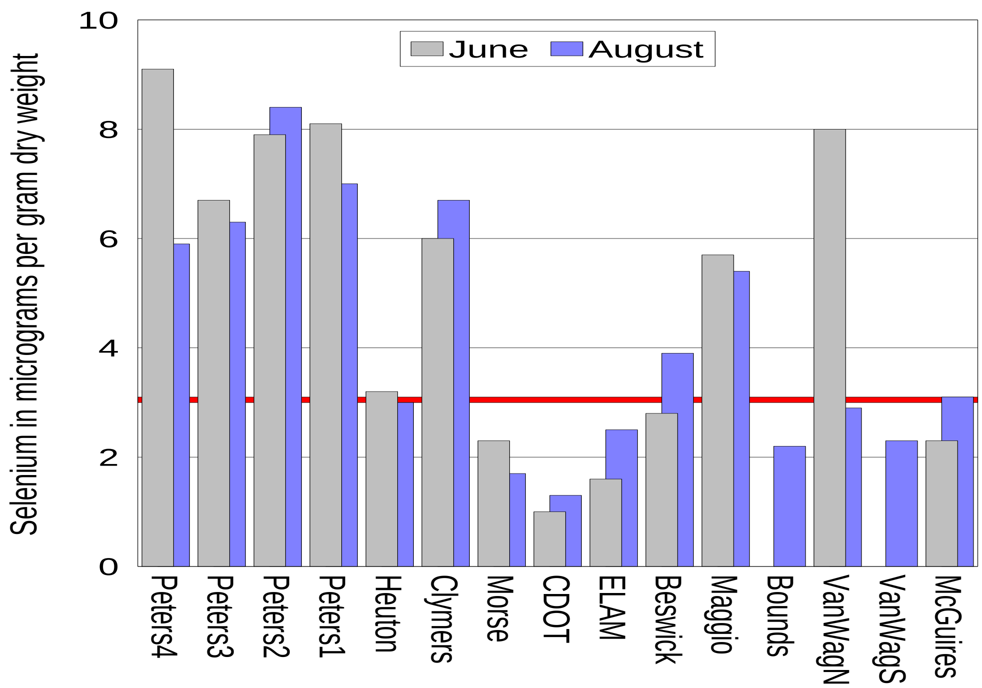


Figure 11 Selenium concentrations (µg/g dry weight) in composite (a) zooplankton and (b) benthic invertebrate samples from razorback sucker grow-out ponds during 2005. Toxicity guideline of 3 ug/g DW from Lemly (1996).

Selenium concentrations in benthic invertebrates were also above the 3 µg/g toxicity guideline (Lemly 1996 and 2002) during June and August in Peters 1-4, Clymers, and Maggio ponds (Figure 11b), and also above the dietary threshold of 4.6 ug/g DW in food found by Hamilton et al. (2005) to cause mortality in razorback sucker larvae. Selenium was elevated in benthic invertebrate samples collected during June in Heuton and Van Wagner N ponds, and during August in Beswick and McGuire ponds. Malloy *et al.* (1999) found small-scale spatial variability in selenium accumulation in chironomid larvae, which they attributed to variability in concentration and bioavailability of selenium in sediment and perhaps the ages of larvae. Grain size and organic carbon content can influence sediment selenium concentrations and bioavailability. Risk of selenium exposure through the detrital food pathway can continue despite a loss from the water column, as long as contaminated sediments are present.

<u>Invertebrate Biomass</u>

Zooplankton & Water Column Invertebrates

Along with zooplankton, some very small macro invertebrates such as corixidae nymphs and Chironomidae larvae were able to swim through the 1 mm mesh in the light traps, and were included in the samples. These small invertebrates along with zooplankton were considered to be available food items to razorback suckers (USFWS 2000b). Zooplankton biomass (grams, dry weight) was considerably higher at Peters 1-4 ponds compared to other razorback sucker grow-out ponds (Appendix 7, Figure 12a). For example, during June, zooplankton samples from Peters 1-4 ponds contained over 200 g of biomass, compared to other ponds with <100 g of biomass. In general, zooplankton biomass was somewhat higher during June as compared to August. In contrast, CDOT pond had higher zooplankton biomass during August compared to June. Zooplankton biomass at Peters 1-4 ponds was primarily composed of cladocerans and copepods. Zooplankton samples from other ponds such as Beswick, Elam, Morse, Bounds, and CDOT also contained the insects water boatmen and backswimmer nymphs (corixidae and notonectidae), water mites (*Hydracarina spp*.), and very small damselfly nymphs. These invertebrates could also be potential food items to razorback suckers. Van Wagner N contained very small fish larvae. Salinities at Maggio and Bounds ponds reached the acute toxicity threshold of 6,000-10,000 mg/L for *Dapnia magna* (Cladocera), and were at the level of concern for the midge *Chironomus utahensis* (USDOI 1998). Salinity has been shown to be a limiting factor for invertebrate production. In grow-out ponds, there was a weak but significant correlation between TDS and zooplankton biomass (r^2=0.28, p=0.003). There was also a significant correlation between inorganic nitrogen and zooplankton biomass (r^2=0.26, p=0.005). Interestingly, there was no correlation between chlorophyll-a and zooplankton biomass, which was surprising, as phytoplankton are considered dietary items for zooplankton. However, Pennak (1989) noted that “algae and protozoa have often been assumed to be the chief foods of Cladocera, to the exclusion of other materials, but it is now well known that organic detritus of all kinds, as well as bacteria, are very important and commonly form the greatest bulk material ingested.” According to Pennak (1989), copepods and cladocerans eat similar material. During 2005, as in most years, razorback suckers were provided with supplemental food pellets in all Peter ponds throughout the growing season (R. Smaniotto, personal communication). Most likely, these food pellets were also providing a nutrient resource for the rich zooplankton growth in Peters ponds. The “Silvercup food pellets fed to razorback suckers in Peters 1-4 ponds only contained 0.05 mg/kg selenium (B.Scheer, pers. Comm.. 2006).

There was also a high incidence of razorback suckers in Peter ponds infested with the parasite copepod anchorworm (Lernaea spp.). The nauplii of Lernaea are free-living plankters and thus provide a food source in their immature stage to razorback suckers. Pennak (1989) suggested that under natural environmental conditions, parasitic copepods are rarely present in sufficient numbers to cause serious injury to the host fish. However, in hatchery ponds such as Peters ponds, fish are crowded in a confined area, providing a much greater opportunity for parasites to find fish hosts (Pennak 1989). The excess nutrients from food pellets may also contribute to

a.

b.

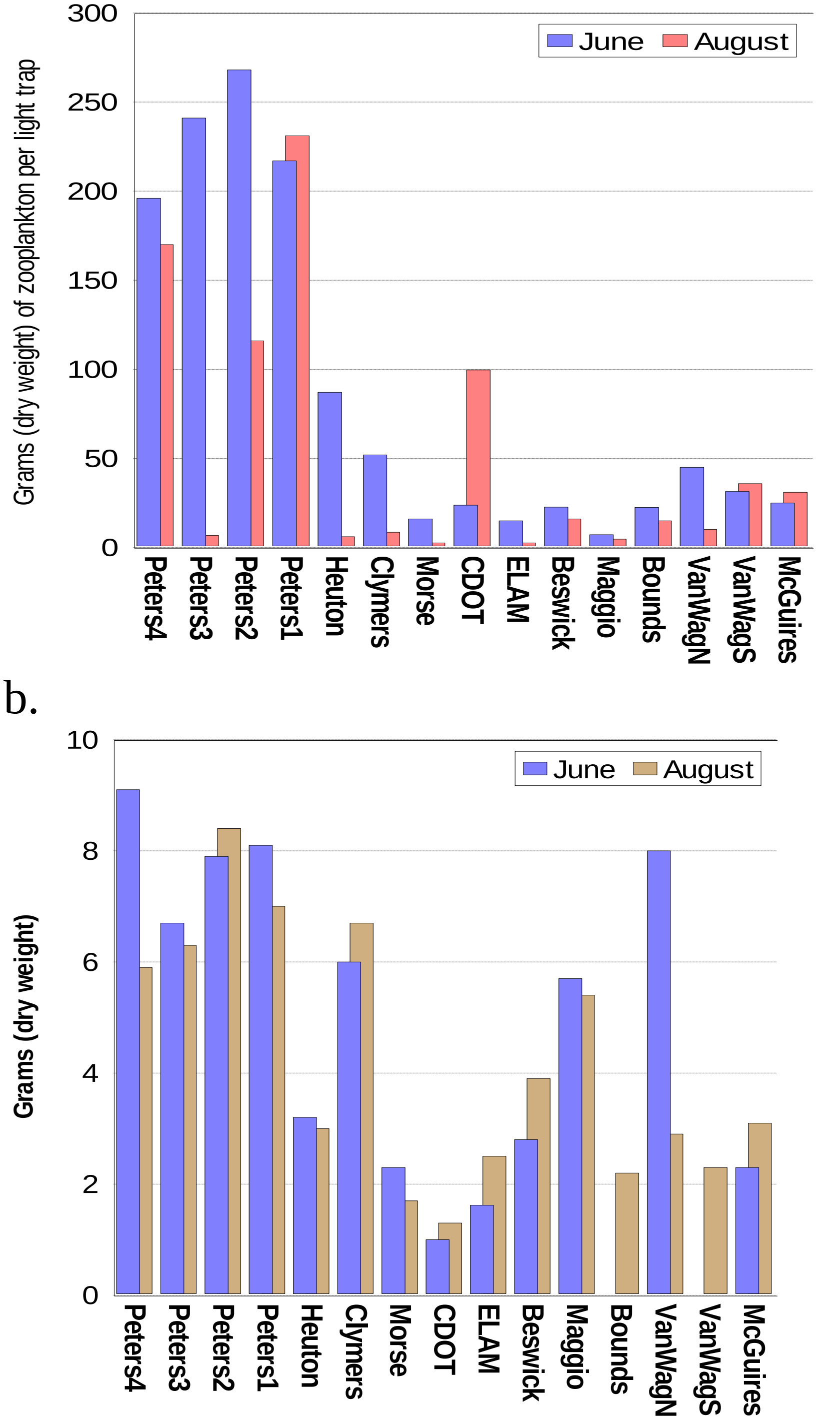


Figure 12. Biomass of zooplankton (a) and benthic invertebrates (b) in

razorback sucker grow-out ponds in 2005.

conditions that favor these parasites. The concerns with Lernaea infestations are blood loss, the risk of acquiring secondary infections from bacteria, fungus, and viral agents, and spreading the parasites to fish in the river upon release. The drastic decrease in zooplankton biomass from June to August in Peters 3 pond is unexplained. Zooplankton biomass also dropped in Peters 2 pond during August to approximately half of what it had been during June. Pennak (1989) noted that pronounced seasonal fluctuations in zooplankton biomass was fairly typical in ponds. Peters 1-4 ponds were treated with 2 ½ % Rodeo for cattail control on 7/14/05 (C. Shannon, Western Colorado Wildlife Habitat Association, personal communication 2006). It was possible that these applications could have reduced zooplankton biomass, although all Peters ponds would have most likely experienced a reduction if herbicide application were the cause of lowered productivity.

Benthic Invertebrates

Benthic invertebrates also seemed to be more numerous at Peters 1-4 ponds (Appendix 6, Figure 12b), followed by Clymer, Maggio, and Van Wagner N ponds. An attempt was made to collect at least a 2 gram sample, and catch per unit effort varied considerable between ponds. Benthic invertebrates consisted mainly of dragonfly (Anisoptera) and damselfly (Zygoptera) nymphs. The high zooplankton and macroinvertebrate densities in the Peters ponds most likely provided a rich food supply for the predaceous dragonfly and damselfly nymphs, as did the supplemental fish feed pellets. Some benthic invertebrate samples also contained mayfly nymphs (Baetidae), amphipods, and midges (Chironomus sp.).

Razorback Sucker Muscle Plug Selenium Results

Accuracy and precision of the neutron activation method were estimated from MURR's own internal quality control. MURR conducted accuracy and method precision check by replicate analyses of NIST Bovine Liver SRM 1577. Results for these analyses are in Table 4. Recovery

Table 4. Results from MURR internal quality control samples.

Year	Material	Certified Range	Weight (g)	Se ug/g	Mean	% Rec	SD	%RSD
2004	NIST 1577a	1.1+/-0.1	0.04769	1.04				
			0.04768	1.07				
			0.04765	1.10				
			0.04772	1.07				
			0.04772	1.03				
			0.04769	1.02				
			0.04772	1.09				
			0.04769	1.12	1.07	100	0.0349	3.3
2005	NIST 1577a	1.1+/-0.1	0.04768	1.15				
			0.04772	1.11				
			0.04772	1.11				
			0.04772	1.10				
			0.04772	1.08				
			0.04766	1.12				
			0.04772	1.14				
			0.04771	1.15				
			0.04772	1.15				
			0.04772	1.21				
			0.04768	1.17				
			0.04768	1.13	1.13	100	0.0336	3

a NIST 1577=National Institute of Standards and Technology Standard Reference Material 1577: Bovine Liver

of selenium from the reference materials analyzed with the samples was excellent, with all results except one being within the certified range values; the one exception (1.21 µg/g) was just outside the upper limit of the certified range (1.20 µg/g). Method precision on the MURR replicate 1577 analyses was 3.3% relative standard deviation for the 2004 sample analysis, and 3.0% for the 2005 sample analysis. The estimated method detection limit for selenium, based on a fish muscle matrix and the dry sample weights submitted, ranged from 0.03 to 0.1 µg/g for 2004 samples, and was 0.05 µg/g for 2005 samples. All quality control results for the study were considered within acceptable limits as specified by CERC.

Hatchery

Selenium concentrations in muscle plugs collected from 20 randomly chosen razorback suckers in the hatchery ranged from 0.69-0.93 ug/g DW (Appendix 8), and are well below the reproductive impairment benchmark of 8 ug/g DW suggested by Lemly (1996) as a toxicity guideline. Thus, razorback suckers in the hatchery did not accumulate high selenium concentrations in the hatchery facility, and these muscle plugs provided a good baseline for comparison to those collected from razorback suckers in grow-out ponds and the Colorado and Gunnison rivers (Figure 13).

Grow-out Ponds

Selenium concentrations in muscle plugs collected from razorback suckers held in grow-out ponds are in Appendix 8. Selenium concentrations in muscle plugs collected during 2004 and 2005 from recaptured razorback suckers that had been at large in the Colorado and Gunnison rivers for at least 8 months after stocking in previous years (Appendix 8). Mean selenium concentrations for all razorback sucker muscle plugs taken during 2005 are compared in Figure 13. Of concern are the high selenium concentrations in razorback suckers contained in Maggio pond. All muscle plugs from the ten razorback suckers collected from Maggio pond contained selenium concentrations that exceeded the 8 µg/g DW selenium toxicity guideline concentration in fish muscle tissue proposed by Lemly (1996b, 2002) as the benchmark for probable reproductive failure. Selenium concentrations in plugs taken from razorback suckers in Maggio pond ranged from 11.9 to 28.2 µg/g DW, and were 1 ½ to over 3 times the toxicity guideline concentration.

The selenium concentrations found in Maggio pond were similar to those found in other studies, where reproductive success was lowered because of selenium toxicity (Lemly 1985, Hermanutz et al. 1992), as well as those found by Hamilton (2001a & 2001b, 2002a) to be associated with the production of deformed larval razorback suckers. High selenium concentrations in muscle plugs corresponded with high selenium concentrations found in water, sediment and invertebrate

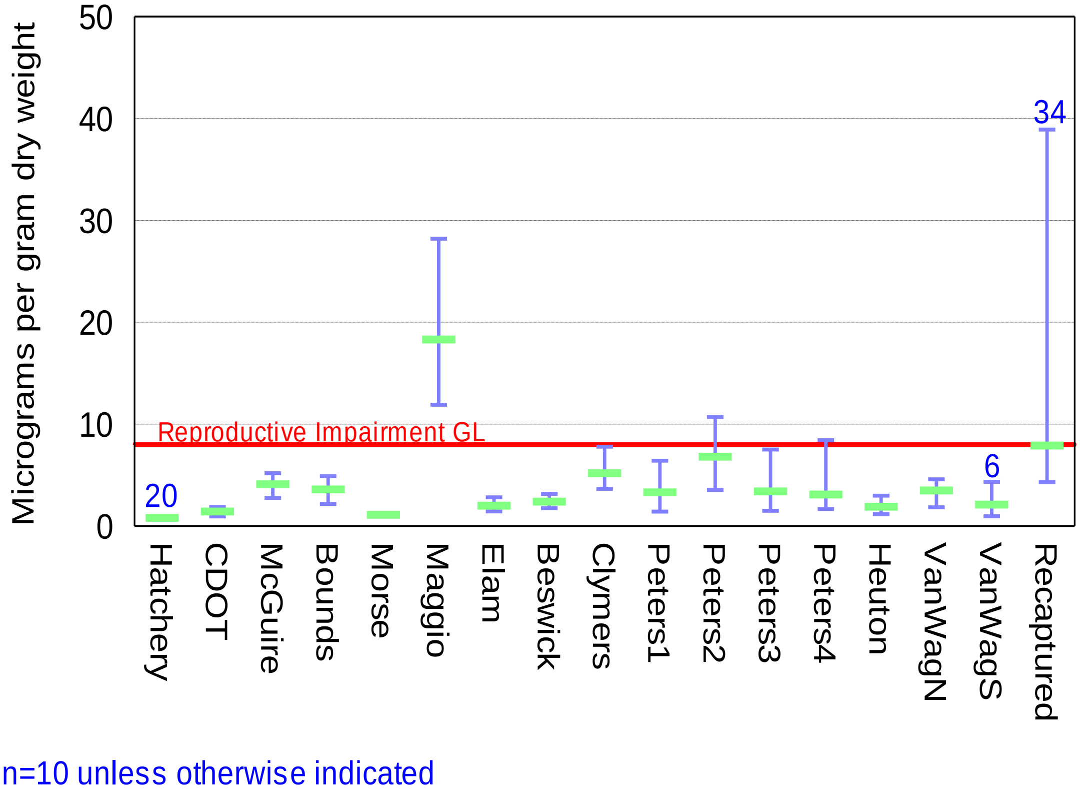


Figure 13. Comparison of high, low, and mean selenium concentrations (µg/g dry weight) in razorback sucker muscle plugs collected from the hatchery, grow-out ponds, and recaptured from the Colorado and Gunnison rivers during 2005. Reproductive impairment guideline of 8 ug/g DW from Lemly (1996).

samples collected in Maggio pond. The mean selenium concentration for ten muscle plugs collected from razorback suckers in Peters2 pond was 6.8 µg/g DW, and was approaching the 8 µg/g DW toxicity guideline. Three out of 10 razorback suckers collected in Peter 2 pond contained selenium in muscle plugs, which exceeded the toxicity guideline concentration. Additionally, one of 10 razorback sucker muscle plugs collected from Peters 4 pond exceeded the selenium toxicity guideline.

Some grow-out ponds are managed as multi-year ponds (Table 1), and razorback suckers were harvested for river stocking after occupying these ponds for more than 1 year. Maggio Pond, being particularly deep, has some older razorback suckers, which were not captured after the initial 6 month growing season, and thus remain until they are captured in subsequent years. Mean total lengths were greatest at McGuire, Bounds, and Maggio ponds which are considered multi-year ponds (Fig. 14). Along with high selenium concentrations found in prey items, high selenium concentrations in razorback suckers in Maggio pond could be partially attributed to fish staying in the pond for more than one growing season, which increased the exposure time for bioaccumulation of high selenium dietary items. When selenium concentrations in muscle plugs (transformed Ln (X+1)) collected from razorback suckers taken from Maggio pond were regressed against total length of these fish, a significant relationship was found (R^2=0.46, p=0.03). However, no significant relationship between selenium in muscle plugs and fish total length was found for either McGuire pond (p=0.09) or Bounds pond (p=0.58).

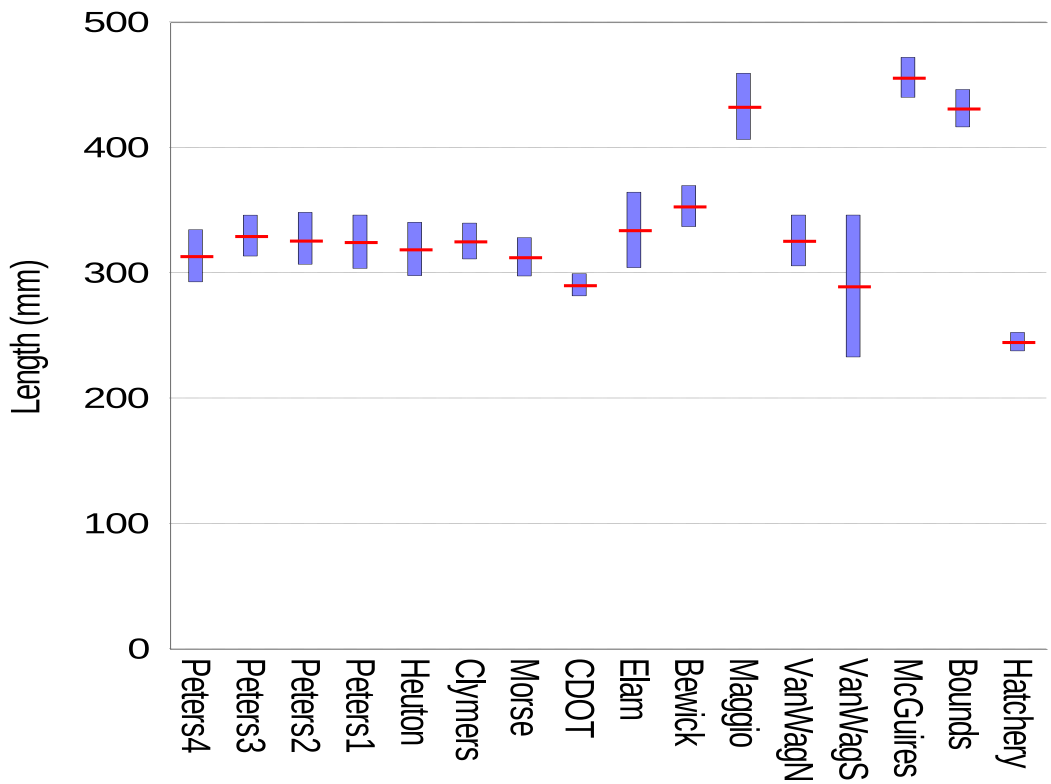


Figure 14. Mean length (and 95% CI's) of razorback suckers harvested from grow-out ponds in 2005 (n=10, VanWagS n=6).

Stocked and Recaptured Razorback Suckers

Razorback suckers previously stocked in the Colorado and Gunnison Rivers were recaptured in 2004 and 2005, after they had been at large for at least 8 months. The goal was to use muscle plug selenium concentrations in recaptured razorback suckers to determine bioaccumulation occurring in designated critical habitat. Razorback suckers were all PIT-tagged before release into the river, to allow researchers to evaluate survival and growth. Thus, for each endangered fish captured and biopsied in the Colorado and Gunnison rivers, there is usually a way to identify individual fish and look up associated history information. Razorback sucker pit tag numbers can reveal stocking location, grow-out pond history, and release date into the rivers. The mean selenium concentration in 2005 samples was 7.9 µg/g DW (n=34) (Figure 13). Of these 34 muscle plugs, 11 had selenium concentrations exceeding the 8 µg/g DW toxicity guideline (Appendix 9). Four of the 11 exceedences were from razorback suckers that had been previously raised in Maggio pond (Figure 15). These four fish contained 8.5, 15.2, 18.1, and 27.1 µg/g DW selenium, and were three of the highest selenium concentrations found in recaptured razorback suckers (Appendix 9). Twelve of the recaptured razorback suckers had been raised in Clymers Pond, and the mean selenium concentration for those recaptured in 2005 was 7.9 µg/g DW; near the toxicity guideline (Appendix 9, Figure 15). Four out of eight of the razorback suckers captured in 2005 and contained in Clymers pond contained selenium concentrations above the toxicity guideline. One razorback sucker exceeding the toxicity guideline had been previously held in Adobe Creek (a tertiary channel of the Colorado River) and exposed to high selenium concentrations during Hamilton's studies (Hamilton et al. 2001a & 2001b) (Figure 15). Another razorback sucker exceeding the toxicity guideline had been raised in Peters 4 pond. After stocking, it seemed that these recaptured razorback suckers most likely retained high selenium residues acquired from the grow-out ponds in their muscle tissue (Figure 15). Osmundson et al. (2000) found that Colorado pikeminnow recaptured from the Colorado River over a 2 or 3-year period also conserved selenium concentrations in muscle plugs from year to year. Hamilton et al. (2001b) found the half-life of selenium depuration in razorback suckers to be greater than 100 days. As Hamilton (2005) noted, depuration of selenium from tissue depends on selenium

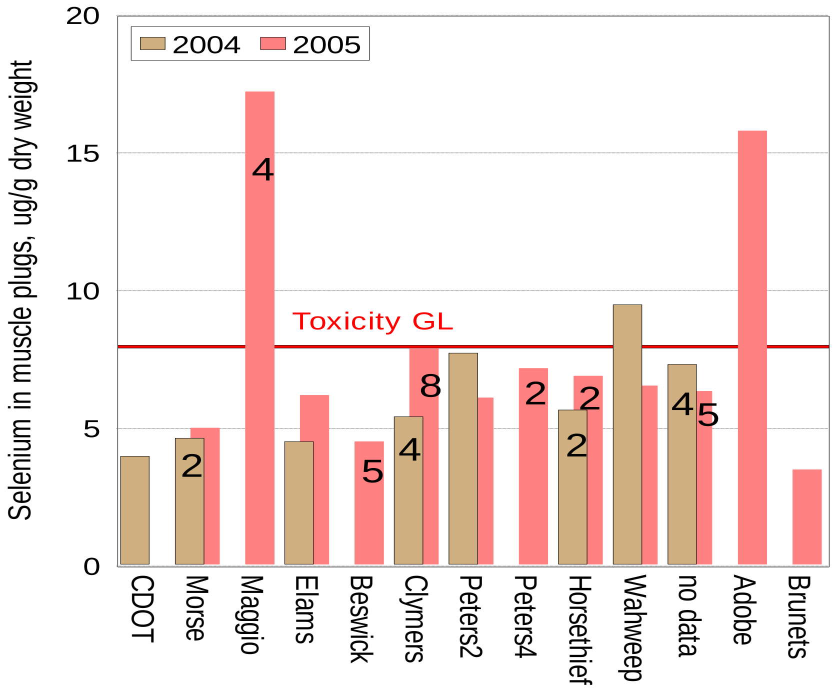


Figure 15. Mean selenium concentration (µg/g dry weight) in muscle plugs from recaptured razorback suckers in the Colorado and Gunnison rivers during 2005 at least 8 months after initial stocking (numbers in bars equal sample size; bars with no numbers represent one fish).

concentrations in the depurating environment, age, size, metabolic activity, season for poikilotherms, initial selenium load of various tissues, and other factors. It is also possible that these razorback suckers were selectively occupying high selenium habitats within the Colorado and Gunnison river systems. One razorback sucker with selenium above the toxicity guideline had been raised at Wahweep National Fish Hatchery, but had been at large since 1977 (Appendix 8), and probably accumulated selenium from the rivers. Razorback suckers historically used backwater and flooded bottomland sites that have been documented to contain high selenium concentrations (Hamilton 1999, Hamilton et al. 2004, Butler et al. 1996). Associated with the high selenium residues in these razorback suckers is the likelihood of impaired reproductive success.

Comparison of razorback suckers to other native suckers and to Colorado pikeminnow

Other native suckers

Selenium concentrations found in muscle plugs taken from other sucker species collected from the Colorado and Gunnison rivers in the Grand Valley are displayed in Appendix 10. Razorback suckers accumulate significantly higher selenium concentrations than native bluehead suckers (*Catostomus discobolus*) (unpaired t-test, $p<0.001$) and native flannelmouth suckers (*Catostomus latipinnis*) ($p=0.001$) (Figure 16). This most likely is due to habitat and diet differences between the sucker species, and possibly metabolic differences. Bluehead suckers select riffle areas with fast-moving water, and scrap algae and other nutrients (including invertebrates) from rocks in the river (McAda 1977). Flannelmouth suckers are found in several habitats in the river, including riffles, runs, eddies, and backwaters (Woodling 1985). They are opportunistic bottom-feeders, and consume a diversity of invertebrate prey items, depending on what is available. Razorback

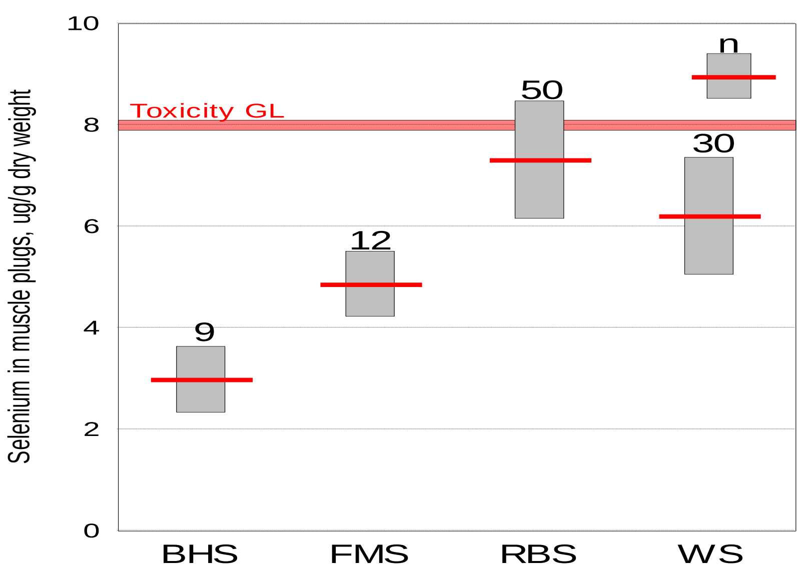


Figure 16. Mean (and 95% CI's) selenium concentration (µg/g dry weight) in native and non-native sucker species captured in the Grand Valley from 2002-2005 (BHS=bluehead, FMS=flannelmouth, RBS=razorback, and WS=white suckers).

suckers occupy higher selenium sites, such as flooded bottomlands and backwater habitats, where invertebrates accumulate high selenium residues (Lemly 1985, Butler et al.1996, Hamilton 1999, Hamilton et al. 2004, McAda 1977, Butler & Osmundson, 2003). This selenium accumulation in razorback muscle tissue suggested that razorback suckers were at higher risk for adverse impacts associated with selenium toxicity compared to other native suckers. White suckers (*Catastomus commersoni*) are a nonnative species to the Colorado and Gunnison rivers (Woodling, 1985). They occupy pools and runs, and are also bottom-feeders, consuming invertebrates plus incidental detritus and plant material (Woodling 1985). Although not significantly lower (unpaired t-test, $p=0.077$), it seems they also contain less selenium residues than razorback suckers (Figure 16). A significant difference in selenium concentrations between razorback suckers and white suckers may not have been detected because most of the razorback suckers were collected from the Colorado River, which has relatively lower water selenium concentrations, and most of the white suckers were collected from the Gunnison River. It is interesting that pre-spawning white suckers captured from the Gunnison River had significantly higher selenium concentrations than those in a post-breeding condition collected in Colorado River water from the Grand Valley canal ($p<0.001$). This is not surprising, as these suckers release thousands of eggs, so a reduction of selenium in their body burden by release of eggs might be expected. As discussed previously, higher selenium concentrations in white suckers from the Gunnison River corresponds to higher water selenium concentrations in the Gunnison River. Furthermore, spawning activity would have reduced whole-body selenium concentrations in white suckers collected from the Colorado River, because selenium is preferentially deposited in eggs, and once eggs are spawned, whole-body selenium residues would be reduced. This section of the Gunnison River between the confluence of the Uncompahgre and Gunnison rivers in Delta, Colorado and the confluence of Gunnison and Colorado rivers in Grand Junction, Colorado is listed on the Colorado state 303(d) list of impaired waters because of selenium contamination (CDPHE 2008a).

Colorado pikeminnow

Selenium concentrations found in wild Colorado pikeminnow captured from the Colorado and Gunnison rivers during 2004 and 2005 are listed in Appendix 10. Colorado pikeminnow are also pit-tagged whenever they are captured, to allow researchers to collect survival and growth data. Two out of 19 Colorado pikeminnow captured in 2004 and two out of 26 Colorado pikeminnow captured in 2005 had muscle plug selenium concentrations above the 8 µg/g DW guideline for fish muscle (Lemly 1996b, 2002). Egg selenium concentrations were estimated from muscle plug concentrations by using the least squares prediction model developed by Osmundson (2007), (Ln[Egg selenium]=0.68 + 0.71 * (Ln [Muscle plug selenium], where $r^2=0.73$, $p<0.0001$. Because contaminant concentrations are lognormally distributed (Ott 1990), least squares regression was performed on natural log-transformed data. Almost all of the estimated Colorado pikeminnow egg concentrations fall in the low hazard category, of 5-10 ug/g DW selenium.

However, a regression model specific to Colorado pikeminnow could improve the confidence of estimated selenium concentrations in eggs. Thus, there is still cause for concern with estimated Colorado pikeminnow egg concentrations approaching the Lemly (1996) toxicity threshold of 10 ug/g selenium DW in eggs and ovaries. Muscle plug selenium concentrations in razorback suckers and Colorado pikeminnow sampled during 2004 and 2005 are displayed in Figure 17. The mean selenium concentration of 7.9 ug/g DW in razorback sucker muscle plugs sampled during 2005 was close to the toxicity guideline concentration of 8 ug/g DW in muscle tissue (Lemly 1996), and was higher than the mean for razorback suckers sampled during 2004, and also the mean selenium concentrations in Colorado pikeminnow muscle plugs sampled in both 2004 and 2005.

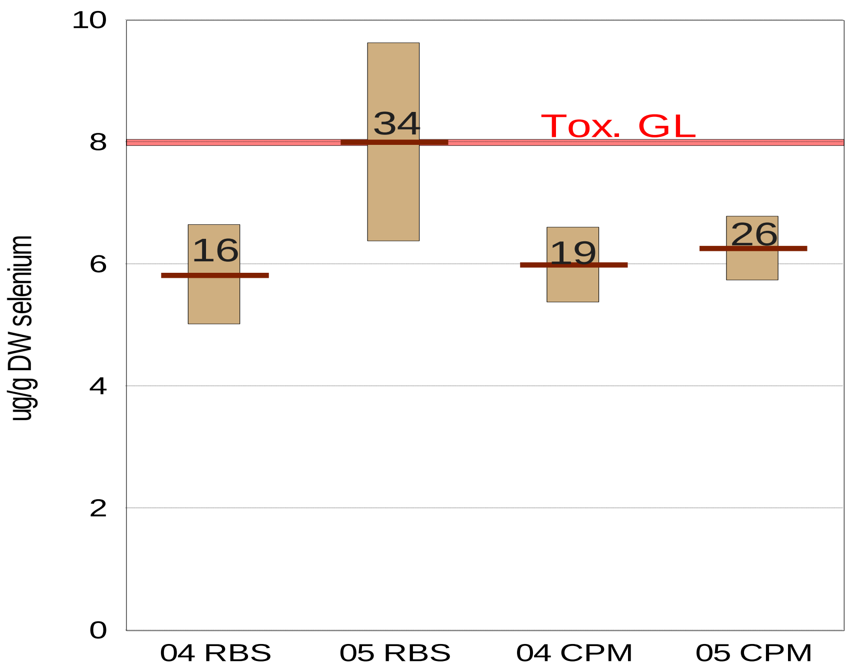


Figure 17. Mean selenium concentration (µg/g dry weight) (and 95% CI's) in razorback sucker (RBS) and Colorado pikeminnow (CPM) muscle plugs collected during 2004 and 2005.

Selenium Hazard Assessment

Lemly (1995) developed a protocol to assess aquatic hazard from selenium contamination. The protocol evaluates the potential of food-chain bioaccumulation and associated reproductive impairment in fish and aquatic birds. Lemly (1995) defined five categories of hazard in his protocol as follows: (1) High hazard denotes an "imminent, persistent toxic threat sufficient to cause complete reproductive failure in most species of fish and aquatic birds;" (2) Moderate hazard indicates "a persistent toxic threat of sufficient magnitude to substantially impair, but not eliminate reproductive success;" some species will be severely affected whereas others will not; (3) low hazard indicates some sensitive species will be marginally affected; (4) minimal hazard reflects slight contamination; (5) and no hazard denotes no toxic threat. Although Lemly (1995) developed his protocol to incorporate five ecosystem components, including water, sediment, benthic invertebrates, fish eggs, and bird eggs, he later modified the protocol for use where no bird eggs are available, and only four components are used to assess risk (Lemly 1996a). Ohlendorf (1997) also suggested using weighting factors to place emphasis on biotic components. Each component was given a score based on the degree of hazard, from one for no identifiable hazard to five for high hazard. The final hazard characterization was determined by adding individual scores and comparing the total to the following criteria (Ohlendorf 1997): ≤ 7 µg/g DW selenium, no hazard; 8-14, minimal hazard; 15-21, low hazard; 22-28, moderate hazard; and 29-35, high hazard.

Selenium concentrations in razorback sucker eggs were estimated from muscle plug concentrations. Selenium concentrations in muscle plugs taken from 19 razorback suckers and corresponding egg samples collected by Hamilton et al. (2001b) were used to develop a prediction model to estimate egg concentrations for this study. Egg concentrations were estimated for each razorback sucker, and mean egg selenium concentrations were calculated for each grow-out pond. Selenium concentrations were Ln-transformed to improve normality, and the regression yielded the following prediction model: Ln Egg= -0.2386 + 1.3466 * Ln MP (r^2=0.86, $p<0.001$, n=19). After conversion from muscle plug to egg concentrations, a mean egg selenium concentration was calculated for each grow-out pond, to incorporate into the hazard assessment protocol.

The hazard assessments for each grow-out pond are displayed in Appendix 12. Maggio pond had a high hazard rating of 35, which is a concern for rearing endangered fish. Also of concern was the moderate hazard rating for Clymer and Peter 2 ponds. The hazard rating for Peter 1, 3, and 4 ponds ranged from low to moderate, depending on water selenium concentrations, which were low during snow runoff, but high during the summer. Although unlikely, if razorback suckers in Peters ponds fed exclusively on the supplemental pellets (that contained minimal selenium), the dietary selenium hazard (invertebrates) (Appendix 12) would drop from high to none, and the resulting scores would drop from 10 to 2. This shift in scores would result in a lowered total hazard score of 8 points, placing all Peters ponds in the minimal risk category. Estimated selenium concentrations in razorback sucker eggs for fish recaptured from the Gunnison and Colorado rivers are displayed in Appendix 9. Lemly's (1995) hazard assessment considered hazard profiles in fish eggs to be: $\leq$ 3 µg/g DW selenium, no hazard; 3-5, minimal hazard; 5-10, low hazard; 10-20, moderate hazard; and >20, high hazard. Five razorback suckers recaptured from the Colorado and Gunnison rivers during 2004 (n=16) had estimated egg selenium concentrations at a moderate hazard rating; the rest were at a low hazard rating. Five recaptured razorback suckers recaptured during 2005 (n=34) had estimated egg selenium concentrations assessed at high hazard, and nine fish had estimated egg selenium concentrations assessed at moderate hazard.

Razorback Sucker Relative Body Condition

During harvest from grow-out ponds, total length and weight measurements were taken on razorback suckers to assess relative body condition after the growing season. Total length and weight measurements of razorback suckers were strongly correlated (least squares regression, $r^2=0.93$, $p<0.0001$). Body condition was assessed for each razorback sucker used for muscle plug analysis, and mean relative body condition of razorback suckers was calculated for each grow-out pond (Figure 18). Relative body condition of razorback suckers was highest in Peters 1-4 ponds compared to all other grow-out ponds. Peters 1-4 ponds also had the highest zooplankton and benthic invertebrate productivity, as well as supplemental feed pellets provided throughout the growing season. The razorback suckers in the middle two Peters ponds (2 & 3) had slightly lower relative body condition than the end ponds (Peters ponds 1 & 4). This difference between Peters ponds could possible be attributed to the drop in zooplankton biomass experienced by the middle ponds during August. Relative body condition in razorback suckers harvested from McGuire and Heuton ponds was also comparatively high. Beswick, Elam, Van Wagner S, and CDOT ponds had razorback suckers with the lowest relative body condition, as well as some of the lowest biomass of zooplankton and benthic invertebrates.

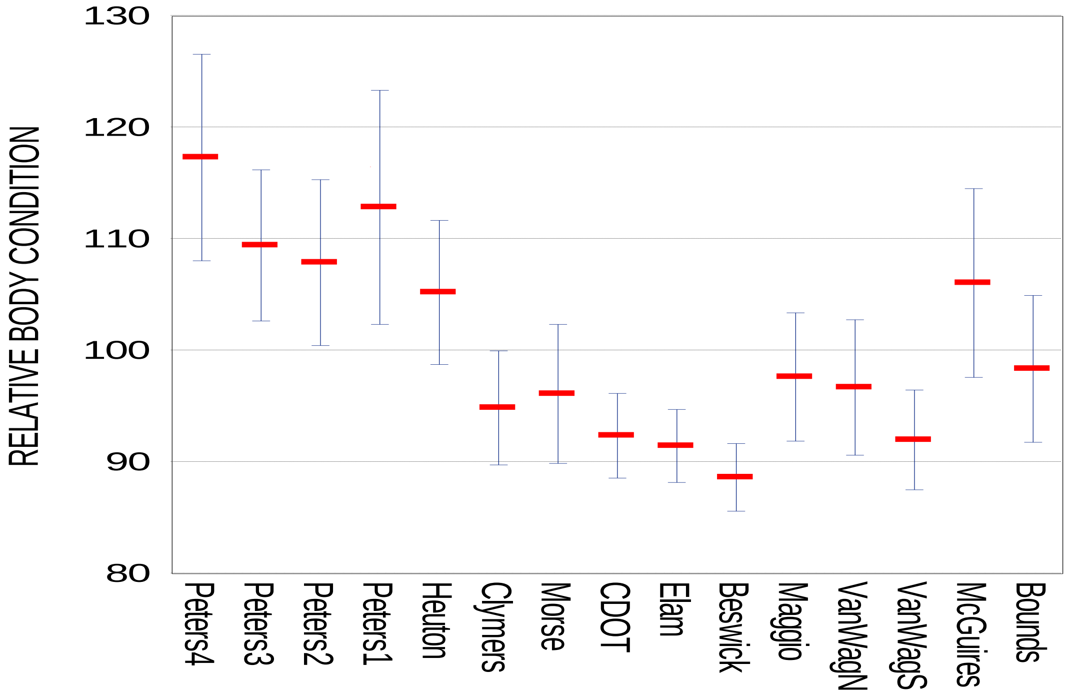


Figure 18. Mean, high, and low relative body condition of razorback suckers in grow-out ponds during 2005 (n=10, VanWagS n=6).

MANAGEMENT RECOMMENDATIONS

To evaluate the success of the stocking program, an investigation conducted from 1995-2001 monitored survival and performance of stocked razorback suckers in the Upper Colorado and Gunnison rivers (Burdick 2003). Results from this study suggest that the survival of the stocked fish in the wild was related to their size, with those over 200 mm in total length having the best survival. At least 2 years of growth are required to produce razorback suckers equal to or greater than 300 mm total length (Czapla 2002). This 2-year time period emphasizes the importance of having grow-out ponds as a necessary component of a successful propagation and stocking program.

We recommend discontinuing the use of Maggio pond as a grow-out pond for razorback suckers.

Razorback suckers accumulated selenium tissue concentrations which were in the high hazard category, and retained high selenium concentrations for at least eight months post-stocking to the Colorado and Gunnison Rivers. These selenium concentrations were high enough for us to expect lowered reproductive output upon release in the Colorado and Gunnison rivers (Hamilton et al. 2005, Lemly 1996b). Selenium concentrations were elevated in water, sediment, and biota in Maggio pond. The fact that Maggio pond is relatively large and deep, and receives groundwater inflow, would make remediation of this site for use as a grow-out pond problematic.

Razorback suckers also accumulated elevated selenium tissue concentrations above toxicity guidelines in Clymers Pond. This site is more amenable to remediation, because selenium was particularly elevated in the sediments, but not in the water. We recommend that Clymers pond be drained after fish harvest, and that selenium-laden sediment is either excavated or the pond lined with a synthetic liner. It may be possible to dry and flush pond sediments to reduce selenium concentrations (Naftz et al. 2005, Hamilton et al. 2004). Removal of the top sediment layers would most likely reduce selenium concentrations in sediment and biota.

Selenium concentrations were elevated in water from Peters 1-4 ponds; especially after snowmelt and associated runoff in the Gunnison River was complete. The fact that these ponds receive Gunnison River water, and thus have high selenium concentrations, and are used to rear endangered razorback suckers, reiterates the need for the continued existence and support of the Gunnison and Grand Valley selenium task forces, as they address remediation of the high selenium concentrations in the Colorado and Gunnison rivers and associated tributaries.

The Van Wagner N & S ponds experienced low dissolved oxygen problems from mid-to-late summer. Increased flow-through of water in these ponds would help flush nutrients, reduce high algae production, and provide more oxygenated water. Installation of aerators would be another management option. Dissolved oxygen should be monitored during mid-to-late summer in Van Wagner N & S, Heuton, and McGuire ponds on at least a weekly basis to identify timing of appropriate flushing. Lower productivity ponds could be improved by using fertilizers, or by providing feed supplementation to razorback suckers in these ponds.

Before any future acquisition of pond leases, a Lemly hazard assessment should be conducted with selenium concentrations determined for water, sediment, invertebrate, and fish samples. This approach would ensure that elevated selenium conditions would be avoided. If shallow ponds are acquired, there needs to be a flow-through system, to avoid low dissolved oxygen problems and resulting fish kills in mid-to-late summer. It is important to get landowner agreement to not apply fertilizers such as urea and pesticides on adjacent land where surface water can drain into the grow-out ponds, as application of chemicals may result in fish kills. It would be desirable to eventually replace leased ponds with new ponds created on government property, where there is more control over pond conditions, source water, and water quality.

REFERENCES

American Public Health Association. 1998. Standard methods for the examination of water and wastewater (20th ed.); Washington, DC, American Public Health Association, American Water Works Association, and Water Environment Federation, pages 3-37 - 3-43.

Arar, E.J., and G.B. Collins. 1997. U. S. Environmental Protection Agency Method 445.0, In vitro determination of chlorophyll a and pheophytin a in marine and freshwater algae by fluorescence, Revision 1.2: Cincinnati, Ohio, U.S. Environmental Protection Agency, National Exposure Research Laboratory, Office of Research and Development.

Bauch, N.J. and M. Malick. 2003. Limnology of Blue Mesa, Morrow Point, and Crystal Reservoirs, Curecanti National Recreation Area, during 1999, and a 25-year retrospective of nutrient conditions in Blue Mesa Reservoir, Colorado: U.S. Geological Survey Water-Resources Investigations Report 02-4199. 101 pages.

Beckon, W., and S. Schwarzbach. 2001. From Water to Wildlife: Lag Time in Selenium Bioaccumulation in a Temporally Variable, Flowing System. http://abstracts.co.allenpress.com/pweb/setac2001/document/?ID=35488.

Bennett. G.W. 1970. Management of Lakes and Ponds. Van Nostrand Reinhold Company. New York, N.Y. 375 pages.

Britton, L.J. and N.G.Gaggiani. 1987. Water-quality assessment of Arvada Reservoir, Denver metropolitan area, Colorado: U.S. Geological Survey Water-Resources Investigations Report 87-4107. 66 pages.

Buchman, M.F. 2008. NOAA Screening quick reference tables, NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle WA, Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, 34 pages.

Burdick, B.D. 2003. Monitoring and evaluating various sizes of domestic-reared razorback sucker stocked in the Upper Colorado and Gunnison rivers: 1995-2001. Final Report prepared for the Upper Colorado River Endangered Fish Recovery Program. Recovery Program Project Number 50. U.S. Fish and Wildlife Service, Colorado River Fisheries Project, Grand Junction, CO 54 pages + appendices.

Butler, D.L. and B.C. Osmundson. 2000. Physical, chemical, and biological data for the Uncompahgre Project Area and the Grand Valley, West-Central Colorado, 1993-98. Open-File Report 99-453. U.S. Geological Survey, Denver, CO. 216 pages.

Butler, D.L. and B.C. Osmundson. 2003. Selenium concentrations in food chain items for migratory aquatic birds and endangered Colorado River fishes occurring within critical habitat in the lower Gunnison and upper Colorado Rivers. Draft Report.

Butler, D.L, R.P. Krueger, B.C. Osmundson, A.L. Thompson, and S.K. McCall. 1991. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Gunnison and Uncompahgre River Basins and at Sweitzer Lake, West-Central Colorado, 1988-89. U.S. Geological Survey Open-File Report 91-4103. U.S. Geological Survey, Denver, CO. 99 pages.

Butler, D.L., W.G. Wright, D.A. Hahn, R.P. Krueger, and B.C. Osmundson. 1994. Physical, chemical, and biological data for detailed study of irrigation drainage in the Uncompahgre Project area and in the Grand Valley, west-central Colorado, 1991-92. U.S. Geological Survey Open-File Report 91-110. U.S. Geological Survey, Denver, CO. 146 pages.

Butler, D.L., W.G. Wright, K.C. Stewart, B.C. Osmundson, R.P. Krueger, and D.W. Crabtree. 1996. Detailed study of selenium and other constituents in water, bottom sediment, soil, alfalfa, and biota associated with irrigation drainage in the Uncompahgre Project area and in the Grand Valley, west-central Colorado, 1991-93. U.S. Geological Survey, Water Resources Investigations Report 96-4138. U.S. Geological Survey, Denver, CO. 136 pages.

Carlson, R.E. 1977. A trophic state index for lakes: Limnology and Oceanography,22(2): 361-369.

Carlson, R.E. 1992. Expanding the trophic state concept to identify non-nutrient limited lakes and reservoirs. pp. 59-71 IN Proceedings of a National Conference on Enhancing the States' Lake Management Programs. Monitoring and Lake Impact Assessment. Chicago.

Carlson, R.E. and J.Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8(3): 559-568.

CDPHE (Colorado Department of Public Health and Environment). 2008a. Section 303(d) list - limited segments requiring TMDL's, 5 CCR 1002-93, Regulation No. 93. Colorado Department of Public Health and Environment, Water Quality Control Commission. 29 pages.

CDPHE (Colorado Department of Public Health and Environment). 2008b. Classifications and numeric standards for the Lower Colorado Basin, 5 CCR 1002-37, Regulation No. 37: Denver, Colo., Colorado Department of Public Health and Environment, Water Quality Control Commission. 64 pages.

CDPHE (Colorado Department of Public Health and Environment). 2008c. The basic standards and methodologies for surface water (5 CCR 1002-31). 181 pages.

CDPHE (Colorado Department of Public Health and Environment Water Quality Control Commission). 2007. Classifications and numeric standards for Gunnison and lower Dolores River Basins, 5 CCR 1002-35, Regulation No. 35: Denver, Colo. Colorado Department of Public Health and Environment, Water Quality Control Commission. 72 pages.

Cole, G.A. 1979. Textbook of Limnology. 2nd Edition. The C.V. Mosby Company. St. Louis, MO 426 pages.

Czapla, T.E. 2002. Facilities plan for the production of endangered fishes to meet state stocking plans as part of the Upper Colorado River Endangered Fish Recovery Program. U.S. Fish and Wildlife Service, Denver, CO. 9 pages.

deBruyn, A.M., A. Hodaly, P.M. Chapman. 2008. Tissue selection criteria: Selection of tissue types for development of meaningful selenium tissue thresholds in fish. Part 1 of Selenium tissue thresholds: Tissue selection criteria, threshold development endpoints, and field application of tissue threshold. Washington (DC, USA): North America Metals Council-Selenium Working Group.

Dowdy, S., and S. Wearden. 1983. Statistics for research. John Wiley and Sons, New York, NY. 537 pages.

Eisler, R. 2000. Handbook of Chemical Risk Assessment: Health Hazards to Humans, Plants, and Animals. Volume 1 Metals. Lewis Publishers, New York, NY. 738 pages.

Engberg, R.A., D.W. Westcot, M. Delamore, and D.D. Holz. 1998. Federal and state perspectives on regulation and remediation of irrigation-induced selenium problems. Pages 1-26 *in* Environmental Chemistry of Selenium, W.T. Frankenberger, Jr., And R.A. Engberg, editors.

Espinosa, L.R., and W.E. Clark. 1972. A polypropylene light trap for aquatic invertebrates. California Fish and Game 58:149-152.

Fairchild, J.F., A.L. Allert, L.C. Sappington, and B. Waddell. 2005. Chronic toxicity of un-ionized ammonia to early life-stages of endangered Colorado pikeminnow (*Ptychocheilus lucius*) and razorback sucker (*Xyrauchen texanus*) compared to the surrogate fathead minnow (*Pimephales promelas*). Archives of Environmental Contaminants & Toxicology 49(3): 378-84. Epub 2005 Aug. 3.

Faires, L.M. 1993. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory--Determination of metals in water by inductively coupled plasma-mass spectrometry. U.S. Geological Survey Open-File Report 92-634. 28 pages.

Fishman, M.J. 1993. Methods of analysis by the U.S. Geological Survey National Water Quality LaboratoryBDetermination of inorganic and organic constituents in water and fluvial sediments. U.S. Geological Survey Open-File Report 93-125. 217 pages.

Fishman, M.J., and L.C. Friedman, editors. 1989. Methods for determination of inorganic substances in water and fluvial sediments (3rd edition): U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A1, 545 pages.

Fishman, M.J., J.W. Raese, C.N. Gerlitz, and R.A. Husband. 1994. U.S. Geological Survey approved inorganic and organic methods for the analysis of water and fluvial sediment, 1954B94. U.S. Geological Survey Open-File Report 94-351. 55 pages.

Garbarino, J.R., and T.M. Struzeski. 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory -- Determination of elements in whole-water digests using inductively coupled plasma- optical emission spectrometry and inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 98-165. 101 pages.

Garbarino, J.R., L.K. Kanagy, and M.E. Cree. 2006. Determination of elements in natural-water, biota, sediment and soil samples using collision/reaction cell inductively coupled plasma-mass spectrometry: U.S. Geological Survey Techniques and Methods, Book 5, Section B, Chapter1, 88 pages.

Goldman, C.R., and A.J. Horne. 1983. Limnology. McGraw-Hill Book Company, New York, NY. 464 pages.

Hamilton, S.J. 1999. Hypothesis of historical effects from selenium on endangered fish in the Colorado River Basin. Human and Ecological Risk Assessment 5(6):1153-1180.

Hamilton, S.J., K.M. Holley, K.J. Buhl, F.A. Bullard, L.K. Weston, and S.F. McDonald. 2001a. The evaluation of contaminant impacts on razorback sucker held in flooded bottomland sites near Grand Junction, Colorado - 1996. Final Report. U.S. Geological Survey, Yankton, SD 302 pages.

Hamilton, S.J., K.M. Holley, K.J. Buhl, F.A. Bullard, L.K. Weston, and S.F. McDonald. 2001b. The evaluation of contaminant impacts on razorback sucker held in flooded bottomland sites near Grand Junction, Colorado 1997. Final Report. U.S. Geological Survey, Yankton, SD 229 pages.

Hamilton, S.J., K.M. Holley, K.J. Buhl, F.A. Bullard, L.K. Weston, and S.G. McDonald. 2002a. Impact of selenium and other trace elements on the endangered adult razorback sucker. Environmental Toxicology 17:297-323.

Hamilton, S.J., K.M. Holley, and K.J. Buhl. 2002b. Hazard assessment of selenium to endangered razorback suckers. The Science of the Total Environment 291:111-121.

Hamilton, S.J., K.M. Holley, K.J. Buhl, F.A. Bullard, L.K. Weston, and S.F. McDonald. 2004. Evaluation of flushing channel in the Colorado River. Environmental Toxicology 19:51-81.

Hamilton, S.J., K.M. Holley, K.J., Buhl, F.A. Bullard, L.K. Weston, and S.F. McDonald. 2005. Selenium impacts on razorback sucker, Colorado River, Colorado. I. Adults. Ecotoxicology and Environmental Safety. 61: 7-31.

Hem, J.D. 1985. Study and interpretation of the chemical characteristics of natural water, third edition: U.S. Geological Survey Water-Supply Paper 2254. 264 pages.

Hermanutz, R.O., K.N. Allen, T.H. Roush, and S.F. Hedtke. 1992. Effects of elevated selenium concentrations on bluegills (*Lepomis macrochirus*) in outdoor experimental streams. Environmental Toxicology and Chemistry 11:217-224.

Hoffman, G.L., M.J. Fishman,, and J.R. Garbarino. 1996. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory--In-bottle acid digestion of whole-water samples: U.S. Geological Survey Open-File Report 96-225. 28 pages.

Horne, A.J. and C.R. Goldman. 1994. Limnology (2nd ed.): New York, McGraw-Hill, 576 pages.

Kuhn, G., M.R. Stevens, and J.G. Elliott. 2003. Hydrology and water quality of Elkhead Creek and Elkhead Reservoir near Craig, Colorado, July 1995-September 2001. U.S. Geological Survey Water-Resources Investigations Report 03-4220. 63 pages.

Lemly, A.D. 1985. Toxicology of selenium in a freshwater reservoir: Implications for environmental hazard evaluation and safety. Ecotoxicology and Environmental Safety 10:314-338.

Lemly, A.D. and G.J. Smith. 1987. Aquatic cycling of selenium: Implications for fish and wildlife. Washington, DC. U.S. Fish and Wildlife Service, Fish and Wildlife Leaflet 12. 10 pages.

Lemly, A.D. 1993. Metabolic stress during winter increases the toxicity of selenium to fish. Aquatic Toxicology 27:133-158.

Lemly, A.D. 1995. A protocol for aquatic hazard assessment of selenium. Ecotoxicology and Environmental Safety 32:280-288.

Lemly, A.D. 1996. Selenium in aquatic organisms. Pages 427-445. IN: Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. W.N. Beyer, G.H. Heinz, A. Redman-Norwood, editors. Lewis Publishers, New York, NY.

Lemly, A.D. 2002. Selenium assessment in aquatic ecosystem: A guide for hazard evaluation and water quality criteria. Springer-Verlag, New York. NY 161 pages.

Maier, K.J., and A.W. Knight. 1994. Ecotoxicology of selenium in freshwater systems. Reviews in Environmental Contamination. and Toxicology 134:31-48.

Malloy, J.C., M.L. Meade, E.W. Olsen. 1999. Small-scale spatial variation of selenium concentrations in chironomid larvae. Bull. Environ. Contam. Toxicol. 62: 122-129.

McAda, C.W. 1977. Aspects of the life history of three catastomids native to the upper Colorado River basin. Masters of Science Thesis. Utah State University, Logan, UT. 107 pages.

McKown D.M., and J.S. Morris. 1978. Rapid measurement of selenium in biological samples using instrumental neutron activation analysis. Journal of Radioanalytical Chemistry 43: 411-420.

Montagne, M. 1998. The Grand Valley Propagation facilities. 1997 Annual Report. U.S. Fish and Wildlife Service. Colorado River Fisheries Project. Grand Junction, CO. 21 pages.

Mueller, D.K. and D.R. Helsel. 1996. Nutrients in the Nation's Waters—Too Much of a Good Thing? U.S. Geological Survey Circular 1136, Denver, CO, 20 pages. http://pubs.usgs.gov/circ/circ1136/circ1136.html

Muth, R.T., Haines, G.B., Meismer, S.M., Wick, E.J., Chart, T.E., Snyder, D.E., Bundy, J.M., 1998. Reproduction and early life history of razorback sucker in the Green River, Utah and Colorado, 1992–1996. Larval Fish Laboratory, Fort Collins, CO. Final report to Recovery Implementation Program for the Endangered Fishes of the Upper Colorado River Basin. Recovery Program Project Number 34. Denver, Colorado. 62 pp.

Naftz, D.L., J. Yahnke, J. Miller, S. Noyes. 2005. Selenium mobilization during a flood experiment in a contaminated wetland: Stewart Lake Waterfowl Management Area, Utah. Applied Geochemistry 20(3): 569-585.

Nesler, T.P. 1998. Five-year stocking plan for endangered Colorado River fish species in Colorado. Colorado Division of Wildlife, Denver. 34 pp.

Ogle, R.S. and A.W. Knight. 1996. Selenium bioaccumulation in aquatic ecosystems: 1. Effects of sulfate on the uptake and toxicity of selenate in *Daphnia magna*. Arch. Environ. Contam. Toxicol. 30: 274.

Ohlendorf, H.M. 1997. Memo to U.S. Fish & Wildlife Service. CH2M Hill, 2485 Natomas Park Drive, Suite 600, Sacramento, CA 95833-2937.

Ohlendorf, H.M. 2002. Ecotoxicology of selenium. Pages 465-500 IN: D.J. Hoffman,. B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr. (Editors) Handbook of Ecotoxicology. 2nd Edition. Lewis Publishers, New York NY.

Ortiz, R.F. 2004. Characterization of water quality in government highline canal at camp 7 diversion and Highline Lake, Mesa County, Colorado, July 2000 through September 2003. U.S.Geological Survey, Scientific Investigations Report 2004-5281. 30 pages.

Osmundson, B.C., T.W. May, J.K. Skorupa, and R.P. Krueger. 2007. Selenium in fish tissue: Prediction equations for conversion between whole body, muscle, and eggs. 28th Annual Meeting in North America of Society of Environmental Toxicology and Chemistry, Milwaukee, Wisconsin, 11-15 November 2007.

Osmundson, B.C., T.W. May, and D.B. Osmundson. 2000. Selenium concentrations in the Colorado pikeminnow (Ptychocheilus lucius): Relationship with flows in the upper Colorado River. Archives of Environmental Contamination and Toxicology 38:479-485.

Osmundson, D.B., R.J. Ryel, M.E. Tucker, B.D. Burdick, W.R. Elmblad, and T.E. Chart. 1998. Dispersal patterns of subadult and adult Colorado squawfish in the Upper Colorado River. Transactions of the American Fisheries Society 127: 943-956.

Osmundson, D.B., and L.R. Kaeding. 1989. Studies of Colorado squawfish and razorback sucker use of the A15-mile reach@ of the upper Colorado River as part of conservation measures for the Green Mountain and Ruedi Reservoir water sales. Final Report. Colorado River Fishery Project. U.S. Fish and Wildlife Service, Grand Junction, Colorado. 85 pages.

Ott, W.R. 1990. A Physical Explanation of the Lognormality of Pollutant Concentrations. Journal of the Air and Waste Management Association, Volume 40, pp 1378 et seq.

Papoulias, D. and W.L. Minckley. 1992. Effects of food availability on survival and growth of larval razorback suckers in ponds. Transactions of the American Fisheries Society 121: 340-355.

Patton, C.J., and J.R. Kryskalla. 2003. Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory. Evaluation of Alkaline Persulfate Digestion as an Alternative to Kjeldahl Digestion for Determination of Total and Dissolved Nitrogen and Phosphorus in Water. U.S. Geological Survey, Water-Resources Investigations Report 03-4174, 33 pages.

Patton, C.J. and E.P. Truitt. 2000. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of ammonium plus organic nitrogen by a Kjeldahl digestion method and an automated photometric finish that includes digest cleanup by gas diffusion. U.S. Geological Survey Open-File Report 00-170. 31 pages

Pennak, R.W. 1989. Freshwater invertebrates of the United States: Protozoa to Mollusca. 3rd Edition. John Wiley & Sons, New York, NY.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. U.S. Fish & Wildlife Service, Washington DC.

Seiler, R.L. 1998. Prediction of lands susceptible to irrigation-induced selenium contamination of water. In: Frankenberg WT, Engberg RA (eds.) Environmental chemistry of selenium. Marcel Dekker, New York, NY, pp. 397-418.

Seiler, R.L., J.P. Skorupa, D.L. Naftz, and T. Nolan. 2003. Irrigation-induced contamination of water, sediment, and biota in the Western U.S.-Synthesis of data from the National Irrigation Water Quality Program. U.S. Geological Survey Professional Paper 1655. 123 pages.

Shacklette, H.T. and J.G. Boerngen. 1984. Element concentrations in soils and other surficial materials of the conterminous United States: U.S. Geological Survey Professional Paper 1270. 105 pages.

Singh, A.K., A. Singh, and M. Engelhardt. 1997. The lognormal distribution in environmental applications. EPA Technology Support Center for Monitoring and Site Characterization, National Exposure Research Laboratory, Environmental Sciences Division, Las Vegas, NV 89193-3478. 19 pages.

Spahr, N.E. L.E. Apodaca, J.R. Deacon, J.B. Bails, N.J. Bauch, C.M. Smith, and N.E. Driver. 2000. Water quality in the Upper Colorado River Basin, Colorado, 1996-98. U.S. Geological Survery Circular 1214. 33 pages.

USDOI (U.S. Department of the Interior). 1998. Guidelines for interpretation of the biological effects of selected constituents in biota, water, and sediment. National Irrigation Water Quality Program Information Report Number 3. 198 pages + appendices, http://www.usbr.gov/niwqp.

USEPA (U.S. Environmental Protection Agency). 1986. Quality criteria for water 1986. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington. Report EPA/440/5-86/001. 398 pages. Available from National Technical Information Service, Springfield, VA 22161.

USEPA (U.S. Environmental Protection Agency). 1993. Method 365.1-Determination of phosphorus by semi-automated colorimetry. Edited by James W. O'Dell, Environmental monitoring systems laboratory, Office of Research and Development, USEPA, Cincinnati, Ohio 45268. 17 pages.

USEPA (U.S. Environmental Protection Agency). 1999. 1999 Update of ambient water quality criteria for ammonia. EPA-822-R-99-014. 153 pages.

USFWS (U.S. Fish and Wildlife Service). 1994. Endangered and threatened wildlife and plants; determination of critical habitat for the Colorado River endangered fishes: razorback sucker, Colorado squawfish, humpback chub, and bonytail chub. Federal Register 59: 13374-13399.

USFWS (U.S. Fish and Wildlife Service). 2002a. Colorado pikeminnow (Ptychocheilus lucius) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado. 71 pages. + appendices.

USFWS (U.S. Fish and Wildlife Service). 2002b. Razorback sucker (Xyrauchen texanus) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado. 78 pages. + appendices.

USGS (U.S. Geological Survey). 1998. National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapter A1 to A9, available online at http://pubs.water.usgs. gov/twri9A

Vollenweider, R.A. 1968. Scientific fundamentals of the eutrophication of lakes and flowing waters with particular reference to nitrogen and phosphorus as factors in eutrophication: Technical Report for Organization for Economic Cooperation and Development, DAS/CSI/68.27. 192 pages.

Waddell, B., and T.S. May. 1995. Selenium concentrations in razorback sucker (Xyrauchen texanus): substitution of non-lethal muscle plugs for muscle tissue in contaminant assessment. Archives of Environmental Contamination and Toxicology 28:321-326.

Ward, J.R., and C.A. Harr, editors, 1990. Methods for collection and processing of surface-water and bed-material samples for physical and chemical analyses: U.S. Geological Survey Open-File Report 90-140, 71 pages.

Wetzel, R.G. 2001. Limnology, Lake and River Ecosystems (3d edition.) Academic Press, San Diego, CA. 1006 pages.

Wilde, F.D., and D.B. Radtke, editors. 1998. Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapter A6, accessed August 25, 2004 http://pubs.water.usgs.gov/twri9A6/.

Williamson, J.H. 1992. Colorado pikeminnow genetic survey-tissue sampling protocol. U.S. Fish and Wildlife Service, Denver, CO. 13 pages.

Woodling, J. 1985. Colorado Little Fish: A Guide to the Minnows and other Lesser Known Fishes in the State of Colorado. Colorado Division of Wildlife, Department of Natural Resources, Denver, CO. 77 pages.

Woods, P.F. 1992. Limnology of Big Lake, south-central Alaska, 1983-84: U.S. Geological Survey Water-Supply Paper 2382. 108 pages.

Wydoski, R.S. 1994. Coordinated hatchery facility plan: need for captive-reared endangered fish and propagation facilities. Recovery Implementation Program for Endangered fishes in the Upper Colorado River Basin. U.S. Fish and Wildlife Service, Denver, CO. 133 pages.

Wydoski, R.S. and J. Hamill. 1991. Evolution of a cooperative recovery program for endangered fishes in the upper Colorado River basin. Pages 123-135 *in* W.L. Minckley and J.E. Deacon, editors. Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson.

Wydoski R.S., and E.J. Wick. 1998. Ecological value of floodplain habitats to razorback suckers in the Upper Colorado River Basin. U.S. Fish and Wildlife Service, Denver, CO. 55 pages.

Appendix 1. Depth profile measurements of water temperature, dissolved oxygen, pH, and specific conductance at razorback sucker grow-out ponds during 2005.

SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
BESWICK POND	3/24/2005	1248	2	8.5	8.6	5702	10.8
BESWICK POND	3/24/2005	1249	4	8.4	8.5	5660	10.8
BESWICK POND	3/24/2005	1250	5	8.6	8.6	5680	10.6
BESWICK POND	3/24/2005	1251	6	8.5	8.5	5670	10.6
BESWICK POND	3/24/2005	1252	7.5	8.7	8.6	5660	10.4
BESWICK POND	6/21/2005	0942	1	8.6	8.6	5960	23.7
BESWICK POND	6/21/2005	0943	2	8.5	8.6	5970	23.7
BESWICK POND	6/21/2005	0944	3	8.5	8.6	5970	23.7
BESWICK POND	6/21/2005	0945	4	8.6	8.6	6000	23.7
BESWICK POND	6/21/2005	0946	5	8.6	8.6	6000	23.7
BESWICK POND	6/21/2005	0947	6	8.6	8.6	6000	23.7
BESWICK POND	6/21/2005	0948	7	8.6	8.6	6000	23.6
BESWICK POND	8/25/2005	1210	0.1	7.5	8.7	6230	24.3
BESWICK POND	8/25/2005	1211	1	7.3	8.8	6220	24.1
BESWICK POND	8/25/2005	1212	2	7.4	8.8	6220	23.6
BESWICK POND	8/25/2005	1213	3	7.7	8.8	6220	23.5
BESWICK POND	8/25/2005	1214	4	7.9	8.8	6240	23.5
BESWICK POND	8/25/2005	1215	5	8	8.8	6240	23.5
BESWICK POND	8/25/2005	1216	6	8.4	8.8	6230	23.4
BESWICK POND	8/25/2005	1217	7	8.9	8.8	6230	23.4
BOUNDS POND	3/25/2005	1400	2	9.3	7.8	6110	9.7
BOUNDS POND	3/25/2005	1401	4	9.2	7.9	6120	9.7
BOUNDS POND	3/25/2005	1403	6	9.2	7.9	6140	9.7
BOUNDS POND	3/25/2005	1405	2	9.2	7.9	6120	9.7
BOUNDS POND	6/20/2005	1410	1	10.4	8.7	6550	24.4
BOUNDS POND	6/20/2005	1411	2	10.8	8.7	6540	23.5
BOUNDS POND	6/20/2005	1412	3	8.7	8.7	6530	23.1
BOUNDS POND	6/20/2005	1413	4	11.8	8.7	6520	23
BOUNDS POND	6/20/2005	1414	5	12.1	8.7	6520	23
BOUNDS POND	6/20/2005	1415	6	12.1	8.7	6520	23
BOUNDS POND	8/22/2005	1320	0.1	6.5	8.3	7150	25.4
BOUNDS POND	8/22/2005	1321	1	7.4	8.4	7140	24.2
BOUNDS POND	8/22/2005	1322	2	7.6	8.5	7120	23.7
BOUNDS POND	8/22/2005	1323	3	8.3	8.5	7110	23.4
BOUNDS POND	8/22/2005	1324	4	9	8.5	7130	23
BOUNDS POND	8/22/2005	1325	5	8.5	8.5	7130	22.8
BOUNDS POND	8/22/2005	1330	3	8.3	8.5	7110	23.4
CANAL INFLOW PETERS	7/18/2005	1100		6.8	8.3	947	23.5
CANAL INFLOW PETERS	8/23/2005	1030		8.4	7.9	1140	20.9

Appendix 1. Depth profile measurements of water temperature, dissolved oxygen, pH, and specific conductance at razorback sucker grow-out ponds during 2005.

SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
CDOT POND, DEBEQUE	3/25/2005	1053	4	10.2	9.2	3160	9.2
CDOT POND, DEBEQUE	6/21/2005	1320	1	8.3	8.7	3250	24.4
CDOT POND, DEBEQUE	6/21/2005	1321	3	8.5	8.7	3230	22.8
CDOT POND, DEBEQUE	6/21/2005	1322	5	8.8	8.7	3230	22.5
CDOT POND, DEBEQUE	6/21/2005	1323	7	9.3	8.7	3230	22.2
CDOT POND, DEBEQUE	6/21/2005	1324	9	9.3	8.7	3230	21.9
CDOT POND, DEBEQUE	6/21/2005	1325	11	9.5	8.7	3220	21.5
CDOT POND, DEBEQUE	6/21/2005	1326	13	9.3	8.7	3170	20.8
CDOT POND, DEBEQUE	6/21/2005	1327	15	8	8.6	3160	19.8
CDOT POND, DEBEQUE	6/21/2005	1328	17	5	8.6	3160	19.4
CDOT POND, DEBEQUE	6/21/2005	1329	19	4.3	8.6	3170	19.1
CDOT POND, DEBEQUE	8/22/2005	1030	2	6.5	9.1	3460	23.6
CDOT POND, DEBEQUE	8/22/2005	1040	0.1	6.5	9.1	3430	23.6
CDOT POND, DEBEQUE	8/22/2005	1041	1	6.5	9.1	3460	23.6
CDOT POND, DEBEQUE	8/22/2005	1042	2	6.5	9.1	3460	23.6
CDOT POND, DEBEQUE	8/22/2005	1043	3	6.4	9.1	3460	23.6
CDOT POND, DEBEQUE	8/22/2005	1044	4	6.5	9.1	3460	23.6
CDOT POND, DEBEQUE	8/22/2005	1045	5	6.4	9.1	3460	23.6
CDOT POND, DEBEQUE	8/22/2005	1046	6	6.1	9.1	3460	23.6
CDOT POND, DEBEQUE	8/22/2005	1047	7	6.1	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1048	8	6.2	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1049	9	6	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1050	10	6.1	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1051	11	6.1	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1052	12	6.1	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1053	13	5.9	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1054	14	6.2	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1055	15	5.4	9.1	3460	23.5
CDOT POND, DEBEQUE	8/22/2005	1056	16	5.4	9.1	3460	23.4
CDOT POND, DEBEQUE	8/22/2005	1057	17	5	9.1	3450	23.4
CLYMERS POND	6/22/2005	1340	1	19.5	8.4	1010	25
CLYMERS POND	6/22/2005	1341	2	17.7	8.3	1000	24.6
CLYMERS POND	6/22/2005	1342	3	17	8.3	990	24.5
CLYMERS POND	6/22/2005	1343	4	16.3	8.2	990	24.4
CLYMERS POND	6/22/2005	1350		17.7	8.3	1000	24.6
CLYMERS POND	8/23/2005	1215	0.1	11.8	7.7	1210	23.8
CLYMERS POND	8/23/2005	1216	1	11.4	7.7	1200	23.6
CLYMERS POND	8/23/2005	1217	2	10.7	7.7	1200	23
CLYMERS POND	8/23/2005	1220	1.5	11.4	7.7	1200	23.6
ELAM POND	3/24/2005	1030	3	9.2	8.3	4410	10.2
ELAM POND	3/24/2005	1031	2	9.2	8.2	4400	10.2

Appendix 1. Depth profile measurements of water temperature, dissolved oxygen, pH, and specific conductance at razorback sucker grow-out ponds during 2005.

SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
ELAM POND	3/24/2005	1032	4	9.2	8.4	4420	10.2
ELAM POND	3/24/2005	1033	5.5	9.2	8.5	4410	10.2
ELAM POND	6/21/2005	1050	1	12.6	9.3	5000	24.3
ELAM POND	6/21/2005	1051	2	12.5	9.3	5000	24.3
ELAM POND	6/21/2005	1052	3	12.5	9.3	5010	24.3
ELAM POND	6/21/2005	1053	4	12.6	9.4	5010	24.2
ELAM POND	6/21/2005	1054	5	10.6	9.3	5000	24
ELAM POND	6/21/2005	1055	6	11.4	9.3	5010	23.9
ELAM POND	6/21/2005	1056	7	4.9	9.1	5020	23.1
ELAM POND	8/25/2005	0950	2	8.1	9.2	5380	23
ELAM POND	8/25/2005	1000	0.1	8.1	9.2	5380	23
ELAM POND	8/25/2005	1001	1	8.1	9.2	5380	23
ELAM POND	8/25/2005	1002	2	8.2	9.2	5390	22.9
ELAM POND	8/25/2005	1003	3	8.6	9.2	5390	22.9
ELAM POND	8/25/2005	1004	4	8.9	9.2	5390	22.9
HEUTON POND	4/21/2005	1130		8.4	8.1	1030	11
HEUTON POND	6/22/2005	0920	1	7.9	8.3	511	20.6
HEUTON POND	6/22/2005	0921	2	8	8.4	512	20.5
HEUTON POND	6/22/2005	0922	3	7.2	8	508	20.2
HEUTON POND	6/22/2005	0923	4	5	8.1	490	19.1
HEUTON POND	6/22/2005	0924	5	2.5	7.8	490	18.1
HEUTON POND	8/24/2005	1007	0.1	4.8	7.8	750	19.7
HEUTON POND	8/24/2005	1008	1	4.7	7.7	760	19.4
HEUTON POND	8/24/2005	1009	2	4.6	7.7	770	19.2
HEUTON POND	8/24/2005	1010	3	4.2	7.7	780	19.2
HEUTON POND	8/24/2005	1011	4	3.4	7.6	760	19.1
HEUTON POND	8/24/2005	1012	5	3.3	7.6	790	19
HEUTON POND	8/24/2005	1020	1.5	4.7	7.7	760	19.4
MAGGIO POND	3/23/2005	1200		9.7	8.2	6640	9.7
MAGGIO POND	3/23/2005	1207	2	9.7	8.2	6650	9.7
MAGGIO POND	3/23/2005	1208	4	9.7	8.2	6640	9.7
MAGGIO POND	3/23/2005	1209	6	9.8	8.2	6690	9.7
MAGGIO POND	3/23/2005	1210	8	9.7	8.2	6610	9.7
MAGGIO POND	3/23/2005	1211	10	9.7	8.2	6630	9.7
MAGGIO POND	3/23/2005	1212	12	9.7	8.2	6620	9.7
MAGGIO POND	3/23/2005	1213	14	9.7	8.2	6640	9.7
MAGGIO POND	3/23/2005	1214	16	9.8	8.2	6650	9.7
MAGGIO POND	6/20/2005	1140	1	10.3	8.6	6960	22.1
MAGGIO POND	6/20/2005	1141	2	11.2	8.6	6970	22.1
MAGGIO POND	6/20/2005	1142	3	11	8.6	6970	22
MAGGIO POND	6/20/2005	1143	4	11.1	8.6	6970	21.9

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SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
MAGGIO POND	6/20/2005	1144	5	11	8.6	6960	21.8
MAGGIO POND	6/20/2005	1145	6	11	8.6	6970	21.7
MAGGIO POND	6/20/2005	1146	7	11	8.6	6970	21.7
MAGGIO POND	6/20/2005	1147	8	11.4	8.6	6960	21.7
MAGGIO POND	6/20/2005	1148	9	11.6	8.6	6970	21.6
MAGGIO POND	6/20/2005	1149	10	12.1	8.6	6970	21.5
MAGGIO POND	6/20/2005	1150	11	11.8	8.6	6970	21.5
MAGGIO POND	6/20/2005	1151	12	11.6	8.6	6970	21.4
MAGGIO POND	6/20/2005	1152	13	11.4	8.6	6970	21
MAGGIO POND	6/20/2005	1153	14	9	8.4	6950	20.5
MAGGIO POND	6/20/2005	1154	15	7	8.3	6950	20.2
MAGGIO POND	6/20/2005	1155	16	5.6	8.2	6950	19.9
MAGGIO POND	6/20/2005	1156	17	3.2	8.1	6940	19.6
MAGGIO POND	8/25/2005	1100	0.1	5.4	8	6850	23.6
MAGGIO POND	8/25/2005	1101	1	5.3	8	6860	23.6
MAGGIO POND	8/25/2005	1102	2	5.2	8	6860	23.5
MAGGIO POND	8/25/2005	1103	3	5.3	8	6860	23.4
MAGGIO POND	8/25/2005	1104	4	5.4	8	6870	23.3
MAGGIO POND	8/25/2005	1105	5	5.6	8.1	6870	23.3
MAGGIO POND	8/25/2005	1106	6	5.7	8.1	6870	23.3
MAGGIO POND	8/25/2005	1107	7	5.8	8.1	6880	23.3
MAGGIO POND	8/25/2005	1108	8	5.9	8.1	6870	23.3
MAGGIO POND	8/25/2005	1109	9	6.1	8.1	6880	23.3
MAGGIO POND	8/25/2005	1110	10	6.4	8.1	6880	23.2
MAGGIO POND	8/25/2005	1111	11	6.3	8.1	6880	23.2
MAGGIO POND	8/25/2005	1112	12	5.8	8.1	6880	23.2
MAGGIO POND	8/25/2005	1113	13	5.5	8.1	6880	23.1
MAGGIO POND	8/25/2005	1114	14	5.5	8.1	6880	23.1
MAGGIO POND	8/25/2005	1115	15	5.4	8.1	6880	23.1
MAGGIO POND	8/25/2005	1116	16	4.9	8	6880	23.1
MAGGIO POND	8/25/2005	1117	17	1	7.3	6940	22.2
MCGUIRE LARGE PD	6/20/2005	1515	1	9.4	8.3	3660	24.9
MCGUIRE LARGE PD	6/20/2005	1516	2	9.2	8.3	3700	23.2
MCGUIRE LARGE PD	6/20/2005	1517	3	9	8.3	3700	22.3
MCGUIRE LARGE PD	6/20/2005	1518	4	8.9	8.3	3710	21.9
MCGUIRE LARGE PD	6/20/2005	1519	5	9	8.3	3710	21.7
MCGUIRE LARGE PD	6/20/2005	1520	6	8.9	8.3	3710	21.6
MCGUIRE LARGE PD	6/20/2005	1521	7	8.8	8.3	3710	21.5
MCGUIRE LARGE PD	6/20/2005	1522	8	8.8	8.3	3710	21.4
MCGUIRE LARGE PD	6/20/2005	1523	9	8.8	8.3	3720	21.3
MCGUIRE LARGE PD	6/20/2005	1524	10	9.7	8.2	3740	20.9
MCGUIRE LARGE PD	6/20/2005	1525	11	10.1	8.2	3740	20.6

Appendix 1. Depth profile measurements of water temperature, dissolved oxygen, pH, and specific conductance at razorback sucker grow-out ponds during 2005.

SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
MCGUIRE LARGE PD	6/20/2005	1526	12	10.8	8.2	3740	20.5
MCGUIRE LARGE PD	6/20/2005	1527	13	11.6	8.1	3730	20.2
MCGUIRE LARGE PD	6/20/2005	1528	14	11.8	8.1	3730	20
MCGUIRE LARGE PD	6/20/2005	1529	15	11.8	8.1	3730	19.6
MCGUIRE LARGE PD	6/20/2005	1530	16	12.2	8.1	3730	19.5
MCGUIRE LARGE PD	8/22/2005	1340	0.1	6.9	7.9	3520	25.5
MCGUIRE LARGE PD	8/22/2005	1341	1	6.9	7.9	3520	24.3
MCGUIRE LARGE PD	8/22/2005	1342	2	6.5	7.9	3510	23
MCGUIRE LARGE PD	8/22/2005	1343	3	6.5	7.9	3500	22.8
MCGUIRE LARGE PD	8/22/2005	1344	4	6.2	7.9	3510	22.7
MCGUIRE LARGE PD	8/22/2005	1345	5	5.8	7.9	3510	22.6
MCGUIRE LARGE PD	8/22/2005	1346	6	5.8	7.9	3510	22.6
MCGUIRE LARGE PD	8/22/2005	1347	7	5.5	7.9	3510	22.5
MCGUIRE LARGE PD	8/22/2005	1348	8	4.5	7.8	3520	22.5
MCGUIRE LARGE PD	8/22/2005	1349	9	3.7	7.7	3530	22.5
MCGUIRE LARGE PD	8/22/2005	1350	10	0.2	7.2	3810	21.8
MCGUIRE LARGE PD	8/22/2005	1351	11		7	3890	20
MCGUIRE LARGE PD	8/22/2005	1352	12		7	3920	19.3
MCGUIRE LARGE PD	8/22/2005	1353	13	0	7	3920	19
MCGUIRE LARGE PD	8/22/2005	1354	15	0	7	3950	18.8
MCGUIRE LARGE PD	8/22/2005	1410	3	6.5	7.9	3500	22.8
MORSE POND	3/23/2005	1012	1	10.2	8.1	3600	8.5
MORSE POND	3/23/2005	1013	2	10.2	8.1	3600	8.5
MORSE POND	3/23/2005	1014	3	10.2	8.1	3600	8.5
MORSE POND	3/23/2005	1020	2	10.2	8.1	3600	8.5
MORSE POND	6/20/2005	1010	0.5	8.2	8.3	3490	19.6
MORSE POND	6/20/2005	1011	1	10.4	8.4	3530	19.4
MORSE POND	6/20/2005	1012	2	9.7	8.4	3590	18.9
MORSE POND	6/20/2005	1013	3	9.4	8.5	3630	18.8
MORSE POND	6/20/2005	1014	4	3.9	8.5	3780	17.7
MORSE POND	6/20/2005	1015	5	0.2	7.2	3840	16.1
MORSE POND	8/25/2005	1330	0.1	8.2	8	3480	21.6
MORSE POND	8/25/2005	1331	1	8	7.9	3480	21.3
MORSE POND	8/25/2005	1332	2	8.9	7.9	3480	21.1
MORSE POND	8/25/2005	1333	3	9.4	8	3480	21
MORSE POND	8/25/2005	1334	4	1.5	7.4	3530	20.1
MORSE POND	8/25/2005	1340	2	8	7.9	3480	21.3
PETERS POND 1	5/31/2005	1203	1	9.3	8.3	341	20.4
PETERS POND 1	5/31/2005	1204	7	7.9	8.1	350	16.7
PETERS POND 1	5/31/2005	1205	6	8.1	8.1	350	16.7
PETERS POND 1	5/31/2005	1206	5	8.2	8.1	351	16.9

Appendix 1. Depth profile measurements of water temperature, dissolved oxygen, pH, and specific conductance at razorback sucker grow-out ponds during 2005.

SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
PETERS POND 1	5/31/2005	1207	4	8.4	8.1	351	17.1
PETERS POND 1	5/31/2005	1208	3	8.6	8.1	351	17.3
PETERS POND 1	5/31/2005	1209	2	8.8	8.2	350	17.4
PETERS POND 1	5/31/2005	1210	1	9.3	8.3	341	20.4
PETERS POND 1	7/18/2005	1417	1.5	6	8.1	852	27.3
PETERS POND 1	7/18/2005	1420	1	6.2	8.1	846	27.3
PETERS POND 1	7/18/2005	1421	2	6	8.1	852	27.3
PETERS POND 1	7/18/2005	1422	3	6	8.1	851	27.2
PETERS POND 1	7/18/2005	1423	4	5.9	8.1	842	26.5
PETERS POND 1	7/18/2005	1424	5	5.8	8.1	840	26.4
PETERS POND 1	7/18/2005	1504	1.8	6.1	8.1	843	28.6
PETERS POND 1	7/18/2005	1506	1	6.1	8.1	843	28.6
PETERS POND 1	7/18/2005	1507	2	6.1	8.1	843	28.6
PETERS POND 1	7/18/2005	1508	3	6.1	8.1	844	27.6
PETERS POND 1	7/18/2005	1509	4	6	8.1	842	27.4
PETERS POND 1	7/18/2005	1510	5	5.9	8.1	840	27
PETERS POND 1	7/18/2005	1511	6	5.9	8.1	841	26.8
PETERS POND 1	8/23/2005	1125	0.1	8	8.1	1100	22.6
PETERS POND 1	8/23/2005	1126	1	8.1	8.2	1100	22.5
PETERS POND 1	8/23/2005	1127	2	8.2	7.9	1100	22.2
PETERS POND 1	8/23/2005	1128	3	7.8	8.2	1100	22.1
PETERS POND 1	8/23/2005	1129	4	7.8	8.2	1100	22.1
PETERS POND 1	8/23/2005	1130	0.6	8.1	8.2	1100	22.5
PETERS POND 2	5/31/2005	1143	1.38	6.3	7.8	400	19.8
PETERS POND 2	5/31/2005	1144	6	6.2	7.9	400	18.2
PETERS POND 2	5/31/2005	1145	5	6.3	7.9	400	18.3
PETERS POND 2	5/31/2005	1146	4	6.4	7.8	400	18.5
PETERS POND 2	5/31/2005	1147	3	6.4	7.9	399	18.6
PETERS POND 2	5/31/2005	1148	2	6.7	7.9	400	18.8
PETERS POND 2	5/31/2005	1149	1	6.3	7.9	400	19.8
PETERS POND 2	8/23/2005	1054	0.1	8.1	8.1	1070	23.2
PETERS POND 2	8/23/2005	1055	1	8.2	8.2	1070	23.2
PETERS POND 2	8/23/2005	1056	2	8.2	8.2	1070	23
PETERS POND 2	8/23/2005	1057	3	8.1	8.2	1070	22.9
PETERS POND 2	8/23/2005	1058	4	8.2	8.2	1070	22.9
PETERS POND 2	8/23/2005	1100	0.6	8.2	8.2	1070	23.2
PETERS POND 3	5/31/2005	1121	1	7.6	8.2	369	18.7
PETERS POND 3	5/31/2005	1122	5	7.6	8.2	369	18.3
PETERS POND 3	5/31/2005	1123	4	7.7	8.2	369	18.4
PETERS POND 3	5/31/2005	1124	3	7.6	8.2	369	18.4
PETERS POND 3	5/31/2005	1125	2	7.6	8.2	368	18.6

Appendix 1. Depth profile measurements of water temperature, dissolved oxygen, pH, and specific conductance at razorback sucker grow-out ponds during 2005.

SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
PETERS POND 3	5/31/2005	1126	1	7.6	8.2	369	18.7
PETERS POND 3	7/18/2005	1245	1	6.8	8.3	882	26.2
PETERS POND 3	7/18/2005	1246	1	6.9	8.2	885	26.4
PETERS POND 3	7/18/2005	1247	2	6.8	8.3	882	26.2
PETERS POND 3	7/18/2005	1248	3	6.7	8.3	882	25.9
PETERS POND 3	7/18/2005	1249	4	6.7	8.3	883	25.8
PETERS POND 3	7/18/2005	1250	5	6.7	8.3	883	25.6
PETERS POND 4	5/31/2005	1111	1	10.3	8.6	350	18.1
PETERS POND 4	5/31/2005	1112	6	9.6	8.5	353	16
PETERS POND 4	5/31/2005	1113	5	9.8	8.6	353	16
PETERS POND 4	5/31/2005	1114	4	9.9	8.6	353	16.5
PETERS POND 4	5/31/2005	1115	3	10	8.6	352	16.8
PETERS POND 4	5/31/2005	1116	2	9.9	8.6	353	17.1
PETERS POND 4	5/31/2005	1117	1	10.3	8.6	350	18.1
PETERS POND 4	7/18/2005	1145	1.2	6.3	8.2	930	25
PETERS POND 4	7/18/2005	1150	1	6.2	8.2	931	25.6
PETERS POND 4	7/18/2005	1151	2	6.3	8.2	930	25
PETERS POND 4	7/18/2005	1152	3	6.2	8.2	931	25
PETERS POND 4	7/18/2005	1153	4	6.2	8.2	930	24.8
PETERS POND 4	7/18/2005	1154	5	6.1	8.2	930	24.6
PETERS POND 4	8/23/2005	1005	0.1	7.9	8.1	1050	22
PETERS POND 4	8/23/2005	1006	1	7.9	8.1	1110	22
PETERS POND 4	8/23/2005	1007	2	7.9	8.2	1110	21.9
PETERS POND 4	8/23/2005	1008	3	7.9	8.2	1120	21.8
PETERS POND 4	8/23/2005	1009	4	7.9	8.2	1120	21.8
PETERS POND 4	8/23/2005	1020	0.6	7.9	8.1	1110	22
VANWAGNER POND N.	4/20/2005	1510		8.3	7.5	858	13.3
VANWAGNER POND N.	6/22/2005	1105	1	11.3	8.9	370	22
VANWAGNER POND N.	6/22/2005	1106	2	11.5	8.9	380	21.9
VANWAGNER POND N.	6/22/2005	1107	3	12.1	8.8	380	21.9
VANWAGNER POND N.	6/22/2005	1108	4	11.7	8.7	380	21.7
VANWAGNER POND N.	6/22/2005	1109	5	5.5	8.4	380	20.4
VANWAGNER POND N.	6/22/2005	1110	6	3.3	7.8	380	19.6
VANWAGNER POND N.	6/22/2005	1111	7	2.1	7.8	390	19.4
VANWAGNER POND N.	6/22/2005	1112	8	1.4	7.8	390	19.3
VANWAGNER POND N.	6/22/2005	1113	9	0.8	7.8	400	18.6
VANWAGNER POND N.	6/22/2005	1140		11.7	8.7	380	21.7
VANWAGNER POND N.	8/24/2005	1130	0.1	10.7	9	610	23.9
VANWAGNER POND N.	8/24/2005	1131	1	11.3	9	610	23.3
VANWAGNER POND N.	8/24/2005	1132	2	5.8	8.4	610	21.8
VANWAGNER POND N.	8/24/2005	1133	3	4.2	8.2	610	21.6

Appendix 1. Depth profile measurements of water temperature, dissolved oxygen, pH, and specific conductance at razorback sucker grow-out ponds during 2005.

SITE NAME	DATES	TIMES	DEPTH (ft)	DO (mg/L)	pH	SP. COND. (us/cm)	TEMP (C)
VANWAGNER POND N.	8/24/2005	1134	4	3.6	8.1	610	21.5
VANWAGNER POND N.	8/24/2005	1135	5	3.4	8.1	610	21.5
VANWAGNER POND N.	8/24/2005	1136	6	3.2	8.1	610	21.5
VANWAGNER POND N.	8/24/2005	1137	7	3	8.1	610	21.5
VANWAGNER POND N.	8/24/2005	1140	1	11.3	9	610	23.3
VANWAGNER POND S.	4/20/2005	1435		8.5	7.5	915	14.3
VANWAGNER POND S.	6/22/2005	1013	1	15.6	8.7	590	23.7
VANWAGNER POND S.	6/22/2005	1014	2	15.5	8.7	580	23.6
VANWAGNER POND S.	6/22/2005	1015	3	15.1	8.6	580	23.3
VANWAGNER POND S.	6/22/2005	1016	4	15.1	8.6	580	23.2
VANWAGNER POND S.	6/22/2005	1017	5	15.2	8.1	590	22.6
VANWAGNER POND S.	6/22/2005	1018	6	13	7.8	610	21.8
VANWAGNER POND S.	6/22/2005	1019	7	10.4	7.6	625	20.8
VANWAGNER POND S.	6/22/2005	1020	8	5.5	7.5	640	20
VANWAGNER POND S.	6/22/2005	1021	9	4.5	7.5	650	19.6
VANWAGNER POND S.	6/22/2005	1022	10	4.8	7.5	650	19.4
VANWAGNER POND S.	8/24/2005	1100	1	6.9	8.9	540	23.9
VANWAGNER POND S.	8/24/2005	1105	0.1	6.9	8.9	540	24
VANWAGNER POND S.	8/24/2005	1106	1	6.9	8.9	540	23.9
VANWAGNER POND S.	8/24/2005	1107	2	6.8	8.9	540	23.3
VANWAGNER POND S.	8/24/2005	1108	3	6.3	8.9	540	23.1
VANWAGNER POND S.	8/24/2005	1109	4	6.1	8.9	540	23.1
VANWAGNER POND S.	8/24/2005	1110	5	5.9	8.9	540	23
VANWAGNER POND S.	8/24/2005	1111	6	5.5	8.9	540	23
VANWAGNER POND S.	8/24/2005	1112	7	5.5	8.9	540	23
VANWAGNER POND S.	8/24/2005	1113	8	6.4	8.9	540	22.9

Appendix 2. Results of low-level nutrient analyses in water samples collected from razorback sucker grow-out ponds during 2005.

Site Name	Date	KJEL filtered mg/l	KJEL unfiltered mg/l total	NH3 mg/l	NO3 mg/l	NO2 mg/l	OrthoP mg/l	P filtered mg/l	P unfiltered mg/l total	TotalN mg/l	Pheo-a ug/l	Chloro-a ug/l	Secchi depth (m)	N:P
CDOT	3/25/2005	0.47	0.4	0.01	0.016	0.001	0.006	0.01	0.011		0.1	0.9	3.7	4.3
CDOT	6/21/2005	0.46	0.47	0.01	0.016	0.002	0.006	0.01	0.018		20.2	47.9	2.7	4.3
CDOT	8/22/2005	0.56	0.52	0.01	0.016	0.002	0.006	0.01	0.016	0.49	0.7	4.1	2.9	4.3
MORSE	3/23/2005	0.74	0.83	0.02	0.016	0.001	0.006	0.02	0.03		0.3	1.2	0.91	5.8
MORSE	6/20/2005	0.76	0.82	0.01	0.016	0.002	0.006	0.01	0.025		0.6	0.5	1.5	5
MORSE	8/25/2005	0.86	0.87	0.02	0.016	0.001	0.006	0.02	0.026	0.83	1.2	2.9	1.2	6
BESWICK	3/24/2005	0.57	0.67	0.01	0.016	0.001	0.006	0.01	0.012		0.2	0.5	2.4	3.5
BESWICK	6/21/2005	0.76	0.88	0.01	0.016	0.002	0.006	0.01	0.028		0.7	2.2	1.8	3.5
BESWICK	8/25/2005	0.87	0.94	0.01	0.016	0.002	0.006	0.01	0.026	0.89	1.1	5.3	2.1	3.8
ELAM	3/24/2005	0.91	0.85	0.01	0.016	0.001	0.006	0.01	0.017		0.2	1.6	1.8	3.5
ELAM	6/21/2005	1.3	1.6	0.01	0.016	0.002	0.006	0.01	0.079		0.4	0.8	1.7	3.8
ELAM	8/25/2005	1.1	1.4	0.01	0.016	0.002	0.006	0.01	0.065	1.32	2.2	18.4	1.7	3.5
MAGGIO	3/23/2005	0.63	0.72	0.07	0.016	0.002	0.006	0.04	0.018		0.4	1.3	4	14.7
MAGGIO	6/20/2005	0.6	0.65	0.05	0.016	0.002	0.006	0.01	0.019		0.4	0.9	4	11.3
MAGGIO	8/25/2005	0.71	0.68	0.08	0.016	0.002	0.006	0.01	0.016	0.68	1.4	4	3.1	15.2
MCQUIRES	6/20/2005	0.66	0.69	0.05	0.016	0.002	0.022	0.06	0.074		2.2	1.7	2.7	2.9
MCQUIRES	8/22/2005	0.62	0.75	0.05	0.016	0.002	0.006	0.01	0.038	0.71	5.6	22.6	1.5	10.5
BOUNDS	3/25/2005	0.67	2.5	0.1	0.016	0.001	0.006	0.01	0.014		0.1	4.2	1.8	18.8
BOUNDS	6/20/2005	0.69	0.77	0.08	0.016	0.002	0.006	0.01	0.028		1.7	5	1.5	15.2
BOUNDS	8/22/2005	0.96	1.3	0.11	0.016	0.002	0.006	0.01	0.036	1.08	3.3	32.4	1.7	21.7

Appendix 2. Results of low-level nutrient analyses in water samples collected from razorback sucker grow-out ponds during 2005.

Site Name	Date	KJEL filtered mg/l	KJEL unfiltered mg/l total	NH3 mg/l	NO3 mg/l	NO2 mg/l	OrthoP mg/l	P filtered mg/l	P unfiltered mg/l total	TotalN mg/l	Pheo-a ug/l	Chloro-a ug/l	Secchi depth (m)	N:P
PETERS Inflow	7/18/2005	0.56	0.52	0.01	0.847	0.008	0.006	0.01	0.061					143
PETERS Inflow	8/23/2005	0.38	0.52	0.01	1.21	0.003	0.003	0.02	0.124	1.5	2.7	3.5		407
PETERS 1	5/31/2005	0.42	0.65	0.01	0.013	0.001	0.006	0.01	0.099		4.5	13.1	0.31	3.8
PETERS 1	7/18/2005	0.71	0.63	0.1	0.341	0.015	0.006	0.01	0.041		1.5	2.6	0.51	73.5
PETERS 1	8/23/2005	0.36	0.57	0.02	0.864	0.009	0.012	0.01	0.055	1.25	4	12.5	0.31	73.7
PETERS 2	5/31/2005	0.56	0.6	0.06	0.044	0.003	0.006	0.02	0.067		3	5.2	0.37	17
PETERS 2	8/23/2005	0.45	0.57	0.01	0.444	0.01	0.006	0.01	0.048	0.89	4.2	9.9	0.46	76
PETERS 3	5/31/2005	0.45	0.59	0.03	0.064	0.003	0.006	0.01	0.072		3.5	8.3	0.31	16
PETERS 3	7/18/2005	0.59	0.51	0.04	0.48	0.01	0.006	0.01	0.052		1.6	2.9		86.2
PETERS 4	5/31/2005	0.41	0.68	0.01	0.008	0.001	0.006	0.01	0.08		6.3	29.9	0.31	3
PETERS 4	7/18/2005	0.51	0.51	0.05	0.557	0.013	0.006	0.01	0.045		1.8	2.2	0.37	101.5
PETERS 4	8/23/2005	0.37	0.51	0.01	0.826	0.009	0.012	0.01	0.052	1.21	2.3	6.2	0.46	69.8
VANWAG N	4/20/2005	0.37	0.75	0.01	0.016	0.002	0.006	0.01	0.099		2.5	10.5		4
VANWAG N	6/22/2005	0.38	0.91	0.01	0.016	0.002	0.045	0.07	0.2		9.4	19.2	0.61	0.58
VANWAG N	8/24/2005	0.61	1.8	0.01	0.016	0.002	0.006	0.02	0.136	1.63	13.8	86.4	0.37	4.3
VANWAG S	4/20/2005	0.58	1	0.01	0.016	0.002	0.006	0.01	0.069		2.7	15.1		3.8
VANWAG S	6/22/2005	0.42	1.3	0.01	0.016	0.002	0.006	0.01	0.082		0.7	2.5	0.61	3.5
VANWAG S	8/24/2005	0.73	1.7	0.05	0.016	0.001	0.006	0.01	0.083	1.51	11.7	50.6	0.61	10.7

Appendix 2. Results of low-level nutrient analyses in water samples collected from razorback sucker grow-out ponds during 2005.

Site Name	**Date**	**KJEL filtered mg/l**	**KJEL unfiltered mg/l total**	**NH3 mg/l**	**NO3 mg/l**	**NO2 mg/l**	**OrthoP mg/l**	**P filtered mg/l**	**P unfiltered mg/l total**	**TotalN mg/l**	**Pheo-a ug/l**	**Chloro-a ug/l**	**Secchi depth (m)**	**N:P**
HEUTON	4/21/2005	0.38	0.64	0.01	0.016	0.002	0.006	0.01	0.067		4	18.1		2.7
HEUTON	6/22/2005	0.39	0.45	0.01	0.016	0.002	0.006	0.01	0.042		2.4	5	1.5	4.3
HEUTON	8/24/2005	0.37	0.39	0.01	0.016	0.002	0.006	0.02	0.043	0.36	4.2	8	1.1	4.3
CLYMERS	4/21/2005	0.48	0.45	0.01	0.009	0.001	0.02	0.04	0.073		0.2	0.5		1.1
CLYMERS	6/22/2005	0.45	0.44	0.01	0.016	0.002	0.006	0.01	0.018		0.6	1	1.2	3.7
CLYMERS	8/23/2005	0.49	0.51	0.01	0.016	0.001	0.006	0.01	0.019	0.51	1.2	3.3	1.1	3.8

Appendix 3. Summary of trophic status indices for total phosphorus, chlorophyll-a, and secchi-disk measurements in grow-out ponds from March through August, 2005

		Total Phosphorus		**Chlorophyll-a**		**Secchi disk**	
Site Name	**Date**	**TSI**	**Classification**	**TSI**	**Classification**	**TSI**	**Classification**
CDOT	3/25/2005	38.7	Oligotrophic	29.6	Oligotrophic	41.3	Mesotrophic
CDOT	6/21/2005	45.8	Mesotrophic	68.6	Eutrophic	44.8	Mesotrophic
CDOT	8/22/2005	44.1	Mesotrophic	44.4	Mesotrophic	44.8	Mesotrophic
MCQUIRE	6/20/2005	66.2	Eutrophic	35.8	Oligotrophic	45.8	Mesotrophic
MCQUIRE	8/22/2005	56.6	Eutrophic	61.2	Eutrophic	53.8	Eutrophic
BOUNDS	3/25/2005	42.2	Mesotrophic	44.7	Mesotrophic	51.3	Eutrophic
BOUNDS	6/20/2005	52.2	Eutrophic	46.4	Mesotrophic	53.9	Eutrophic
BOUNDS	8/22/2005	55.8	Eutrophic	46.4	Mesotrophic	52.6	Eutrophic
MORSE	3/23/2005	53.2	Eutrophic	32.4	Oligotrophic	61.3	Eutrophic
MORSE	6/20/2005	41.1	Mesotrophic	23.8	Oligotrophic	53.9	Eutrophic
MORSE	8/25/2005	51.1	Eutrophic	41	Mesotrophic	57.1	Eutrophic
MAGGIO	3/23/2005	45.8	Mesotrophic	33.2	Oligotrophic	40.2	Mesotrophic
MAGGIO	6/20/2005	46.6	Mesotrophic	29	Oligotrophic	40.2	Mesotrophic
MAGGIO	8/25/2005	44.1	Mesotrophic	44.2	Mesotrophic	43.9	Mesotrophic
ELAM	3/24/2005	45	Mesotrophic	35.2	Oligotrophic	51.3	Eutrophic
ELAM	6/21/2005	67.2	Eutrophic	28.4	Oligotrophic	52.6	Eutrophic
ELAM	8/25/2005	64.3	Eutrophic	71.6	Eutrophic	52.8	Eutrophic
BESWICK	3/24/2005	40	Mesotrophic	23.8	Oligotrophic	47.2	Mesotrophic
BESWICK	6/21/2005	52	Eutrophic	38.3	Oligotrophic	50.1	Eutrophic
BESWICK	8/25/2005	51	Eutrophic	47	Mesotrophic	49.1	Mesotrophic
CLYMERS	4/21/2005	66	Eutrophic	23.8	Oligotrophic		
CLYMERS	6/22/2005	45.8	Mesotrophic	30.6	Oligotrophic	57.1	Eutrophic
CLYMERS	8/23/2005	46.6	Mesotrophic	42.3	Mesotrophic	59.1	Eutrophic
PETERS Inflow	7/18/2005	63.4	Eutrophic		--		--
PETERS Inflow	8/23/2005	73.7	Eutrophic	42.9	Mesotrophic		--
PETERS 1	5/31/2005	70.4	Eutrophic	55.8	Eutrophic	77.1	Eutrophic
PETERS 1	7/18/2005	57.7	Eutrophic	40	Mesotrophic	69.9	Eutrophic
PETERS 1	8/23/2005	99.3	Eutrophic	55.4	Eutrophic	77.1	Eutrophic
PETERS 2	5/31/2005	60.6	Eutrophic	46.8	Mesotrophic	74.5	Eutrophic
PETERS 2	8/23/2005	60	Eutrophic	53.1	Eutrophic	71.3	Eutrophic

Appendix 3. Summary of trophic status indices for total phosphorus, chlorophyll-a, and secchi-disk measurements in grow-out ponds from March through August, 2005

		Total Phosphorus		Chlorophyll-a		Secchi disk	
Site Name	**Date**	**TSI**	**Classification**	**TSI**	**Classification**	**TSI**	**Classification**
PETERS 3	5/31/2005	65.8	Eutrophic	51.4	Eutrophic	77.1	Eutrophic
PETERS 3	7/18/2005	61.1	Eutrophic	41	Mesotrophic		
PETERS 4	5/31/2005	67.3	Eutrophic	63.9	Eutrophic	77.1	Eutrophic
PETERS 4	7/18/2005	59	Eutrophic	38.3	Oligotrophic	74.5	Eutrophic
PETERS 4	8/23/2005	61.1	Eutrophic	48.5	Mesotrophic	71.3	Eutrophic
HEUTON	4/21/2005	64.8	Eutrophic	59	Eutrophic		--
HEUTON	6/22/2005	58.1	Eutrophic	46.4	Mesotrophic	53.9	Eutrophic
HEUTON	8/24/2005	58.4	Eutrophic	51	Eutrophic	59.1	Eutrophic
VANWAG N	4/20/2005	70.4	Eutrophic	53.7	Eutrophic		--
VANWAG N	6/22/2005	47.3	Mesotrophic	59.6	Eutrophic	67.1	Eutrophic
VANWAG N	8/24/2005	75	Eutrophic	74.3	Eutrophic	74.5	Eutrophic
VANWAG S	4/20/2005	65.2	Eutrophic	59	Eutrophic		
VANWAG S	6/22/2005	58	Eutrophic	46.4	Mesotrophic	67.1	Eutrophic
VANWAG S	8/24/2005	58.4	Eutrophic	51	Eutrophic	67.1	Eutrophic

Appendix 4. Major ion and total dissolved solid concentrations in razorback sucker grow-out ponds during 2005.

Site Name	Date	Temp C	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	Alk mg/L	Cl mg/L	F mg/L	SiO2 mg/L	SO4 mg/L	TDS mg/L
CDOT	3/25/2005	9.2	13.4	28.2	2.76	694	794	295	4.3	11.3	463	1990
CDOT	6/21/2005	21.9	11.2	30.8	2.68	670	783	296	4.3	6.87	473	1960
CDOT	8/22/2005	23.6	10.8	27.6	2.64	696	805	308	4.2	8.78	478	2020
MCGUIRE	6/20/2005	21.4	382	232	7.83	248	205	246	0.6	19.3	1720	
MCGUIRE	8/22/2005	22.8	320	210	7.13	226	200	230	0.5	18.1	1530	2670
BOUNDS	3/25/2005	9.7	504	508	13.4	539	176	477	0.6	7.99	3220	5370
BOUNDS	6/20/2005	23.1	490	564	13.2	573	126	529	0.5	6.91	3510	5770
BOUNDS	8/22/2005	23.4	524	594	15.5	634	96	563	0.6	6.29	3780	6170
MORSE	3/23/2005	8.5	230	174	12.3	438	128	353	0.9	0.87	1410	2690
MORSE	6/20/2005	18	194	177	7.26	419	63	357	0.8	4.96	1430	2630
MORSE	8/25/2005	21.3	201	166	11.2	407	94	350	0.9	1.13	1380	2580
MAGGIO	3/23/2005	9.7	418	544	13.8	729	180	492	0.7	6.77	3620	5930
MAGGIO	6/20/2005	21.7	403	578	12.5	784	144	515	0.7	7.9	3720	6110
MAGGIO	8/25/2005	23.6	390	557	12.7	795	105	511	0.6	6.78	3790	6130
ELAM	3/24/2005	10.2	40.2	150	17.1	782	287	904	0.8	0.6	730	2800
ELAM	6/21/2005	24.3	20.2	168	18	814	282	1030	0.9	8.51	810	3040
ELAM	8/25/2005	23	21.5	169	20.2	932	298	1140	0.8	7.12	871	3340
BESWICK	3/24/2005	10.6	49.8	350	16.6	954	299	843	0.7	2.8	1840	4230
BESWICK	6/21/2005	23.7	39.1	369	15.8	936	291	866	0.8	8.15	1870	4280
BESWICK	8/25/2005	24.1	34.6	374	16.6	987	335	919	0.9	10.8	1950	4490
CLYMERS	4/21/2005	11.7	76	25.4	4.22	58.6	138	14.2	0.4	12	231	504
CLYMERS	6/22/2005	24.6	67.8	38.9	3.11	93.9	99	23.5	0.5	12.2	377	677
CLYMERS	8/23/2005	23.6	93.6	41.2	3.98	107	152	24.2	0.7	19.4	416	797
PETERS Inflow	7/18/2005	23.5	110	33.5	3.3	49	154	7.57	0.4	10.3	329	640
PETERS Inflow	8/23/2005	20.9	138	39.5	3.94	62.5	160	8.41	0.5	14.2	411	
PETERS 1	5/31/2005	20.4	39.4	11.3	2.11	15.3	85	2.52	0.2	12	81.1	215
PETERS 1	7/18/2005	27.3	96.3	29.5	3.22	42.9	141	6.5	0.4	10.7	280	556
PETERS 1	8/23/2005	22.5	133	39.5	4.05	63.2	159	8.57	0.5	11.9	395	
PETERS 2	5/31/2005	19.8	46.3	12.6	2.76	17.1	103	3.18	0.2	13.3	88.5	246
PETERS 2	8/23/2005	23.2	118	38.6	4.16	61.6	145	8.64	0.5	8.56	388	718

Appendix 4. Major ion and total dissolved solid concentrations in razorback sucker grow-out ponds during 2005.

Site Name	Date	Temp C	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	Alk mg/L	Cl mg/L	F mg/L	SiO2 mg/L	SO4 mg/L	TDS mg/L
PETERS 3	5/31/2005	18.7	42.3	12.2	2.35	15.8	93	2.69	0.2	10.9	83.8	226
PETERS 3	7/18/2005	26.2	99.6	31.7	3.13	45.7	139	7.17	0.4	7.06	302	582
PETERS 4	5/31/2005	18.1	40	11.7	2.02	15.5	83	2.56	0.2	11.1	84.7	218
PETERS 4	7/18/2005	25	105	33.1	3.27	48.2	145	7.34	0.4	9.23	322	618
PETERS 4	8/23/2005	22	131	39.1	3.94	63.2	162	8.56	0.5	11.4	401	
HEUTON	4/21/2005	11	78	18.2	5.3	115	146	149	0.3	7.83	133	595
HEUTON	6/22/2005	20.2	26.5	13	1.43	56.8	75	71.4	0.2	0.59	64.7	279
HEUTON	8/24/2005	19.4	54.4	13.8	2.88	76.6	122	106	0.3	2.67	82.9	413
VANWAG N	4/20/2005	13.3	66.6	18.6	4.27	94.7	145	109	0.3	8.28	116	504
VANWAG N	6/22/2005	21.7	37.2	10.5	2.71	26.6	111	29.4	0.2	6.81	39.9	220
VANWAG N	8/24/2005	23.3	32.3	12.8	4.7	62.9	79	86	0.2	8.79	74.2	329
VANWAG S	4/20/2005	14.3	62.8	19.6	5.23	107	160	129	0.4	1.34	135	557
VANWAG S	6/22/2005	22.6	35.5	16.3	3.71	63.6	94	78.3	0.3	3.48	85.2	343
VANWAG S	8/24/2005	23.9	28.2	13.6	3.77	57.1	80	71	0.2	6.89	67.8	296

Appendix 5. Metal concentrations in water samples (ug/L) from razorback suckers grow-out ponds during 2005.

Site Name	Date	Cd	Cu	Fe total	Pb	Mn (dis.)	Mn total	Se	Ag (dis.)	Zn	Hardness mg/L as CaCO3
CDOT	3/25/2005	0.05	2.4	60	0.13	0.6	4.6	1.2	0.4	2	149
CDOT	6/21/2005	0.06	2.6	80	0.34	0.5	4.7	0.6	0.4	3.3	154
CDOT	8/22/2005	0.05	2.7	30	0.15	0.8	2.9	1.4	0.4	2.7	140
MCGUIRE	6/20/2005	0.12		50	0.11	500	428	2.2	0.4	4.2	1906
MCGUIRE	8/22/2005	0.12	7.5	20	0.18	0.8	309	1.9	0.4	6.9	1661
BOUNDS	3/25/2005	0.06	9.8	60	0.12	8.8	18.5	4.6	0.6	10.3	3343
BOUNDS	6/20/2005	0.06	9.5	70	0.39	12.6	17.8	2.7	0.6	14.3	3537
BOUNDS	8/22/2005	0.12	16	130	0.47	23.4	143	0.3	0.6	15	3745
MORSE	3/23/2005	0.08	4.7	90	0.14	30.7	34.1	2.2	0.4	5.6	1288
MORSE	6/20/2005	0.04	4.1	80	0.12	17.5	21.4	1.5	0.4	2.9	1211
MORSE	8/25/2005	0.08	7.8	70	0.08	63.1	82.4	2.1	0.4	4	1183
MAGGIO	3/23/2005	0.17	11.1	40	0.24	57.5	76.1	7.9	0.6	11.7	3275
MAGGIO	6/20/2005	0.15	8.9	40	0.24	20.3	55.9	6.5	0.6	8.2	3377
MAGGIO	8/25/2005	0.17	13.9	30	0.74	73.4	136	6.8	0.6	9.7	3259
ELAM POND	3/24/2005	0.05	3.5	30	0.19	2	7.1	1.6	0.4	4	716
ELAM POND	6/21/2005	0.12	5.9	20	0.29	10.4	22.9	1.5	0.6	4.4	739
ELAM POND	8/25/2005	0.12	10.6	10	0.24	2.7	6.8	2.4	0.6	10.3	747
BESWICK	3/24/2005	0.08	5.3	40	0.24	7.4	19.9	3.4	0.6	5.6	1560
BESWICK	6/21/2005	0.12	1.8	50	0.24	1.6	88.1	2	0.6	2.2	1611
BESWICK	8/25/2005	0.06	6.7	20	0.16	24	33.7	3.2	0.6	4.6	1620
CLYMERS	4/21/2005	0.04	1.3	300	0.08	64	76.3	2.2	0.2	1	294
CLYMERS	6/22/2005	0.14	16.6	40	0.38	11.8	38.8	1.4	0.2	27.1	329
CLYMERS	8/23/2005	0.04	1.9	30	0.18	7.7	42.8	1.4	0.2	0.41	403
PETERS Inflow	7/18/2005	0.04	2.7	470	0.06	8.8	42.6	5.9	0.2	1.8	412
PETERS Inflow	8/23/2005	0.02	3	1380	0.05	5.4	68	5.4	0.2	1.4	507
PETERS 1	5/31/2005	0.04	1.8	680	0.08	2.4	36.4	1.7	0.2	0.9	145
PETERS 1	7/18/2005	0.04	2.5	280	0.06	3.8	20.8	4.2	0.2	1.3	362
PETERS 1	8/23/2005	0.04	3.2	450	0.08	0.7	16.8	5.1	0.2	2.2	366
PETERS 2	5/31/2005	0.04	1.8	460	0.08	5.3	26.4	1.6	0.2	1	167
PETERS 2	8/23/2005	0.04	3	230	0.23	0.5	21.2	5.9	0.2	2.4	453
PETERS 3	5/31/2005	0.04	1.9	710	0.08	2.1	30.1	2.1	0.2	0.8	156
PETERS 3	7/18/2005	0.04	2.9	430	0.04	1.4	14.8	5.2	0.2	1.1	379
PETERS 4	5/31/2005	0.04	1.9	590	0.08	5.8	38	1.5	0.2	1.8	148
PETERS 4	7/18/2005	0.04	3.7	350	0.1	4.2	25.1	5.3	0.2	1.9	398

Appendix 5. Metal concentrations in water samples (ug/L) from razorback suckers grow-out ponds during 2005.

Site Name	Date	Cd	Cu	Fe total	Pb	Mn (dis.)	Mn total	Se	Ag (dis.)	Zn	Hardness mg/L as CaCO3
PETERS 4	8/23/2005	0.04	3.3	350	0.23	0.9	15.2	5.3	0.2		488
HEUTON	4/21/2005	0.05	1.9	110	0.05	2.4	9.3	1.1	0.2	1.8	270
HEUTON	6/22/2005	0.03	2.2	120	0.27	1.3	3.5	0.5	0.2	5.5	120
HEUTON	8/24/2005	0.04	1.1	260	0.21	5.2	12.3	0.42	0.2	2.4	193
VANWAG N	4/20/2005	0.02	1	580	0.05	7.5	51.3	1	0.2	2.9	243
VANWAG N	6/22/2005	0.04	2.2	300	0.14	1.1	54.9	0.5	0.2	1.2	136
VANWAG N	8/24/2005	0.03	10.2	250	0.27	0.7	41	0.33	0.2	8.8	133
VANWAG S	4/20/2005	0.03	2.2	300	0.23	1	25.9	1	0.2	1.3	237
VANWAG S	6/22/2005	0.03	0.9	150	0.04	0.2	19.6	0.9	0.2	0.7	156
VANWAG S	8/24/2005	0.04	0.7	100	0.09	0.5	19.4	0.42	0.2	0.9	126

Appendix 6. Trace element concentrations (mg/kg) in sediment samples collected from razorback sucker grow-out ponds during 2005.

Sample Site	Collection Date	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Si	Sr	Ti	V	Zn
CDOT	7/22/2005	11500	4.8	3.14	167	0.55	33700	0.321	5.92	12.8	8.86	17000	< 0.0253	2160	7390	362	1.38	1920	10.3	526	14.8	3210	0.187	471	196	112	30	49.1
CDOT	7/22/2005	14900	5.44	3.54	215	0.642	34400	0.324	6.76	13.9	10.6	19300	< 0.0247	2640	7810	356	1.2	2480	11	489	14.9	2790	0.191	627	217	104	34.5	53.3
MCGUIRE	7/22/2005	7060	6.54	4.66	107	0.385	77700	1.09	5.03	10.5	10.8	12700	< 0.0253	1490	7500	1140	12.2	1590	11.6	540	49.4	6490	1.67	275	279	124	25.9	114
MCGUIRE	7/22/2005	7050	6.85	3.56	101	0.413	74700	1.16	5.34	11.1	10.9	13000	< 0.0242	1590	7610	1070	11.8	1220	12.1	569	54.9	6660	1.65	295	261	125	26.3	132
BOUNDS	7/22/2005	7760	10.2	6.58	141	0.459	40300	0.714	6.3	12.3	11.3	14200	< 0.0248	1700	8410	403	2.68	1900	12.5	527	43.7	4130	0.612	306	158	149	35.2	96.6
BOUNDS	7/22/2005	8180	14.8	6.94	148	0.45	46700	0.701	6	14.7	14.5	15500	< 0.0247	1580	9910	436	2.64	2420	14.6	665	56.8	3320	0.707	163	175	132	30.8	87.2
MORSE	7/28/2005	14600	7.36	14.4	166	0.694	58100	0.36	6.33	18.4	23.8	17400	< 0.0244	3730	11100	261	2.22	1020	16.5	705	11.1	5590	0.826	721	177	138	46.6	58.8
MORSE	7/28/2005	16000	7.62	16.8	186	0.778	59900	0.325	6.69	19.9	16.9	18500	< 0.0256	4050	10400	276	2.32	1170	17.4	728	12.2	5080	0.857	546	173	122	51.1	63.4
MAGGIO	7/25/2005	9080	6.62	5.86	107	0.509	63300	0.463	4.88	14	9.53	14900	< 0.0253	1850	8980	397	12.5	2770	13.1	912	12	6090	4.9	193	408	135	27.8	41.6
MAGGIO	7/25/2005	8300	5.66	6.53	102	0.427	55000	0.433	5.01	11.3	9.43	14000	< 0.025	1630	6640	340	13.8	2020	12.2	588	15.8	5440	5.99	276	439	232	31.4	42.4
ELAM	7/25/2005	11100	8.33	5.07	182	0.614	51200	0.632	6.52	14.5	13.2	17000	< 0.0252	2320	9460	400	2.38	2190	14.5	585	24.4	3830	0.792	398	212	129	33.3	82
ELAM	7/25/2005	9140	7.38	4.27	163	0.532	52400	0.502	5.4	12.4	11.4	15200	< 0.0244	1980	9160	359	2.23	1920	12.9	599	21.6	3930	0.728	354	213	93.3	29.7	73.9
BESWICK	7/28/2005	8800	5.4	4.31	148	0.414	36400	0.811	4.5	14.5	6.56	13700	< 0.0238	1470	6970	331	2.64	2290	10.7	513	41.3	3410	0.435	236	148	249	27.4	106
BESWICK	7/28/2005	5700	4.75	4.04	127	0.293	30700	0.849	3.95	9.01	7	11400	< 0.025	1170	5970	273	2.64	1970	8.39	447	36	2980	0.348	190	148	237	21.2	91.7
CLYMERS	7/25/2005	6580	4.12	4.23	88.3	0.341	96100	0.362	5.08	6.82	16	13500	< 0.024	1480	4480	456	3.56	702	8.35	511	7.54	7640	5.74	239	644	390	31.1	38.9
CLYMERS	7/25/2005	6690	4.56	5.84	93.6	0.371	108000	0.368	5.61	7.35	21.6	14500	< 0.025	1590	4590	485	4.17	688	9.23	488	7.68	7650	6.27	303	715	343	32.6	42.5
PETER1	7/18/2005	12000	3.86	4.04	255	0.793	35800	0.315	6.16	10.4	20.6	17600	< 0.0245	2520	6330	315	0.98	581	9.49	623	11.8	477	0.787	719	129	230	38.8	56
PETER1	7/18/2005	11100	3.75	1.97	195	0.768	37000	0.303	5.61	9.32	20	15400	< 0.0246	2380	6180	301	0.98	496	9.13	587	11.7	503	0.873	681	126	109	30.5	52.9
PETER2	7/18/2005	13100	3.82	4.99	255	0.987	37900	0.292	5.46	8.93	18.2	14300	< 0.0251	2790	6100	319	1	565	7.97	537	12	587	0.77	1190	144	95.5	27.9	45.8
PETER2	7/18/2005	17500	3.78	5.84	285	1.17	40600	0.252	5.83	10.4	18.7	16000	< 0.0247	3480	7320	365	0.99	579	8.63	586	12	578	0.906	1170	148	134	31.8	50.6
PETER3	7/18/2005	16000	2.21	6.3	205	1.03	31700	0.254	4.23	7.62	16.4	10900	< 0.0245	3660	5140	171	0.98	257	6.73	361	10.3	392	0.855	1100	116	20.4	18.9	35
PETER3	7/18/2005	13100	2.52	2.73	203	0.941	30900	0.243	4.22	6.9	18.8	10700	< 0.0252	3060	4910	191	1.01	234	6.97	369	10.9	467	1.06	594	112	6.91	16.7	36.8
PETER4	7/18/2005	13500	3.47	4.91	176	0.899	36800	0.358	4.45	8.65	15.6	11900	< 0.0249	3240	5950	244	0.99	247	8.7	440	12.3	629	1.64	471	112	20.9	21.2	46.3
PETER4	7/18/2005	12900	3.13	4.49	185	0.869	34500	0.36	4.07	7.8	16.9	11400	< 0.0248	2950	5240	239	0.99	264	7.58	394	10.8	684	1.26	1120	109	20.6	20	40.8

Appendix 7. Trace element concentrations (ug/g DW) in zooplankton (ZP) and benthic invertebrate (BI) samples collected in razorback sucker grow-out ponds during 2005.

Site	Invert.	Month	Dry Wt.	% Moist.	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Na	Ni	Pb	S	Se	Sr	V	Zn
CDOT	ZP	June	27.6	98.1	2670	3.2	21.8	71.6	0.1	20200	0.99	1.2	124	25.7	3150	0.14	5240	75.5	6.4	48800	4.6	2.9	15100	2.5	480	4.8	206
CDOT	ZP	June	23.7	96.7	2120	2.1	11.5	51.3	0.09	13600	2.4	0.9	53.1	25.6	2740	0.12	3410	63.9	3.6	22500	2.9	2.2	9690	2.7	309	3.6	378
CDOT	ZP	August	99.6	93.9	163	2.5	8.4	4.81	<0.05	1640	0.71	<0.47	0.97	12.3	317	0.09	2180	19	1	23300	<0.47	0.28	11100	2.7	30.5	<0.95	127
CDOT	ZP	August	70	95.7	178	2	13.9	6.3	<0.05	2030	0.63	<0.5	4.5	12	376	0.11	2920	17.1	1.5	40900	0.65	0.54	14700	2.3	43.8	<1	160
MCGUIRE	ZP	June	25.2	97.4	1500	4.6	23.6	41.4	0.08	87200	0.41	0.96	67.6	24.5	2150	0.05	11600	422	5	14200	4	3.2	30200	3.8	476	4	116
MCGUIRE	ZP	August	37.3	96.5	1720	2.4	13.1	30.8	0.05	21300	0.3	0.92	96.5	13.1	2050	<0.03	7190	215	5.2	8360	3.8	1.3	20100	2.6	159	4.1	91.5
MCGUIRE	ZP	August	24.3	97.7	1000	2.2	21.9	90.3	<0.05	22900	0.36	0.63	70	18.8	1160	<0.03	10000	203	4.9	12700	2.8	1.3	28200	2.8	195	2.2	101
MCGUIRE	ZP	June	25.2	97.4	1500	4.6	23.6	41.4	0.08	87200	0.41	0.96	67.6	24.5	2150	0.05	11600	422	5	14200	4	3.2	30200	3.8	476	4	116
BOUNDS	ZP	June	23.2	97.9	714	4.8	44.4	21.1	<0.05	71000	0.4	<0.51	22.8	13.1	2210	0.05	25800	336	2.5	30600	2.2	3.1	74200	2.6	568	2.2	111
BOUNDS	ZP	June	21.9	98	945	4.1	42.4	32.1	0.06	74200	0.34	0.67	70.6	25	2410	<0.02	25300	204	4.7	28500	2.7	4.3	83700	1.7	649	3.5	93.7
BOUNDS	ZP	August	15.1	98.4	616	2.8	51.6	16.7	0.05	82300	0.32	<0.45	1.5	16.8	1170	<0.02	30300	139	1.3	33300	1.2	3.4	106000	1.1	772	2.1	83.1
BOUNDS	ZP	August	14.9	97.2	1200	9	43.3	31.3	0.07	67200	1.4	0.95	1.7	15	3820	<0.03	22400	1650	1.4	22200	1.9	5	58100	1.9	577	4.5	135
MORSE	ZP	June	16	95.2	1730	2	27.2	36.6	0.07	20500	3	2.4	10.3	44.7	2250	0.08	6070	105	2.5	12400	2.1	2.5	17100	2.7	251	5.1	338
MORSE	ZP	August	3.2	98	4400	2.9	37	69.8	0.2	26600	1	2.3	69.3	51	5640	<0.04	7770	249	3.5	10500	9.2	5.5	22200	1.5	331	12.3	266
MORSE	ZP	August	2	96.8	1040	1.2	18.7	38.1	<0.2	16300	0.85	<2	37.1	21.3	2410	<0.05	3710	92.2	<3.9	5450	3.1	2.5	11400	<0.94	208	<3.9	301
MAGGIO	ZP	June	1.8	93.5	3620	2.5	19.5	79.5	0.19	109000	0.97	1.9	7.8	30.6	6650	<0.02	6780	188	5.8	6390	6.8	7.9	40400	2	149	14.2	91.8
MAGGIO	ZP	June	7.3	97.5	2830	3.1	51.7	61.4	0.15	110000	2.3	1.1	56.3	44.6	3490	<0.03	22200	120	9.4	31000	5.4	6.4	84200	4	136	6.5	122
MAGGIO	ZP	August	4.7	97.3	2950	1.9	41.5	43.2	0.14	66400	0.6	1.2	310	20.2	4340	<0.03	22600	108	14	32100	9.11	19.4	76700	4.2	695	7.1	110
ELAM	ZP	June	15.2	95	530	1.4	9.4	20	<0.05	5430	1.1	0.57	6.5	22.4	1180	0.07	6040	92.4	1.3	20500	1	2.3	11800	2.2	28.9	1.4	254
ELAM	ZP	August	3.7	98.8	7230	3.6	34.5	118	0.39	37200	1.3	4.2	10.3	44	12000	<0.05	16900	353	<4.2	26600	10.1	20.1	9670	<1	161	16	221
ELAM	ZP	August	1.6	95.6	8670	5.9	31.4	198	0.49	35000	2	4.6	11.9	34.1	16800	<0.04	14700	407	<1.8	11100	11.8	21.7	6010	1.4	130	19.9	387
BESWICK	ZP	June	22.7	97.1	810	1.5	23.5	25.8	<0.05	6720	3.8	0.73	8.4	18.2	1370	0.07	13300	131	1.8	36000	1.2	5.4	27600	2.2	51.7	1.8	257
BESWICK	ZP	August	21.1	96.7	593	1.3	23.6	16.3	<0.05	6120	2.9	0.54	20.2	17.6	1290	0.05	14200	115	2.6	32600	1.6	6.3	25800	3.7	51	1.4	239
BESWICK	ZP	August	11.2	97.4	1390	2	39.1	42.5	0.06	10200	2	1.1	53.8	32.3	3130	0.03	14600	162	3.7	33500	3.7	6.3	25600	2.9	68.1	3.3	180
CLYMER	ZP	June	52	98.6	1870	2.2	19.9	41.4	0.08	30100	0.62	0.89	35.7	75	2520	0.08	5020	160	2.3	9060	4.4	12.3	17600	6.8	422	4.5	261
CLYMER	ZP	June	52.4	96.6	1140	3.9	9.6	25.4	0.06	18800	0.46	0.65	0.97	21.4	1480	0.12	2760	201	<0.99	5580	1.2	1.7	11800	9.4	231	2.9	129
CLYMER	ZP	August	11.2	98.3	3980	3	36.5	92.2	0.19	40200	1.6	1.7	69.1	23.3	5220	0.05	5900	1340	3.4	9030	5.4	4.7	16800	7.5	473	10.2	224
CLYMER	ZP	August	5.9	98.8	11600	3	33.6	163	0.5	23100	3.2	6.3	661	46	16400	0.06	6710	1180	22.3	5900	23.4	12.6	11200	5.7	289	28.8	313
PETER1	ZP	June	185.1	95.8	825	3.4	4.2	30.4	0.05	35600	0.51	<0.49	1.8	15.9	842	0.06	1920	55.4	<0.97	2400	0.72	1.2	7730	4.5	315	1.7	118
PETER1	ZP	June	207.2	96	506	3.7	3.1	21.1	<0.05	24600	0.31	<0.47	1.9	9.36	545	0.05	1750	39.9	<0.95	2920	0.52	0.55	7480	5	213	1.1	95.2
PETER1	ZP	August	173.9	97.5	855	4.6	6.3	14.7	<0.05	15800	0.83	<0.5	2.5	14.5	773	0.09	2710	30.3	<1	5080	1.1	0.86	11700	4.4	124	1.8	129

Appendix 7. Trace element concentrations (ug/g DW) in zooplankton (ZP) and benthic invertebrate (BI) samples collected in razorback sucker grow-out ponds during 2005.

Site	Invert.	Month	Dry Wt.	% Moist.	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Na	Ni	Pb	S	Se	Sr	V	Zn
PETER1	ZP	August	166.5	97	872	3.7	8.41	17	0.05	12700	0.91	0.6	1.8	15.8	819	0.12	3730	33.3	<1	6480	0.78	0.91	14700	4.7	119	2	151
PETER2	ZP	June	239.9	96	1340	5.33	5.1	36.5	0.08	37800	0.79	0.71	2.1	16.6	1170	0.07	2230	51.8	<0.95	4530	1.3	1.2	9030	6	237	2.4	113
PETER2	ZP	June	241	97.2	1470	4.4	4.5	39.3	0.09	52400	0.94	0.65	1.5	14.5	1240	0.05	2180	47.3	<0.96	3090	1.1	1.2	7880	5.6	278	2.5	105
PETER2	ZP	August	7.6	97.7	3690	3.3	14.4	64.6	0.17	17900	1.6	1	43.9	41	2570	0.07	3800	52.3	4.4	34100	3.4	4.1	14000	4.9	180	8.2	19100
PETER2	ZP	August	6	98.8	4480	2.1	12.9	69.2	0.23	21800	1.5	2	251	30.4	4640	0.08	2930	105	9.2	2930	8.5	4.3	8390	4.1	171	9.2	899
PETER3	ZP	June	268	97.7	1910	5	5.9	52	0.1	55700	1.1	0.85	3.1	31.1	1620	0.05	2650	86.7	<0.98	4080	1.3	1.8	9350	8.8	303	3.4	150
PETER3	ZP	August	101.2	97.4	720	2.3	9.1	16.5	<0.05	13700	0.87	0.51	6.5	20.5	711	0.06	3630	28.6	1.2	7510	1.1	0.75	15000	6.6	128	1.7	2500
PETER3	ZP	August	131.3	97.1	413	2	8.3	14.4	<0.05	13100	0.99	<0.49	2.2	17.1	519	0.09	3640	24.6	<0.97	6980	0.88	0.5	15000	6	128	1.1	431
PETER4	ZP	June	217.3	95.9	430	3.8	3.4	25.7	<0.05	31300	0.43	<0.49	2.3	12.1	518	0.04	1770	43.8	<0.97	2830	0.55	0.58	8220	4.1	529	1.1	106
PETER4	ZP	August	230.6	97.4	458	5.5	6.8	10.7	<0.05	11200	0.69	<0.51	1	29.6	522	0.07	2980	18.4	<1	6070	0.79	0.5	13200	6.6	110	1.2	120
PETER4	ZP	August	48.8	99.1	3840	3.3	26.5	72.3	0.19	60700	0.88	1.1	28.1	17	3050	0.05	9030	58.2	2.1	12500	3.4	2.7	28800	5.2	537	7.8	163
HEUTON	ZP	June	87.1	99.1	4210	3.8	8.4	83.8	0.21	30000	0.84	2.5	122	25.5	5620	0.15	4110	136	5.3	10100	8.2	6.2	7570	5.5	171	9.8	162
HEUTON	ZP	August	5.5	97.7	7000	3.4	6.9	121	0.4	47800	1.1	4	603	48.6	11100	0.13	4590	118	20.7	2930	18.6	11.4	3780	1.7	214	18.1	290
HEUTON	ZP	August	6.1	98.2	5730	3.2	7.9	96.6	0.29	42100	1.5	2.5	209	37.5	7710	0.1	3560	82	8.8	3210	11.1	14.9	3970	1.8	191	13.6	170
VANWAGN	ZP	June	36.9	95.8	1110	2.1	2.7	33.2	0.05	8360	0.37	0.72	50.6	15.1	1500	0.04	1890	57.6	2.7	2700	2.4	1.7	7220	2.7	49.5	2.9	184
VANWAGN	ZP	June	53	97.5	482	1.8	2.7	35	<0.05	6790	0.32	0.52	17.8	13.1	723	0.03	1710	38.7	1.1	2860	1	0.99	7870	2.5	46.8	1.7	87.3
VANWAGN	ZP	August	10.2	98	3140	2.3	4	71.8	0.15	17600	1.8	1.7	73.7	25.5	3870	0.05	2530	81.2	3.2	3550	5.8	5	6760	2.3	90.4	8.3	159
VANWAGN	ZP	August	3.8	97.9	2410	2	3.3	56.8	0.11	14300	0.92	1.5	6.2	49.3	3680	0.04	2380	60.6	<1.6	2610	4.3	13.5	6460	2.4	65.2	5.4	242
VANWAGS	ZP	June	31.4	95	138	1.7	2.8	26.2	<0.05	7080	0.52	<0.49	7.5	15.2	410	<0.02	1430	20	1.2	3430	0.6	0.7	7770	3.5	51.4	<0.97	86.6
VANWAGS	ZP	August	35.9	98.2	239	1.7	2.7	27.6	<0.05	3510	0.38	<0.52	8.9	14.2	402	<0.03	1860	12.6	<1	5110	0.92	0.71	9240	3.8	41.2	1.1	98
VANWAGS	ZP	August	10	99.1	1130	1.4	6.6	55.4	<0.16	11000	0.84	<1.6	84.7	18.4	2170	<0.04	2320	35.4	4.6	4600	4.3	3.3	7500	3.4	71.7	4.1	136
MCGUIRE	ZP	June	25.2	97.4	1500	4.6	23.6	41.4	0.08	87200	0.41	0.96	67.6	24.5	2150	0.05	11600	422	5	14200	4	3.2	30200	3.8	476	4	116
MCGUIRE	ZP	August	37.3	96.5	1720	2.4	13.1	30.8	0.05	21300	0.3	0.92	96.5	13.1	2050	<0.03	7190	215	5.2	8360	3.8	1.3	20100	2.6	159	4.1	91.5
MCGUIRE	ZP	August	24.3	97.7	1000	2.2	21.9	90.3	<0.05	22900	0.36	0.63	70	18.8	1160	<0.03	10000	203	4.9	12700	2.8	1.3	28200	2.8	195	2.2	101
CDOT	BI	June	4.4	94.4	2710	1.8	13.6	52.3	0.11	5930	0.27	1.8	321	16.3	4900	0.05	2370	94.4	13.7	11800	9.7	2	6030	1	64.2	6.9	118
CDOT	BI	August	4.4	91.7	277	0.94	8.5	4.8	<0.05	1130	0.12	<0.49	4.7	12	344	0.09	1160	16	<0.99	12500	<0.49	0.25	7190	1.3	12.6	<0.99	96.2
MCGUIRE	BI	June	2.7	95.4	930	0.85	9.4	17	<0.09	18200	2.1	<0.92	103	11.6	1280	<0.05	4310	249	5.3	5110	4.5	0.68	11200	2.3	116	2.2	78.6
MCGUIRE	BI	August	3.5	95.3	813	1.1	11.9	12.6	<0.05	22900	0.26	0.88	182	13.1	1650	<0.02	4890	216	8.2	6490	6.9	1	14200	3.1	139	2.4	98.4
BOUNDS	BI	August	1.6	94.2	312	6.3	25.6	17	<0.11	45100	0.35	<1.1	37.4	16.7	2160	0.05	8770	2250	3	11800	2.9	2.1	42200	2.2	385	<2.2	102

Appendix 7. Trace element concentrations (ug/g DW) in zooplankton (ZP) and benthic invertebrate (BI) samples collected in razorback sucker grow-out ponds during 2005.

Site	Invert.	Month	Dry Wt.	% Moist.	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Na	Ni	Pb	S	Se	Sr	V	Zn
MORSE	BI	June	4.3	94.7	1420	1.5	28.2	23.4	0.06	25400	0.1	0.67	53.4	17	1440	0.04	4160	372	3.3	7950	3.5	0.97	12200	2.3	313	4.3	127
MORSE	BI	August	2.7	92.3	792	1.6	15	17.7	<0.05	8100	0.25	0.55	28.8	15.6	940	0.04	2970	47.9	1.5	8360	2.5	0.74	10600	1.7	79	2.6	92.9
MAGGIO	BI	June	4.4	95.6	330	1.1	23.7	8.7	<0.07	35100	0.13	<0.66	14.7	10.3	424	<0.03	9530	65	5	15000	1.7	0.57	34100	5.7	370	<1.3	96.2
MAGGIO	BI	August	2	93.1	842	1.2	25.2	11.5	<0.06	16000	0.39	<0.61	19.4	15.6	1040	<0.03	9430	81.8	2.8	12800	2.2	2.3	24900	5.4	136	2.1	103
ELAM	BI	June	8.9	88.1	61.3	0.73	8.1	8.4	<0.05	1240	0.09	<0.49	1.5	12.8	142	0.05	1830	15.4	<0.98	9610	<0.49	0.15	6400	1.6	4.6	<0.98	81.1
ELAM	BI	August	6.3	91.5	509	1.2	11.4	14.2	<0.05	2680	0.3	0.53	11.2	13.1	750	0.06	3260	33.1	<1	17100	1.6	1.2	8610	2.2	13.6	1.2	99.8
BESWICK	BI	June	9	94.3	301	1.2	15.7	8.2	<0.05	4410	0.43	<0.48	16.4	13.1	487	0.05	6450	88.4	1.3	18600	1.5	2.9	14900	2.8	26.1	<0.96	104
BESWICK	BI	August	6.6	92.8	223	0.99	21.9	6.5	<0.05	1960	0.26	<0.48	6.4	15.6	316	0.1	5080	61.6	<1	16300	0.82	1.1	12600	3.9	11.7	<0.96	117
CLYMERS	BI	June	25.9	83.7	117	2.3	3.5	2.67	<0.05	3340	0.21	1.2	110	34.3	1390	0.07	1840	96.2	3.1	7980	53.3	0.71	6380	6.3	36.7	<1.0	499
CLYMERS	BI	June	4.6	93.9	647	1	7.3	18.3	<0.05	11500	0.12	0.5	28.5	15.6	1030	0.06	1500	230	1.2	5170	2.7	0.73	6980	5.7	118	2	106
CLYMERS	BI	August	5.2	93.2	260	1.2	7.7	6.9	<0.05	6270	0.19	<0.48	5.6	15.9	365	0.04	1600	90	<0.97	5250	0.67	0.3	7600	6.7	68	<0.97	98
PETER1	BI	June	4.1	96.9	3110	2.1	5	39.2	0.16	9790	1.2	3.2	165	22.9	3370	<0.05	1970	75.9	5.9	3340	8.5	2.7	6140	9.1	75.9	5.6	112
PETER1	BI	August	6.7	88.9	2030	1.7	5.1	20.6	0.09	19100	0.47	1.4	9.6	19.5	1390	0.07	1830	29.6	<1	3970	2	1.4	6230	5.9	75.1	3.5	120
PETER2	BI	June	3.5	94.5	6260	1.9	6.3	1530	0.4	9240	1.7	6	507	26.5	7210	0.03	2250	85	18	1570	14	4.1	4580	6.7	63	9.8	94
PETER2	BI	August	4.8	87.7	1140	1.7	3.2	13.9	0.05	8570	0.64	1.2	11.6	23.3	842	0.08	1380	15.3	<1	4940	1.7	0.88	6340	6.3	34.3	2.1	115
PETER3	BI	June	2.3	95.6	3350	1.6	6.1	45.1	0.17	12700	0.86	2.3	211	19.3	4290	0.05	1850	102	7	2020	12.9	2.9	4280	6.6	84.6	7.1	105
PETER3	BI	June	6.3	92	1250	2.8	<3.9	17.4	<0.19	4950	0.64	2.8	23.6	15.8	1400	<0.05	1820	60.7	<3.9	6460	3.3	1.6	6690	9.2	30.7	<3.9	66.3
PETER3	BI	August	2.5	94.2	4500	1.9	5.9	39.1	0.2	11500	1	3.2	275	21.5	4720	0.04	2340	73.8	10.5	3080	10.7	2.7	6650	8.4	66.5	8.6	104
PETER4	BI	June	4.8	95.7	3020	2.4	4.3	32.1	0.13	11000	1.5	2.4	136	22.9	3160	0.06	1950	101	4.9	3740	6	2.2	5970	8.1	124	5.8	111
PETER4	BI	August	4.1	94.2	1010	1.4	3.7	8.7	0.05	5920	0.53	1.9	26	19.5	832	0.05	1440	17.2	1.3	3980	2.2	0.69	6400	7	38.5	2	102
HEUTON	BI	June	4.2	95.3	1160	1.1	2.6	20.5	0.05	8960	0.22	0.94	117	13.7	1900	0.09	1310	27.8	4.9	4440	5.1	1.8	5190	3.2	36.2	3.1	96.8
HEUTON	BI	August	8.6	93.3	764	1.4	1.9	15.5	<0.05	7490	0.55	1.1	17.9	18.6	1050	0.12	1320	30.3	1.2	4410	1.7	1.3	6300	3	22.9	1.9	124
VANWAGN	BI	June	0.9	98.6	1840	2.2	2.9	23.6	0.09	5180	0.56	2.1	55	17.1	1890	0.04	1650	57	2.3	4460	2.7	1.3	5460	8	30.1	3.6	85.7
VANWAGN	BI	August	2.9	88.7	268	0.49	<1.1	3.7	<0.05	2060	2.8	<0.53	16.5	17.1	388	0.06	950	12.6	<1.1	6430	1.4	0.44	5890	1.1	8.07	<1.1	88.3
VANWAGN	BI	August	2.8	90.3	813	0.61	1.2	10.7	<0.06	2780	0.15	<0.56	32.4	17.8	1020	0.06	1200	19.7	1.5	6190	2.8	0.96	5430	1.4	11.8	2.2	86.9
VANWAGS	BI	August	2.3	93.5	425	0.66	10	11.9	<0.05	4520	0.54	<0.54	37.7	12.7	767	0.04	1270	17.1	2.3	3620	2.8	0.53	6400	3	25.6	1.4	95.1

Appendix 8. Selenium concentrations in razorback sucker muscle plugs taken from hatchery fish before spring stocking in grow-out ponds, and during harvest approximately six months later.

Location	Date	ID or Hatch. Lot	MP % Moist.	MP Weight (mg)	MP Se (ug/g)	Fish Length (mm)	Fish Weight (g)	Egg Se[1] (ug/g)
Hatchery	3/17/2005	409	67.9	15	0.77	278	261	0.55
Hatchery	3/17/2005	1-0407	75.6	18.2	0.8	235	137	0.58
Hatchery	3/17/2005	2-0407	72.9	13.7	0.79	273	231	0.57
Hatchery	3/17/2005	401	74	18.7	0.75	248	162	0.53
Hatchery	3/17/2005	1-0408	69.6	13.7	0.76	240	159	0.54
Hatchery	3/17/2005	1-0410	74.2	16.8	0.8	270	239	0.58
Hatchery	3/17/2005	1-0402	74.4	14.7	0.82	257	195	0.6
Hatchery	3/17/2005	421	75	16.5	0.93	290	291	0.71
Hatchery	3/17/2005	2-0408	70.4	13.8	0.91	226	122	0.69
Hatchery	3/17/2005	1-0411	71.9	11.4	0.79	265	204	0.57
Hatchery	3/17/2005	404	72.6	15.2	0.79	270	228	0.57
Hatchery	3/17/2005	415	68.3	12	0.69	234	146	0.48
Hatchery	3/17/2005	2-0402	70.5	17.7	0.79	235	132	0.57
Hatchery	3/17/2005	2-0411	69.7	18.5	0.72	260	202	0.51
Hatchery	3/17/2005	3-0402	73.7	11.7	0.84	240	154	0.62
Hatchery	3/17/2005	424	73.2	20.5	0.8	260	214	0.58
Hatchery	3/17/2005	3-0411	69.3	16.9	0.71	243	181	0.5
Hatchery	3/17/2005	3-0408	70.4	15.1	0.89	203	81	0.67
Hatchery	3/17/2005	2-0410	71.4	16.3	0.8	241	163	0.58
Hatchery	3/17/2005	420	73.7	12.8	0.86	215	125	0.64
CDOT	10/13/2005	5047	80.9	17.1	1.15	281	183	0.95
CDOT	10/13/2005	6B2C	78.6	14.8	0.97	275	180	0.76
CDOT	10/13/2005	72B4	79	26.1	0.95	277	171	0.74
CDOT	10/13/2005	7235	77.8	22.8	1.54	283	194	1.4
CDOT	10/13/2005	A601	79.6	28.4	1.55	301	237	1.4
CDOT	10/13/2005	343F	80.3	26	1.74	288	191	1.7
CDOT	10/13/2005	E77B	79.3	17.7	1.48	277	165	1.3
CDOT	10/13/2005	11	80.9	25.4	1.59	284	194	1.5
CDOT	10/13/2005	1F97	82.1	23.6	1.5	320	254	1.4
CDOT	10/13/2005	6A5A	80.1	27.1	1.87	310	224	1.8
McGuire	9/20/2007	6D11	78.1	19	5.19	464	1036	7.2
McGuire	9/20/2007	768F	77.8	19.3	4.76	437	857	6.4
McGuire	9/20/2007	2BCD	77.1	22.9	4.98	445	893	6.8
McGuire	9/20/2007	4F54	76.8	27.8	4.64	415	775	6.2
McGuire	9/20/2007	D181	69.7	31.6	3.75	485	987	4.7
McGuire	9/20/2007	6A81	70.3	19.2	4.4	425	979	5.8
McGuire	9/20/2007	3EBA	63.3	28.8	2.77	450	987	3.1
McGuire	9/20/2007	28B6	67.6	25.7	2.9	502	1275	3.3
McGuire	9/20/2007	F31E	70.5	31.2	3.37	473	1199	4
McGuire	9/20/2007	2F13	74.2	21.7	4.14	455	910	5.3
Bounds	7/6/2005	8D8Q	58.1	10.8	2.17	445	780	2.2
Bounds	7/6/2005	1151	69.8	25.9	4.29	420	650	5.6
Bounds	7/6/2005	F7A7	72.4	13.2	4.91	455	945	6.7
Bounds	7/6/2005	D3C8	76.6	22.7	3.54	420	650	4.3

Appendix 8. Selenium concentrations in razorback sucker muscle plugs taken from hatchery fish before spring stocking in grow-out ponds, and during harvest approximately six months later.

Location	Date	ID or Hatch. Lot	MP % Moist.	MP Weight (mg)	MP Se (ug/g)	Fish Length (mm)	Fish Weight (g)	Egg Se[1] (ug/g)
Bounds	7/6/2005	BA16	72.4	21.8	3.16	415	810	3.7
Bounds	7/6/2005	DA5B	71.2	21.7	2.97	400	645	3.4
Bounds	7/6/2005	B18E	72	17.4	3.53	485	1080	4.3
Bounds	7/6/2005	C55A	70.6	14.4	3.91	420	715	4.9
Bounds	7/6/2005	EDDB	69.5	16.7	2.84	410	635	3.2
Morse	9/29/2005	201E	77.4	20.4	1.1	346	346	0.9
Morse	9/29/2005	FE61	80.2	20.4	1.16	304	246	0.96
Morse	9/29/2005	F3F3	78.7	25.9	1.09	320	336	0.88
Morse	9/29/2005	4669	78.8	25.2	1.15	314	250	0.95
Morse	9/29/2005	4BCB	78.9	24	1.17	305	223	0.97
Morse	9/29/2005	6B4C	75.9	22	1.08	343	329	0.87
Morse	9/29/2005	733B	78.8	19.4	1.25	281	189	1.1
Morse	9/29/2005	32DB	78.6	26.9	0.99	280	198	0.78
Morse	9/29/2005	1ACA	74.9	20.4	1.1	342	390	0.9
Morse	9/29/2005	8BED	78.8	21.9	1.16	284	180	0.96
Maggio	9/7/2005	45FQ	63	26.2	11.9	516	1279	22.1
Maggio	9/7/2005	DBBC	69.4	25.8	20.2	427	795	45.1
Maggio	9/7/2005	97FB	74.4	21.9	19.5	407	578	43
Maggio	9/7/2005	7BE8	68.6	14.2	25.3	416	668	61.1
Maggio	9/7/2005	869B	78.2	14.6	17.6	401	696	37.5
Maggio	9/7/2005	8A1E	73.6	27.1	19.5	476	935	43
Maggio	9/7/2005	7B8A	67.3	16.9	13.6	422	718	26.5
Maggio	9/7/2005	3B3F	55.2	37.9	12.5	468	1030	23.6
Maggio	9/7/2005	6DCA	67.5	29.4	14.3	424	772	28.3
Maggio	9/7/2005	83E1	75.5	23.1	28.2	362	415	70.7
Elam	8/25/2005	1713	78.1	23.8	1.85	296	215	1.8
Elam	8/25/2005	63F2	77.6	23.3	1.91	275	172	1.9
Elam	8/25/2005	E404	81.5	16.7	1.72	316	279	1.6
Elam	8/25/2005	2A2D	77.9	19.8	2.68	340	314	3
Elam	8/25/2005	63DD	76.9	27.2	1.9	350	350	1.9
Elam	8/25/2005	F8CD	79.8	24.6	1.68	315	254	1.6
Elam	8/25/2005	1939	79.1	25.1	1.44	316	279	1.3
Elam	8/25/2005	309E	78.6	25.3	1.54	302	205	1.4
Elam	8/25/2005	0DAA	74.3	25.1	2.64	449	865	2.9
Elam	8/25/2005	1572	75.4	22.1	2.82	376	458	3.2
Elam	8/25/2005	1713	78.1	23.8	1.85	296	215	1.8
Elam	8/25/2005	63F2	77.6	23.3	1.91	275	172	1.9
Elam	8/25/2005	E404	81.5	16.7	1.72	316	279	1.6
Beswick	9/15/2005	5FD8	76.5	22	2.55	394	515	2.8
Beswick	9/15/2005	37E4	77.8	21.5	3.15	389	491	3.7
Beswick	9/15/2005	4B9D	74.6	14.2	2.78	360	407	3.1
Beswick	9/15/2005	FCE2	76.7	17.2	2.58	355	335	2.8
Beswick	9/15/2005	18D0	79.4	20.7	2.28	319	255	2.4

Appendix 8. Selenium concentrations in razorback sucker muscle plugs taken from hatchery fish before spring stocking in grow-out ponds, and during harvest approximately six months later.

Location	**Date**	**ID or Hatch. Lot**	**MP % Moist.**	**MP Weight (mg)**	**MP Se (ug/g)**	**Fish Length (mm)**	**Fish Weight (g)**	**Egg Se[1] (ug/g)**
Beswick	9/15/2005	47DA	77.7	21.2	1.89	358	367	1.9
Beswick	9/15/2005	7020	77.5	25.3	2.68	371	462	3
Beswick	9/15/2005	5F67	77.7	20.2	2.01	320	266	2
Beswick	9/15/2005	3A07	77.7	19.2	1.76	332	298	1.8
Beswick	9/15/2005	7F75	79.1	20.2	2.28	326	284	2.4
Clymer	10/20/2005	FDEC	77.8	11.7	7.19	311	235	11.2
Clymer	10/20/2005	F829	79	19.4	4.4	322	272	5.8
Clymer	10/20/2005	C868	76.9	25.4	3.72	299	244	4.6
Clymer	10/20/2005	2F5E	77.7	22.1	4.88	376	472	6.7
Clymer	10/20/2005	9B34	78.6	25	4.79	308	278	6.5
Clymer	10/20/2005	DCF8	78.4	15.4	7.79	297	236	12.5
Clymer	10/20/2005	CC9C	73	19.9	6.21	351	377	9.2
Clymer	10/20/2005	E46A	77.6	14	4.44	321	272	5.9
Clymer	10/20/2005	C806	75.1	19.7	3.65	330	278	4.5
Clymer	10/20/2005	C0A3	76.4	22.5	5.1	330	328	7.1
Peter1	10/24/2005	ECD8	80.7	24.6	6.42	278	182	9.6
Peter1	10/24/2005	3B84	78.9	22.9	5.45	287	225	7.7
Peter1	10/24/2005	9659	75	31.2	2.8	332	377	3.2
Peter1	10/24/2005	F94B	74.3	21.6	4.57	297	303	6.1
Peter1	10/24/2005	3510	75.7	18.2	3.71	339	405	4.6
Peter1	10/24/2005	3CD9	73.4	21.8	1.42	318	307	1.3
Peter1	10/24/2005	3E54	72.9	18.7	1.77	383	544	1.7
Peter1	10/24/2005	BBDB	73.6	25.7	1.46	291	303	1.3
Peter1	10/24/2005	1F1D	78.8	25.4	2.83	360	415	3.2
Peter1	10/24/2005	EAE9	75.3	25.6	2.9	355	530	3.3
Peter2	10/27/2005	3DE1	81	24.2	3.99	303	239	5.1
Peter2	10/27/2005	9DC2	75.6	24.2	6.09	340	435	9
Peter2	10/27/2005	E158	78	19.8	6.8	301	295	10.4
Peter2	10/27/2005	93E1	77.9	24.3	9	329	328	15.2
Peter2	10/27/2005	9471	78.9	14.7	9.61	340	337	16.6
Peter2	10/27/2005	0FED	75.1	25.8	5.71	340	438	8.2
Peter2	10/27/2005	CF92	80.8	21.7	10.7	261	170	19.2
Peter2	10/27/2005	4522	75.6	24.1	4.74	371	516	6.4
Peter2	10/27/2005	494B	74.6	25.2	3.53	375	540	4.3
Peter2	10/27/2005	E165	79	23.6	7.88	307	260	12.7
Peter3	10/26/2005	47FA	73.4	26.5	2.93	327	404	3.4
Peter3	10/26/2005	7FFD	78.8	20.3	3.97	312	271	5
Peter3	10/26/2005	D013	77.9	17.4	7.52	327	325	11.9
Peter3	10/26/2005	DC49	70	30.6	2.13	349	481	2.2
Peter3	10/26/2005	EF30	72.5	26.1	2.85	357	464	3.2
Peter3	10/26/2005	DF62	75.5	19.4	2.94	355	437	3.4
Peter3	10/26/2005	26B4	80.2	15.5	2.89	264	155	3.3
Peter3	10/26/2005	F9CA	64.8	38.5	1.63	319	325	1.5
Peter3	10/26/2005	E9F2	69.6	32.5	1.5	345	413	1.4

Appendix 8. Selenium concentrations in razorback sucker muscle plugs taken from hatchery fish before spring stocking in grow-out ponds, and during harvest approximately six months later.

Location	Date	ID or Hatch. Lot	MP % Moist.	MP Weight (mg)	MP Se (ug/g)	Fish Length (mm)	Fish Weight (g)	Egg Se[1] (ug/g)
Peter3	10/26/2005	956A	76.9	29.3	5.19	333	385	7.2
Peter3	10/26/2005	47FA	73.4	26.5	2.93	327	404	3.4
Peter4	11/1/2005	F7DE	75.6	30.1	1.92	355	451	1.9
Peter4	11/1/2005	41D2	77.4	26.1	2.78	285	242	3.1
Peter4	11/1/2005	2AD7	74.2	28.2	2.29	305	324	2.4
Peter4	11/1/2005	8B31	79.7	25.7	1.68	309	286	1.6
Peter4	11/1/2005	FB52	70.8	23.3	1.82	345	471	1.8
Peter4	11/1/2005	3F2C	75.8	33.8	3.42	343	454	4.1
Peter4	11/1/2005	48B6	79.8	30	4.8	267	161	6.5
Peter4	11/1/2005	3359	79	26.7	8.43	261	166	13.9
Peter4	11/1/2005	C46F	75.9	28.4	1.87	351	465	1.8
Peter4	11/1/2005	7D8C	76.9	41.8	2.2	307	373	2.3
Heuton	9/1/2005	8D58	77.7	28.7	1.82	333	339	1.8
Heuton	9/1/2005	4C7A	76.8	30.1	1.7	377	518	1.6
Heuton	9/1/2005	ECDF	77.9	28.7	1.86	341	420	1.8
Heuton	9/1/2005	547C	77.4	24.1	2.34	306	272	2.5
Heuton	9/1/2005	4439	79.1	27.4	2.99	261	184	3.4
Heuton	9/1/2005	7F6E	75.6	24.7	1.63	335	351	1.5
Heuton	9/1/2005	3AF3	76.3	25.5	1.35	341	335	1.2
Heuton	9/1/2005	4A54	79.1	25.4	1.16	281	183	0.96
Heuton	9/1/2005	60BB	79	20.7	2.22	280	212	2.3
Heuton	9/1/2005	3C6D	76.6	23.9	1.86	327	356	1.8
VanWagN	8/29/2005	7377	78.5	20.1	1.84	376	480	1.8
VanWagN	8/29/2005	44C3	76.6	23.1	4.43	327	333	5.9
VanWagN	8/29/2005	3D13	70.4	14.5	2.4	342	416	2.6
VanWagN	8/29/2005	77B1	79	18.5	4.23	308	223	5.5
VanWagN	8/29/2005	6BA7	80.6	19	3.34	314	266	4
VanWagN	8/29/2005	F45A	76.1	11.6	4.02	290	205	5.1
VanWagN	8/29/2005	4685	82.1	18.2	4.59	286	191	6.1
VanWagN	8/29/2005	4DF1	77.4	13.1	3.91	371	459	4.9
VanWagN	8/29/2005	7DF0	78.1	16.8	2.89	286	216	3.3
VanWagN	8/29/2005	7ADE	66.9	5.6	2.98	350	344	3.4
VanWagS	9/6/2005	71A1	82.4	11.8	2.26	229	83	2.4
VanWagS	9/6/2005	4CBB	80.8	11.6	1.06	268	158	0.85
VanWagS	9/6/2005	8A5F	79.7	23.8	0.97	297	219	0.76
VanWagS	9/6/2005	2DFA	71	22.2	2.16	427	717	2.2
VanWagS	9/6/2005	4A3C	80.3	18.8	4.34	243	110	5.7
VanWagS	9/6/2005	224E	79.4	16.2	1.63	268	160	1.5
VanWagS	9/6/2005	71A1	82.4	11.8	2.26	229	83	2.4
VanWagS	9/6/2005	4CBB	80.8	11.6	1.06	268	158	0.85

[1] Estimated from muscle plug selenium using equation derived from razorback sucker data described in Hamilton (2001b).

Appendix 9. Selenium concentrations in razorback sucker muscle plugs taken from fish at large for at least eight months in the Colorado and the Gunnison rivers.

Fish ID	Date	River Mile	Length (mm)	Selenium (ug/g DW)	Pond/Year stocked	Egg Se[1] (ug/g DW)	Risk Assess.
RZ0166	4/6/2004	165.7	430	5.3	Morse/01	7.4	low
RZ5368	4/6/2004	159.1	450	4.28	no stocking data	5.6	low
RZ6A5E	4/7/2004	156.7	455	4.84	no stocking data	6.6	low
RZ3574	May-04	GUN 3.0	413	9.49	Wahweep hatchery/96	16.3	mod
RZ235E	5/7/2004	153.4	435	4.52	Elams/02	6	low
RZ3D3D	5/13/2004	153.3	386	7.73	Pet2/02	12.4	mod
RZ0243	5/13/2004	157.1	500	6.72	Horsethief Brood/03	10.3	mod
RZ5005	5/13/2004	156.9	473	3.98	Morse/00	5.1	low
RZ0F6E	5/20/2004	153.7	456	8.55	no stocking data	14.2	mod
RZ1F0B	5/21/2004	174.4	411	4.91	Clymers/00	6.7	low
RZ506E	5/21/2004	174.4	430	4.89	Clymers/00	6.7	low
RZ7E73	5/25/2004	168.7	495	7.32	no stocking data	11.5	mod
RZ0133	7/12/2004	146.4	425	3.99	CDOT/02	5.1	low
RZ1959	7/13/2004	131.8	421	5.89	Clymers/02	8.6	low
RZ0166	7/19/2004	Redl. FL	443	4.62	Horsethief/01	6.2	low
RZ227F	7/21/2004	Redl. FL	457	5.99	Clymers/99	8.8	low
RZ5368	4/5/2005	159.1	460	4.77	no stocking data	6.5	low
RZ3801	4/5/2005	159.1	322	5.8	Beswick/04	8.4	low
RZ2159	4/6/2005	154.4	435	5.01	Morse/02	6.9	low
RZ7F5E	4/6/2005	154.1	380	6.22	Clymers/02	9.2	low
RZ247A	4/6/2005	154.1	354	3.73	Beswick/04	4.6	min
RZ4054	4/6/2005	153.7	366	3.5	Brunets/04	4.3	min
RZ3200	4/6/2005	167.7	476	6.33	no stocking data	9.5	low
RZOD68	4/7/2005	177	360	27.1	Maggio/04	67	high
RZ4B05	4/7/2005	175.8	396	6.11	Peters2/04	9	low
RZ2E63	4/7/2005	175.4	470	6.54	Wahweep/97	9.9	low
RZ4DOA	4/7/2005	171.1	438	5.19	Clymers/02	7.2	low
RZ3E04	4/11/2005	GUN 2.6	426	10.1	no stocking data	17.7	mod
RZ104F	4/11/2005	GUN 2.6	516	15.8	Adobe/01	32.4	high
RZ7E72	4/11/2005	169.8	443	5.83	Peters4/01	8.5	low
RZ5C2E	4/11/2005	167.7	433	8.53	Peters4/01	14.1	mod
RZ4D6E	4/11/2005	168.8	464	12.1	Clymers/01	22.6	high
RZ1C22	4/15/2005	162	406	10.1	Clymers/01	17.7	mod
RZ4039	4/20/2005	154.7	405	5.44	Elam/02	7.7	low
RZ0613	4/21/2005	176.3	444	4.53	Clymers/00	6	low
RZ523B	5/16/2005	184.1	435	8.48	Maggio/04	14	mod
RZ751B	5/17/2005	175.5	395	5.18	Beswick/04	7.2	low
RZ0938	5/17/2005	176.5	349	4.17	Beswick/04	5.4	low
RZ594D	5/17/2005	175.5	384	3.7	Beswick/04	4.6	min
RZ166C	5/17/2005	172.2	455	18.1	Maggio/04	38.9	high
RZ5D4D	5/17/2005	172	388	5.97	no stocking data	8.7	low
RZ1062	6/1/2005	154.2	443	15.2	Maggio/04	30.8	high
RZ3D18	6/2/2005	152.7	435	6.89	Elam/00	10.6	mod
RZF69C	6/2/2005	174.4	375	4.57	no stocking data	6.1	low
RZ084C	7/24/2005	Redl. FL	497	7.67	Horsethief brood/01	12.2	mod
RZ153F	8/2/2005	Redl. FL	395	9.42	Clymers/02	16.1	mod
RZEBFA	8/16/2005	Redl. FL	445	6.94	Clymers/02	10.7	mod
RZ194F	8/23/2005	Redl. FL	461	6.47	Clymers/01	9.7	mod
RZ431A	8/29/2005	Redl. FL	395	9.96	Clymers/02	17.4	low
RZ212E	4-May	GUN 3.0	446	6.12	Horsethief/03	9	low

[1] Estimated from muscle plug concentration using Hamilton (2001b) data.

Appendix 10. Selenium concentrations (ug/g DW) in native suckers captured in the Gunnison and Colorado rivers from 2002-2004.

Species[1]	Se ug/g DW	Date	Location	River Mile
BHS	2.3	April/04	Redls. Fish ladder	Gun R. 3.1
BHS	1.47	April/04	Redls. Fish ladder	Gun R. 3.1
BHS	3.07	April/04	Redls. Fish ladder	Gun R. 3.1
BHS	5.16	April/04	Redls. Fish ladder	Gun R. 3.1
BHS	2.52	April/04	Redls. Fish ladder	Gun R. 3.1
BHS	2.72	April/04	Redls. Fish ladder	Gun R. 3.1
BHS	2.76	Aug./02	Redls. Parkway	166.3 to166.7
BHS	3.04	Aug./02	Redls. Parkway	166.3 to166.7
BHS	3.64	Aug./02	Utah/CO Stateline	131.9
FMS	4.09	Mar./04	Salt Creek	at Colo.R. 144.2
FMS	3.79	Mar./04	Salt Creek	at Colo.R. 144.2
FMS	7.28	April/04	Redls. Fish ladder	Gun R. 3.1
FMS	3.56	April/04	Redls. Fish ladder	Gun R. 3.1
FMS	6.15	April/04	Redls. Fish ladder	Gun R. 3.1
FMS	4.63	April/04	Redls. Fish ladder	Gun R. 3.1
FMS	5.23	April/04	Redls. Fish ladder	Gun R. 3.1
FMS	4.23	Aug./02	32 Road	177.4
FMS	4.28	Aug./02	32 Road	177.4
FMS	3.57	Aug./02	Utah/CO Stateline	131.9
FMS	5.72	Aug./02	Redls. Parkway	166.3 to166.7
FMS	5.6	Aug./02	Redls. Parkway	166.3 to166.7
WS	12.3	April 18/03	Redls. Fish ladder	Gun. R. 3.1
WS	9.23	April 18/03	Redls. Fish ladder	Gun. R. 3.1
WS	9.44	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	9.44	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	10.5	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	11.4	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	9.57	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	9.29	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	9.75	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	10.5	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	5.58	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	6.29	April 5/02	Redls. Fish ladder	Gun. R. 3.1
WS	9.13	April 18/03	Redls. Fish ladder	Gun. R. 3.1
WS	8.47	April 18/03	Redls. Fish ladder	Gun. R. 3.1
WS	3.04	April 18/03	Redls. Fish ladder	Gun. R. 3.1
WS	2.81	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	2.53	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	4.31	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	3.52	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	4.27	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	3.14	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	3.58	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	2.95	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185

[1]BHS=Bluehead sucker, FMS=flannelmouth sucker, WS=White sucker

Appendix 10. Selenium concentrations (ug/g DW) in native suckers captured in the Gunnison and Colorado rivers from 2002-2004.

Species[1]	**Se ug/g DW**	**Date**	**Location**	**River Mile**
WS	4.09	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	3.59	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	2.81	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	3.15	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	3.14	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	4.32	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185
WS	3.4	Nov. 18/02	Grand Valley Canal	Colo R.water diverted at RM 185

[10]BHS=Bluehead sucker, FMS=flannelmouth sucker, WS=White sucker

Appendix 11. Selenium concentrations in muscle plugs taken from wild Colorado pikeminnow in the Colorado and Gunnison rivers during 2004 and 2005.

Fish ID	Date	River Mile	Length	MP Selenium ug/g DW	Egg[1] Selenium ug/g DW
PM4B1A	4/7/2004	156.5	747	8.05	8.6
PM1F46	4/6/2004	162.7	712	7.04	7.82
PM6C21	4/6/2004	164.3	671	5.53	6.59
PM3002	4/6/2004	159	861	6.17	7.13
PM3476	4/13/2004	153.3	585	5.87	6.88
PM25D6	4/13/2004	154.7	658	5.94	6.94
PM5A70	5/3/2004	167.3	834	4.97	6.11
PM4B39	5/4/2004	168.7	690	7.08	7.85
PM0B42	5/4/2004	167.7	595	4.99	6.13
PM775A	5/10/2004	167.9	603	7.77	8.39
PM0666	5/10/2004	GUN 1.2	715	7.45	8.14
PM276E	5/10/2004	167.9	638	8.03	8.59
PM4E43	5/14/2004	183	769	3.83	5.08
PM3405	5/17/2004	GUN 2.7	660	6.38	7.3
PM7E34	5/17/2004	169.9	724	6.48	7.4
PM4D72	5/18/2004	166.2	792	3.67	4.93
PM1C6F	5/18/2004	162.8	591	3.94	5.19
PM3A31	5/18/2004	159.4	782	5.77	6.79
PM2D15	5/18/2004	165.2	850	4.56	5.75
PM99C7	4/4/2005	159.1	745	5.54	6.6
PM83F6	4/4/2005	159.1	604	7.7	8.33
PM9B44	4/11/2005	169.8	474	6.24	7.18
PM9070	4/4/2005	182.8	752	3.79	5.05
PM7BA6	4/7/2005	173.1	654	3.76	5.02
PM93AB	4/7/2005	169.2	579	6.21	7.16
PM7559	4/4/2005	184.8	641	3.6	4.86
PM561F	4/19/2005	162.8	511	7.41	8.11
PM1603	4/19/2005	158.5	817	6.76	7.6
PMA580	4/19/2005	162.1	558	8.4	8.87
PM6867	4/19/2005	162.1	660	7.4	8.1
PM922D	4/19/2005	159	810	6.72	7.57
PM12AE	4/21/2005	175.5	624	6.74	7.59
PM9B27	4/21/2005	175.5	606	5.47	6.54
PM6FEB	4/21/2005	173.1	683	7.08	7.85
PM604F	4/22/2005	156.8	645	6.41	7.32
PM8906	4/22/2005	156.8	620	5.84	6.85
PM553A	5/16/2005	183.2	663	3.98	5.22
PM561F	4/19/2005	162.8	511	7.41	8.11

Appendix 11. Selenium concentrations in muscle plugs taken from wild Colorado pikeminnow in the Colorado and Gunnison rivers during 2004 and 2005.

Fish ID	Date	River Mile	Length	MP Selenium ug/g DW	Egg[1] Selenium ug/g DW
PM1603	4/19/2005	158.5	817	6.76	7.6
PMA580	4/19/2005	162.1	558	8.4	8.87
PM6867	4/19/2005	162.1	660	7.4	8.1
PM922D	4/19/2005	159	810	6.72	7.57
PM12AE	4/21/2005	175.5	624	6.74	7.59
PM9B27	4/21/2005	175.5	606	5.47	6.54
PMC3B0	5/16/2005	183	638	4.41	5.62

[1] Egg selenium concentrations estimated from muscle plug concentrations.

[11] Egg selenium concentrations estimated from muscle plug concentrations.

Appendix 12. Selenium hazard assessment (using Lemly (1995) and Ohlendorf (1997) methods) of razorback sucker grow-out ponds using data collected from grow-out ponds during 2005.

Site	Environmental component	Range of Selenium concentrations[1]	Evaluation by component			Totals for the site	
			Hazard Score (Lemly 1996)	Weighting Factor (Ohlendorf 1997)	Score	Score	Hazard
CDOT							
	Water	0.6-1.4	None to Min (1-2)	1	1 to 2		
	Sediment	0.19	None (1)	1	1	7 to 8	None-Minimal
	Invertebrates	1.02-1.31	None (1)	2	2		
	Fish eggs	1.24	None (1)	3	3		
McGuires							
	Water	1.9-2.2	Min-Low (2-3)	1	2 to 3		
	Sediment	1.65-1.67	Min (2)	1	2	14-15	Minimal-Low
	Invertebrates	2.3-3.1	Min (2)	2	4		
	Fish eggs	4.9	Min (2)	3	6		
Bounds							
	Water	0.3-4.6	None to Min (1-2)	1	1 to 4		
	Sediment	0.61-0.7	None (1)	1	1	12 to 20	Minimal-Low
	Invertebrates	2.2	Min to High (2-5)	2	4 to 10		
	Fish eggs	4.2	Min (2)	3	6		
Morse							
	Water	1.5-2.2	Min-Low (2-3)	1	2 to 3		
	Sediment	0.83-0.86	None (1)	1	1	8-11	Minimal
	Invertebrates	1.7-2.3	None to Min (1-2)	2	2 to 4		
	Fish eggs	0.92	None (1)	3	3		
Maggio							
	Water	6.5-7.9	High (5)	1	5		
	Sediment	4.9-6.0	High (5)	1	5	35	High
	Invertebrates	5.4-5.7	High (5)	2	10		
	Fish eggs	39.6	High (5)	3	15		
Elam							
	Water	1.5-2.4	Min-Low (2-3)	1	2 to 3		
	Sediment	0.73-0.79	None (1)	1	1	8-9	Minimal
	Invertebrates	1.4-2.8	None (1)	2	2		
	Fish eggs	2	None (1)	3	3		
Beswick							
	Water	2-3.4	Min to Mod (2-4)	1	2 to 4		
	Sediment	0.35-0.44	None (1)	1	1	10 to 14	Minimal
	Invertebrates	2.8-3.9	Min to Low (2-3)	2	4 to 6		
	Fish eggs	2.5	None (1)	3	3		
Clymer							
	Water	1.4-2.2	Min-Low (2-3)	1	2 to 3		
	Sediment	5.7-6.3	High (5)	1	5	26-27	Moderate
	Invertebrates	5.7-6.7	High (5)	2	10		
	Fish eggs	7	Low (3)	3	9		

[1]Selenium concentrations in ug/L for water, ug/g sediment, benthic invertebrate, and fish egg. Sample sizes for components are: water n=3, sediment n=2, benthic invertebrates n=1-3, fish eggs 6-10.

Appendix 12. Selenium hazard assessment (using Lemly (1995) Ohlendorf (1997) methods) of razorback sucker grow-out ponds using data collected from grow-out ponds during 2005.

			Evaluation by component			Totals for the site	
Site	**Environmental component**	**Range of Selenium concentrations**[2]	**Hazard Score (Lemly 1996)**	**Weighting Factor (Ohlendorf 1997)**	**Score**	**Score**	**Hazard**
Peters 1							
	Water	1.7-5.1	Min to High (2-5)	1	2 to 5		
	Sediment	0.79-0.87	None (1)	1	1	19-22	Low-Moderate
	Invertebrates	7-8.1	High (5)	2	10		
	Fish eggs	3.4	Min (2)	3	6		
Peters 2							
	Water	1.6-5.9	Min to High (2-5)	1	2 to 5		
	Sediment	0.77-0.91	None (1)	1	1	22-25	Moderate
	Invertebrates	6.6-9.2	High (5)	2	10		
	Fish eggs	9.6	Low (3)	3	9		
Peters 3							
	Water	2.1-5.2	Low to High (3-5)	1	3 to 5		
	Sediment	0.86-1.06	None (1)	1	1	20-22	Low-Moderate
	Invertebrates	6.3-6.7	High (5)	2	10		
	Fish eggs	3.4	Min (2)	3	6		
Peters 4							
	Water	1.5-5.3	Min to High (2-5)	1	2 to 5		
	Sediment	1.26-1.64	Min (2)	1	2	20-23	Low-Moderate
	Invertebrates	5.9-9.1	High (5)	2	10		
	Fish eggs	3	Min (2)	3	6		
Heuton							
	Water	0.42-1.1	None to Min (1-2)	1	1		
	Sediment	0.63-0.64	None (1)	1	1	11	Minimal
	Invertebrates	3.04-3.2	Low (3)	2	6		
	Fish eggs	1.77	None (1)	3	3		
VanWagnerN							
	Water	0.3-1	None to Min (1-2)	1	1 to 2		
	Sediment	0.77-1.2	None to Min (1-2)	1	1 to 2	12 to 20	Minimal-Low
	Invertebrates	2.8-8	Min to High (2-5)	2	4 to 10		
	Fish eggs	3.99	Min (2)	3	6		
VanWagnerS							
	Water	0.4-1	None to Min (1-2)	1	1 to 2		
	Sediment	3.1-3.6	Mod (4)	1	4	12-13	Minimal
	Invertebrates	2.3	Min (2)	2	4		
	Fish eggs	1.7	None (1)	3	3		

[1] Selenium concentrations in ug/L for water, ug/g sediment, benthic invertebrate, and fish egg. Sample sizes for components are: water n=3, sediment n=2, benthic invertebrates n=1-3, fish eggs 6-10.