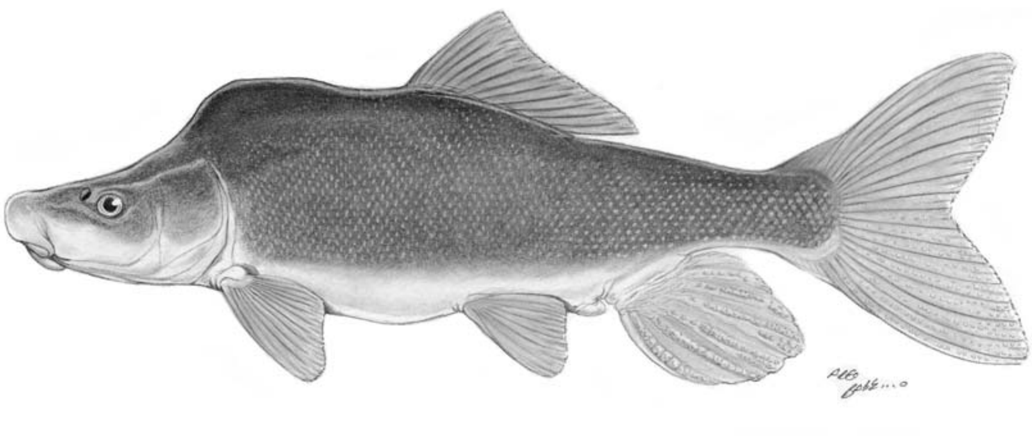
Factors Affecting Growth of Razorback Sucker (*Xyrauchen texanus*) In Captivity: Literature Review and Knowledge Assessment



David Ward
Mike Childs
William Persons

Arizona Game and Fish Department
Research Branch
2221 West Greenway Road
Phoenix, AZ 85023

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Abstract

The few remaining razorback sucker populations are sustained by captive rearing and stocking programs. Captive-reared razorback suckers commonly experience high predation when stocked into natural environments. This creates the need to rear fish to larger sizes in captivity and to find new ways to improve growth for captive-reared fish. We reviewed published literature and agency reports for information on factors that affect growth of razorback sucker. Site visits to razorback sucker production facilities and surveys of fish hatchery personnel were conducted to obtain information on current rearing practices. Razorback sucker growth is extremely variable and impacted by many factors including fish size and age, sex, density, amount of living space, quality and quantity of food, genetics, and temperature. This makes evaluations of individual factors that affect growth difficult. Culture practices for razorback suckers vary widely and include differences in rearing environments, rearing densities, feeding regimes and types of feed, as well as grading or sorting practices. The focus at most razorback rearing facilities is production, so the types of data that are collected are often insufficient for detailed evaluations of rearing practices on growth. Calculated growth rates from the literature vary widely and range from 0.2 to 1.8 mm/day. Typically the highest growth rates are reported from natural or semi-natural pond environments. These growth rates indicate that juvenile razorback suckers have a very high growth potential under ideal rearing conditions. Detailed, replicated studies are needed to accurately compare the effects of individual rearing practices on growth. These types of studies will ultimately provide both time and cost-savings to production facilities by reducing the time it takes for razorback suckers to reach stocking size, improving overall production efficiency.

Introduction

State and federal wildlife management agencies have been rearing razorback suckers in captivity since the 1970s (Toney 1974, Hamman 1985) to augment declining natural populations. Both wild-caught larvae and captive-bred fish are reared at fish hatcheries and grow-out ponds throughout the southwestern United States (reviewed in Mueller 2006). Each facility has unique environmental conditions and different rearing methods that yield different growth rates. Unlike commercial fish species, which have been cultured and studied extensively, little published information is available on the effects of various rearing methods on growth of razorback sucker.

Low survival rates of stocked razorback suckers (Brooks 1986, Marsh and Brooks 1989, Marsh and Pacey 2005) have caused target sizes for stocking to steadily increase in efforts to reduce predation mortality (Marsh et al. 2005, Schooley and Marsh 2007). Rearing fish to larger sizes comes with increased costs and creates the need to know which factors have the greatest impact on growth rate, and how these factors can be controlled to maximize growth. This document compiles and summarizes information on current captive rearing practices and associated growth rates for razorback sucker.

We reviewed relevant published literature and agency reports on razorback sucker to compile background information regarding the effects of environmental factors and rearing methods on growth. A questionnaire was developed (Appendix 1) and sent to hatchery managers who rear razorback suckers. Follow-up surveys were also conducted by telephone (Appendix 2). Information on rearing densities, water quality, diseases, and management practices at each facility were recorded. Site visits to Bubbling Ponds State Fish Hatchery in Arizona, Dexter National Fish Hatchery in New Mexico, Grand Valley Endangered Fish Facility in Colorado, Ouray National Fish Hatchery in Utah, and the

Willow Beach National Fish Hatchery in Arizona were also conducted as part of this knowledge assessment. Telephone interviews were conducted with personnel from other locations that produce razorback suckers (Uvalde National Fish Hatchery, Hualapai Ponds, Lake Mead Fish Hatchery, and J.W. Mumma Fish Hatchery) or facilities that formerly produced razorback suckers but currently focus on other species (Wahweap Fish Hatchery, Achii Hanyo National Fish Hatchery, Mora National Fish Hatchery).

Information from all of these sources is summarized to aid future researchers in the design of more detailed studies on razorback sucker growth. Understanding the factors that control razorback sucker growth will allow expanded fish-rearing capabilities and aid in reaching management objectives for stocked fish. Preservation of genetic resources for razorback suckers depends on captive rearing and stocking programs until permanent solutions to factors that prevent wild recruitment can be found.

Summary of Facilities

There are over 50 locations that have been used to rear razorback suckers (Table 1). These include both intensive culture facilities with raceways or circular tanks, as well as production ponds, golf-course ponds, and natural floodplain-wetlands. The majority of razorback suckers that are stocked come from six major production facilities: Bubbling Ponds State Fish Hatchery, The Grand Valley Endangered Fish Facility, and Dexter, Ouray, Willow Beach, and Uvalde National Fish Hatcheries. Tables 2-3 outline the types of fish holding facilities and water quality conditions that exist at each of these main production locations. A brief summary of procedures for rearing razorback suckers at each of these facilities follows.*

* These summaries are based on interviews conducted with hatchery personnel in July 2007 during site visits. This information is provided only to give a brief overview of razorback grow-out procedures. Please verify accuracy of specific information with individual hatchery managers.

Table 1. List of locations that have been used to grow-out razorback suckers

Facility	Location	Citation
Fish Hatcheries		
Bubbling Ponds State Fish Hatchery	Page Springs, Arizona	Mueller 2006
Grand Junction Endangered Fish Facility	Grand Junction, Colorado	Czapla 2002, Pfeifer 2000, Nesler et al. 2003, Bingham et al. 2003
(24-road Hatchery)		
Dexter National Fish Hatchery	Dexter, New Mexico	Uliberri 2003a
Mumma State Fish Hatchery	Near Alamosa, Colorado	Schnoor and Logan 2002
Lake Mead Hatchery	Boulder City, Nevada	BR 2006
Ouray National Fish Hatchery	Near Vernal, Utah	Czapla 2002, Irving et al. 2004, Pfeifer et al. 2003, Mueller 2006, USFWS 1999
Uvalde National Fish Hatchery	Uvalde, Texas	BR 2006
Wahweap Fish Hatchery	Bigwater, Utah	Czapla 2002, Gustavson and Bradwisch 2000
Willow Beach National Fish Hatchery	Below Hoover Dam on Colorado River, Arizona	Hanson 1996
Achii Hanyo	Near Parker, Arizona	USFWS 2005
Colorado Grow-out ponds		
Peters ponds	Grand Junction, Colorado	Thad Bingham, personal communication
26 road pond	Grand Junction, Colorado	Pfeifer et al. 1999
Bounds pond 7	Grand Junction, Colorado	Pfeifer et al. 1999
Clymers Pond	Confluence of Colorado and Gunnison	Pfeifer et al. 1999, Czapla 2002
Colorado - 18 additional leased ponds	Grand Valley, Colorado	Pfeifer 2000
Dike road pond	Grand Valley, Colorado	Pfeifer et al. 1999
Highline ponds	Grand Valley, Colorado	Pfeifer et al. 1999
Horsethief rearing ponds	Grand Junction, Colorado	Pfeifer 2000, Czapla 2002
Golf Courses		
Blythe municipal golf course	Blythe, California	
Karsten golf course/ ASU Research Park	Mesa, Arizona	Marsh 1994, Marsh 1987
Page golf course ponds	Page, Arizona	Mueller and Wick 1998
Wildlife Refuges		
Buenos aires NWR	South of Tucson, Arizona	Marsh 1987
Cibola High Levee Pond	Cibola National Wildlife Refuge, Near Blythe, California	Marsh 2000, Minckley and LaBarbara 1999, Mueller 2006
Overton wildlife Management area	Near Lake Mead inflow, Nevada	BR 2006
Senator Wash	North of Yuma, Arizona	Kretschmann and Leslie 2006, Minckley and LaBarbara 1999

Continued on next page

Table 1. Continued. List of locations that have been used to grow-out razorback suckers.

Backwaters		
Davis cove	Lake Mohave, Arizona	Mueller 1992, Mueller and Burke 2005
Arizona juvenile	Lake Mohave, Arizona	Salisbury 1998
South Sidewinder	Lake Mohave, Arizona	Salisbury 1998
Yuma Cove	Lake Mohave, Arizona	Mueller 1992, Mueller and Burke 2005
Dandy	Lake Mohave, Nevada	Salisbury 1998
North Chemeheuvie	Lake Mohave, Nevada	Salisbury 1998
North 9 Mile	Lake Mohave, Nevada	Ty Wolters BR, personal communication
Willow	Lake Mohave, Nevada	Ty Wolters BR, personal communication
Nevada Egg	Lake Mohave, Nevada	Ty Wolters BR, personal communication
Nevada Larvae	Lake Mohave, Nevada	Ty Wolters BR, personal communication
Green River Floodplain Wetlands		
Above Brennan	Near Vernal, Utah	Pfeifer et al. 2003
Bonanza Bridge	Near Vernal, Utah	Pfeifer et al. 2003
Johnson bottom	Near Vernal, Utah	Modde and Haines 2005
Leota 10	Near Vernal, Utah	USFWS 1999
Leota bottom	Near Vernal, Utah	Modde and Haines 2005
Old charley Wash	Near Vernal, Utah	Modde and Haines 2005, Modde 1996
Leased ponds in the Uintah basin	Near Vernal, Utah	Irving et al. 2004, Pfeifer et al. 2003
Other		
Floyd Lamb state park (Tuele spring)	Las Vegas, Nevada	Marsh 1994
Trinidad State Junior College	Alamosa, Colorado	Schnoor and Logan 2002
Grow-out ponds	Near Farmingotn, NM	Schnoor and Logan 2002

Table 2. Facilities available at major razorback sucker fish hatcheries.

Location	Water Source	Type of Facility	Number	Size (Surface Acres)	Volume (Gallons)	Flow (gpm)
Bubbling Ponds Fish Hatchery	Open spring	Lined Pond	6	0.25	1,000,000	275
	2200 gpm	Earthen pond	2	0.25	1,000,000	275
		Linear Raceways	3		2,250	
		Square concrete tank	2		6,300	
		Circular tank	6		650	
Dexter National Fish Hatchery	5 shallow aquifer wells	Lined/Earthen ponds	46	0.1 to 1.0		
	2000 gpm	Linear Raceways	4		5,500	
		Rectangular tanks	20		540	
		Circular tanks	40		120	
		Circular tanks	50		200	
		Aquaria	80		10	
		Aquaria	20		40	
Grand Junction Native Fish Facility	municipal drinking water	Circular tank	14		900	12
		Circular tank	78		200	5
Horsethief rearing ponds	Pumped river water	Earthen Pond	8	0.25 – 0.5		
Ouray National Fish Hatchery	7 shallow wells	Lined pond	24	0.125 - 0.25		10
	600 gpm	Circular tank	30		120	5
		Circular tank	27		900	10 - 15
Willow Beach National Fish Hatchery	Solar heated	Linear Raceway	3		1,500	
	Colorado River water	Linear Raceway	16		16,000	
		Aquaria	60		10 gallon	
Uvalde National Fish Hatchery	2 Deep Aquifer Wells	Lined ponds	11	1.0		
	1,500 gpm	Earthen ponds	37	.25 – 1.0		
		Linear Raceways	2		6,500	
		Linear Raceways	12		1,000	
		Circular tanks	12		200	
		Circular tanks	3		3,000	

Table 3. Water quality ranges at each culture facility.

Location		Season			
		Spring (Mar-May)	Summer (Jun-Aug)	Fall (Sept-Nov)	Winter (Dec-Feb)
Bubbling Ponds	Temperature (C)	15-20	22-24	19-21	13-16
	PH	7.8-8.0	7.3-8.6	7.3-8.4	7.3-8.0
	D.O (mg/L)	5.8-14.0	5.8-14.0	5.8-14.0	5.8-14.0
	Alkalinity (mg/L)				
	Pathogens	Ich, Costia Trichodina Aeromonas/Pseudomonas Columnaris	Ich, Costia Trichodina Aeromonas Columnaris	Ich, Costia Trichodina Aeromonas Columnaris	Ich, Costia Trichodina Aeromonas Columnaris
Dexter	Temperature (C)	17-20	22-28	17-20	10-16
	PH	7.5-8.5	7.5	8.5	7.5
	D.O (mg/L)	2.8 – 9.7	2.8 – 9.7	2.8 – 9.7	2.8 – 9.7
	Alkalinity (mg/L)	165 - 188	165 - 188	165 - 188	165 - 188
	Pathogens	Minimal - only what	is brought in with	incoming fish	
Grand Junction	Temperature (C)	23-25	23-25	23-25	23-25
	PH	7.7-8.0	7.7-8.0	7.7-8.0	7.7-8.0
	D.O (mg/L)	7.0-7.5	6.5-7.0	6.0-6.5	4.5-5.5
	Alkalinity (mg/L)	100	100	100	100
	Pathogens	None at intensive	culture facility, Ich at	broodstock ponds	
Ouray	Temperature (C)	11-25	11-25	11-25	11-25
	PH	7.4-8.2	7.4-8.2	7.4-8.2	7.4-8.2
	D.O (mg/L)	5.0-12.0	5.0-7.2	5.0-7.2	5.0-7.2
	Alkalinity (mg/L)	119	119	119	119
	Pathogens	Costia	Costia	Costia	Costia
Willow Beach	Temperature (C)	17-20	20-25	17-20	13-18
	PH	7.5-8.0	7.5-8.0	7.5-8.0	7.5-8.0
	D.O (mg/L)	3.0-9.0	3.0-6.0	3.0-9.0	4.0-9.0
	Alkalinity (mg/L)	300-400	300-400	300-400	300-400
	Pathogens	Ich, Costia columnaris Aeromonas	Ich, Costia columnaris Aeromonas	Ich, Costia columnaris Aeromonas	Ich, Costia columnaris Aeromonas
Uvalde	Temperature (C)	19-26	26-28	18-28	14-18
	PH	7.7-8.2	7.7-8.2	7.7-8.2	7.7-8.2
	D.O (mg/L)	4.0-12.0	4.0-12.0	4.0-12.0	4.0-12.0
	Alkalinity (mg/L)	226	226	226	226
	Pathogens		Columnaris		

Bubbling Ponds State Fish Hatchery

Bubbling Ponds Fish Hatchery in Arizona does not maintain razorback sucker broodstock on site. Razorback suckers are received either as juveniles from Willow Beach National Fish Hatchery or as newly-hatched larvae from Dexter National Fish Hatchery. Larval fish are typically placed into an unfertilized, unlined, 0.6-acre pond in the spring. In September, the pond is harvested by draining the pond and seining. All fish that have reached the target size (300 mm TL) are stocked. Fish that are too small to stock are split up equally between the six remaining grow-out ponds at an average density of about 5,000-7,000 fish per pond. Fish are fed by hand at approximately 2.5% body weight, split between morning and evening feedings. Fish are either fed a catfish diet made by Rangen® that is enriched with spirulina and krill, or razorback sucker diet made by Silvercup®, depending on availability. Fish are monitored visually and by sampling using a cast net. When a large number of fish have grown to the target size they are harvested by draining the pond and seining. Fish are again sorted by hand and the largest fish are stocked. Fish that have not reached the target size are returned to the ponds for further grow-out. On average it takes one to two years for fish to reach the target size with fish growing an average of 0.6 mm/day. Target numbers for production are 12,000 razorback suckers annually (300 mm TL). The biggest difficulty in rearing razorback suckers at Bubbling Ponds Fish Hatchery is protozoan parasite infestations (Ich) and associated bacterial infections that come from an open spring source that is inhabited by mosquitofish.

Dexter National Fish Hatchery

Dexter National Fish Hatchery maintains four separate razorback sucker broodstocks. These fish are spawned on site and larval fish are placed directly into

0.1-acre ponds at a density of about 20,000 larvae per pond (50-100 thousand per acre). Ponds are fertilized with alfalfa pellets and superphosphate two weeks prior to receiving larvae to produce natural feed for larval fish. Ponds are fertilized again with alfalfa pellets one week after larvae are introduced. Fish are fed a catfish starter diet (sizes 1-3) made by Rangen® that is enhanced with spirulina and krill, and then switched over to the razorback diet once they are large enough to eat 1-mm crumble. Fish are fed twice a day by hand, four days a week at 2.5-6.0 % body weight. Feed ration is decreased if excess feed is seen remaining on the pond bottom following feedings. Fish are not graded or sorted during this grow-out period. Razorback suckers are harvested in the fall by draining ponds completely. Fish are sorted at harvest and distributed to other facilities for further grow-out depending on current size requirements. Razorback suckers are on average 100-200 mm TL after the first growing season and generally take 12-18 months for a majority of the fish to reach 300 mm TL. There are 16 different species of fish maintained at Dexter National Fish Hatchery and having sufficient pond space to grow out separate groups of fish is the limiting factor for production of razorback suckers at this location.

Grand Valley Native Fish Facility

The Grand Valley Native Fish Facility maintains its own brood stock in eight ponds located at the Horsethief Basin Wildlife Area in Grand Junction, Colorado. Fish are spawned on site and larvae are reared indoors in fiberglass tanks at the 24-Road Fish Hatchery in Grand Junction. The 24-Road Hatchery consists of two separate recirculating systems that operate using dechlorinated city water and two large fluidized-bed sand filters and rotating-drum filters for waste removal. Fish are held in 4-foot (n=78) or 8-foot (n=14) diameter fiberglass tanks. Larval fish are started on prepared feeds immediately after swim-up and fed exclusively razorback feeds made by Silvercup®. Fish are started on a 0-250 micron razorback diet for the first 10-12 days and then fed with gradually increasing feed sizes based on observations of feeding (250-400 micron, #1 starter). Feed sizes are mixed when transitioning to the next larger feed size. These razorback diets are specially sifted by Dr. Rick Barrows (USDA Hagerman Experiment Station, Idaho). Razorbacks are typically eating 1-mm extruded pellets by the time they are 3.5 to 4 inches in length. Fish are fed approximately 7.0% body weight per day initially and then gradually reduced to 1.5% body weight by the time they reach the 300-mm TL target size. Fish are fed seven days a week using 12-hr belt feeders. It takes 12-16 months to grow fish to the target size in the hatchery.

Razorback suckers are sorted after three months and culled to about 4,000 fish per family lot. Culled fish are stocked into leased grow-out ponds. Stocking densities for juveniles in these ponds is based on previous stocking and harvest rates and is pond specific. Grow-out ponds are harvested periodically using Fyke nets or trap nets and fish of the target size are stocked. Disease problems (Ich, Lernea), water quality problems (low DO), and difficulty in removing all of the fish are challenges for grow-out of razorback suckers in these natural ponds.

Fish reared in the 24-Road facility are sorted again at four to five months of age into small and large size groups to obtain more uniform growth rates. Batch estimates of fish weight are done every month for each tank. A group of fish are weighed and counted to give an average weight for the tank with lengths estimated based on a length/weight chart. The biggest difficulties for growing out razorback suckers at the 24-Road Fish Hatchery are insufficient space and water flow (oxygen) to grow fish to the target size.

At the Horsethief Basin Ponds where broodstock are reared, diseases such as Ich are problematic because water is pumped directly from the Colorado River.

Ouray National Fish Hatchery

Ouray National Fish Hatchery maintains its own brood stock and spawns fish on-site. Larvae are transferred from indoor hatching tanks to unfertilized 0.2-acre outdoor ponds and stocked at densities of 10,000-20,000 larvae per pond. Even though outdoor ponds are covered with bird netting, avian predators still get caught in the nets if they can see fish. Ponds are dyed blue as the fish grow to prevent avian predation. While in the outdoor ponds, fish are fed a slow-sinking salmon diet made by Silvercup®, twice daily, by hand. Amount of feed is based on periodic sample counts. Fish are grown until late September at which time temperatures require that all fish, other than adult broodstock, be brought inside for the winter. Ponds are drained completely and fish are sorted by hand. Fish that have reached the target size (300 mm TL) are stocked into the Green and Colorado rivers. All remaining fish are moved indoors and held in 3-foot (n= 30) or 8-foot (n=27) diameter circular tanks. On average it takes 12-18 months to grow fish to the 300 mm TL at Ouray hatchery.

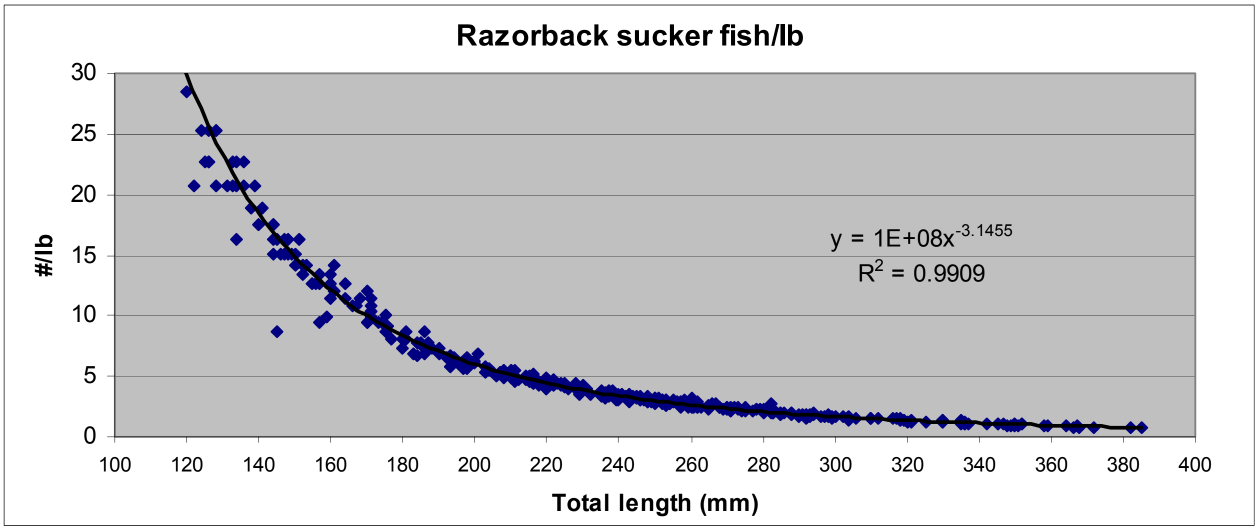
Razorback suckers are held during the winter in a recirculating system that operates using two large fluidized-bed sand filters and a rotating-drum filter for solids removal. Fish are fed the Silvercup® razorback diet using belt feeders. There is currently capacity to hold only 20,000, 200-300 mm TL fish inside the facility and any extra fish are stocked into floodplain-wetlands or used for research purposes. Ouray no longer leases any private grow-out ponds. Grow-out ponds were troublesome due to poor water quality, harvesting difficulties, and non-native fish introductions. The biggest difficulty for production of razorback suckers at the Ouray National Fish Hatchery is space during the winter to maintain large numbers of fish, and high iron and manganese in the well water that must be filtered out prior to use.

Willow Beach National Fish Hatchery

Willow Beach National Fish Hatchery receives wild-caught larvae from Lake Mohave. Larvae are treated for diseases with formalin and malachite green and placed in 45, ten-gallon flow-through aquaria. Recirculated, solar heated water, 22-25°C, is used to allow production of warmwater fish at this traditionally coldwater facility (Figiel 2003, Figiel et al. 2005). Fish are fed brine shrimp nauplii to satiation every hour and after 14 days small amounts of specialized larval fish diet (Encapsulon, Cyclopeeze, spirulina, and artificial plankton) are introduced. After 30-60 days fish are transferred to six, 32-gallon fiberglass troughs at densities of 1,000 to 1,500 fish per tank and then a month later moved outside to eight recirculating raceways that use a combination of well water and solar-heated water to maintain temperatures of 22-25°C during the summer months.

When in the outside raceways, fish are fed the razorback diet using belt feeders and fed by hand at 1.0-7.0% body weight per day. Feed amount is adjusted based on sample counts according to a feed conversion program developed for razorback suckers by Willow Beach Hatchery personnel. This program uses length and number-per-pound generated from several years of razorback growth data (Figure 1). Fish are sorted opportunistically and are not handled during the summer months when water temperatures are above 20°C. In 2004, the target size for stocking was 325 mm TL or greater (WBNFH 2004) with a target of producing 6,000 fish per year. Reaching this target size usually takes two growing seasons. The biggest difficulty in rearing razorback suckers at Willow Beach National Fish Hatchery is insufficient space to grow fish to increased target sizes (400-500 mm TL).

Figure 1. Relationship between length and number of fish per pound.



* Developed by personnel at Willow Beach National Fish Hatchery using several years of growth data.

Uvalde National Fish Hatchery

Uvalde National Fish Hatchery in Texas receives 35,000-60,000 razorback sucker fry annually in March/April from Dexter National Fish Hatchery. The fry are acclimated in bags submerged in the pond for a minimum of one hour and released into a 1-acre fertilized pond, where they are reared for the remainder of the summer. Fingerlings are fed a starter razorback diet when they reach approximately 50 mm TL. In April/May, the previous year class of razorbacks are captured from their over-wintering pond, enumerated, graded, and split into 1-acre grow-out ponds. Approximately 4,000-5,000 fish will be placed in each 1-acre pond for summer grow-out. Fish are reared for approximately 150 days (May-Oct) and fed the Bozeman razorback diet two times a day/ five days a week at 1.5-3.0 % body weight per day, based on average water temperature. In general, juvenile razorback suckers (received as fry during the previous spring) reach the target size of 300 mm TL in approximately 6 months. In 2006/2007, Uvalde produced 6,000 razorback suckers, 300 mm TL for introduction into the San Juan River. Starting in 2008, Uvalde NFH will be producing and distributing 12,000, 300 mm TL razorbacks for stocking into the San Juan River. Predation from migrating cormorants has occurred, but timing of harvest and overwintering protection methods such as covering ponds with netting or placing fish indoors helps to minimize losses during the cormorant migration (November to March). Uvalde has experienced razorback mortalities because of bacterial problems but these are usually resolved through the use of oxytetracyline medicated feed.

Overview of Differences in Culture Methods

Several main differences were noted when conducting surveys at each of the five main production facilities for razorback sucker (See Appendix 3). These differences include different stocking and rearing densities (Table 4-5), various feeding regimes and type of feeds (Table 7), as well as differences in grading or sorting practices. Some of these differences are related to whether or not razorback suckers are being reared in extensive-culture facilities (ponds) or intensive-culture settings (raceways or tanks). Some practices are unique to a single facility or a couple of facilities (Table 6). Managers at each facility were asked to identify the biggest difficulty or constraint that they experience when growing-out juvenile razorback suckers at their respective location. Space constraints, water quality, and disease problems were the main factors limiting production of razorback suckers at these facilities (Table 8). Calculated or reported growth rates from the literature varies widely (Table 9) and range from 0.2 to 1.8

mm/day. These growth rates indicate that juvenile razorback suckers have a very high growth potential under optimal rearing conditions.

Table 4. Stocking densities for larvae and fry in ponds.

Location	Pond Size	Number of Fish	Fish Size	Number/Acre
Dexter	0.1	20,000	Larvae	50,000-100,000
Ouray	0.2	10,000-20,000	Larvae	50,000-100,000
Bubbling Ponds	0.25	5,000-7,000	Fry	20,000-28,000
Wahweap	0.4	5,000	Fry	12,500
Uvalde	1.0	35,000	Fry	35,000

Table 5. Rearing densities at intensive culture facilities.

Location	Size of tank	Gallons	Flow rate	Lbs of fish	Kg of fish	Max Lbs/gallon
Ouray	3 foot circular	120	5	20-53	9-24	0.44
	8 foot circular	850	10-15	42-146	19-66	0.17
Grand Junction	4 foot circular	200	5	16-66	7.5-30	0.33
	8 foot circular	850	12	66-253	30-115	0.29
Lake Mead	6 foot square	750	2-5	20-65	9-29	0.09

Table 6. Rearing practices that are unique to specific rearing facilities.

Facility	Unique practice or methods
Bubbling Ponds	Larval fish reared in unfertilized unlined pond Higher water flows through ponds than at other facilities
Dexter	Fertilizes ponds prior to larvae introduction with alfalfa pellets and superphosphate
Grand Junction/Ouray	Use of fluidized-bed sand filters for removal of nitrates and nitrites
Horsethief Basin	Use of surface agitators for aeration in broodstock ponds
Lake Mead	Rearing of fish in square fiberglass tanks - 750 gallon
Ouray	Water dyes to prevent predation, supplemental aeration in ponds - air stones
Willow Beach	Artemia fed to larval fish, and specialized larval fish diets Rearing fish in recirculating outdoor raceways with solar heated water Attempted rearing fish in net pens in the Colorado River
Uvalde	Ponds are fertilized prior to receipt of fry to start them on a more natural diet

Table 7. Types of feed used at razorback sucker hatcheries.

Location	Holding environment	Larval fish	Juvenile to Adult Fish
Bubbling Ponds	Unlined pond	Unfertilized ponds, natural foods	Rangen® Catfish diet Silver Cup® razorback diet depending on availability
Dexter	Lined pond	Ponds fertilized with alfalpha pellets and superphosphate, natural foods	Rangen® Catfish diet Silver Cup® razorback diet once they are large enough to take 1 mm feed
Grand Junction	Fiberglass circular tank	0-250 micron razorback diet - 1st 10 days Progressively larger sifted razorback diet	Silver Cup® razorback diet Small sizes specially sifted by Rick Barrows
Ouray	Fiberglass circular tank Lined ponds	0-250 micron razorback diet - 1st 10 days Progressively larger sifted razorback diet	Silver Cup® razorback diet Silver Cup® Slow sinking salmon diet
Willow Beach	Aquaria Fiberglass troughs Outdoor raceways	Brine shrimp naupli Encapsulon, Cyclopeeze, spirulina, and artificial plankton	Silver Cup® razorback diet Silver Cup® razorback diet
Uvalde	Lined and unlined ponds	Ponds fertilized with alfalpha pellets and superphosphate; invertebrate production	Silver Cup® razorback diet

Table 8. Factors limiting production at major razorback sucker facilities.

Location	Biggest problem or factor limiting production
Bubbling Ponds	Disease problems associated with an open spring water source
Dexter	Space constraints - 16 different species on station makes it
	difficult to maintain separate razorback stocks
Grand Junction	Space constraints related to water quality and dissolved
	oxygen limitations of recirculating systems
Ouray	Water quality problems caused by high iron and manganese
	Winter temperatures that require all fish to be moved indoors
	Space constraints related to water quality and dissolved oxygen
Willow Beach	Space constraints. Growing fish to increasingly larger sizes
	results in insufficient space on station for new fish
Uvalde	Summer temps can get high-requiring power usage to triple due to higher groundwater pumping to keep ponds cool.

Table 9. Reported and calculated growth rates from the literature.

Location	Calculated Growth Rate (mm/day)	Citation	Comments
Arizona Juvenile, lake Mohave	0.95 *	Salisbury 1998	82 mm at stocking, 8 months of growth, density =1000 fish/acre
Bonita Creek	0.792*	Brooks 1986	40 mm juveniles, for 2 months
Cibola High Levee Pond	0.88 - 1.19 * [a]	Marsh 2000	57-167 mm fish out for 3 years
Cibola High Levee Pond	0.267	Minckley and LaBarbara 1999	3 years, fish caught with trammel nets
Cibola High Levee Pond	0.2 +	Mueller et al 2004	5 year study on tagged fish
Cibola High Levee Pond	0.2 +	Mueller 2006	86 fish, growth rate based on recaptures, growth slowed at 350 mm +
Dexter	0.426	Minckley 1983	ponds in 1981
Dexter	0.58 * [a]	Uliberri 2003b	200-250 mm stocked. Density = with 3,256/0.98 acre pond, 44.8 % achieved 305 mm
Floodplain wetland - Green river	0.48 – 0.77	Modde and Haines 2005	first 160 days of life
Floodplain wetland - Stirrup	0.6	Brunson and christopherson 2005	larval fish, 64 days
Floodplain wetland - Stirrup	0.4	Brunson and christopherson 2005	density of 18,000 larvae per acre
Floodplain wetland - Stirrup	0.92	Brunson and christopherson 2005	4,000 larvae per acre
Green River, floodplain wetland	0.71 to 1.08	Modde and Haines 2005	Larval fish, first few months of growth
Green River, floodplain wetlands	1.3	Birchell and christopherson 2004	100 mm, growth rates at Ouray were only 50 % that of floodplain wetlands
Humphrey pond, Colorado	1.4 *	Kaeding and osmundson 1989	55 mm at stocking, fertilized pond
Lake Mead	0.048 *	Ruppert 1999	Adult, Lake mead recaptures, out for 1 year
Lake Mohave backwater	1.11 * [a]	Burke 1995	Month old larvae stocked
Dandy backwater, Lake Mohave	0.97 *	Salisbury 1998	82 mm at stocking, 8 months of growth, density =1000 fish/acre
North Chemeheuvie, Mohave	0.78 *	Salisbury 1998	82 mm at stocking, 8 months of growth, density =1000 fish/acre
Ouray National Fish Hatchery	0.5 *	USFWS 1999	Average yearling in ponds
Ouray National Fish Hatchery	0.38 *	USFWS 1999	Average yearling in raceways or tanks
Ouray National Fish Hatchery	0.56 - 0.7 *	Tyus 1998	April to Oct in ponds, 127 mm to 157 mm at end of 1st season
Page, AZ golf course	0.54 - 0.68 * [a]	Mueller and Wick 1998	115 mm to 360 mm in 12 – 15 month period, collected with trammel net
Rinderknecht pond, Utah	0.268 *	Pfeifer et al 2003	juvenile fish (145 mm) , stocked at 444 per acre
Uvalde	0.56 + *	USBR 2006	Stocked <200 mm, into ½ acre pond and harvested >300 mm six months later
Vincent Pond, Utah	0.382 *	Pfeifer et al 2003	Larval fish, stocked at 2500 per acre
Yuma Cove	1.06 *	Mueller 1995	Naturally spawned larval fish
Yuma Cove	1.8 * [a]	Mueller and Burke 2005	Stocked as 25 mm larvae, reached 300 mm by end of summer

* Calculated growth rates based on information provided in the literature

[a] Approximations of maximum growth potential (based on average maximum sizes of fish reported at harvest

General Information on Factors that Affect Fish Growth

Growth in fish is extremely variable, and is impacted by many different physiological and environmental factors. Growth rates are known to change with size and age, sex, season, activity level, density, amount of living space, quality and quantity of food, genetics, and temperature (Brett 1979). Growth experiments conducted at different times of year can result in growth rates that are not comparable. As fish become larger their physiological potential to grow decreases making determination of growth rate dependent on the size of the starting fish and the length of the experiment (Busacker et al. 1990). Genetic factors also have great potential to influence growth rate. Some species have strains and races that display vastly different growth potentials (Reinitz et al. 1979). All of these factors combine to make assessment of the individual factors controlling fish growth difficult.

Water temperature is probably the most important variable affecting growth rate. All of the basic functions that affect growth such as feeding, digestion, and metabolism are temperature-dependent. Growth is inseparably tied to bioenergetics and therefore also tightly tied to temperature. When temperatures are below optimum, daily temperature fluctuations can stimulate growth. Photoperiod is also commonly linked to water temperature and can influence growth rates in fish (reviewed in Brett 1979).

Fish density is known to affect growth and can alter growth rates in several ways. Fish that exhibit strong territorial behaviors or natural schooling tendencies will experience reduced growth if densities are too high or too low (Brett 1979). Dominance hierarchies where some fish feed more aggressively than others can also lead to high variability in growth rates (Koebele 1985). Crowded conditions also cause physical interference between fish and poor water quality, which reduces growth (Busacker et al.

1990). The effects of fish numbers, space, and feeding opportunity are frequently correlated and often difficult to distinguish (Brett 1979).

It is impossible to study the effects of environmental factors on growth without also evaluating feed rations (Brett 1979). Amount of food, quality of the diet, particle size, number of feedings per day, and time of feeding have all been shown to affect growth (Busacker et al. 1990). In controlled laboratory studies food is usually fed ad libitum (constantly available) and other variables are altered to assess impacts of environmental factors on growth. These studies are usually conducted in tanks or raceways because researchers must verify that food is constantly available to the fish, which is difficult to do in large pond environments where the fish and the bottom are often not visible (Busacker et al. 1990).

Specific Information on Razorback Sucker Growth

Variable growth

Growth in razorback suckers is naturally highly variable and may be a function of their evolutionary history (USFWS 2002). Minckley (1983) speculated that wide size variation in a single cohort of razorback suckers may be adaptive, with fast-growing fish that reproduce at a young age surviving better in high discharge years and slow-growing, smaller fish surviving better during drought periods. This highly variable growth rate makes rearing razorback suckers in a production setting difficult because fish from a single cohort do not reach the target stocking size simultaneously. One of the major tasks for aquaculture is to maximize both individual growth and total production (Gerking 1978). This becomes more difficult when the species being cultured exhibits highly variable growth rates because of genetic influences, as is the case with razorback suckers.

Razorback sucker growth is typically very rapid during the first year of life and then declines with age. First year growth can be as low as 50 mm and as high as 350 mm (Valdez et al. 1982, Minckley 1983, Mueller 1995). Razorback sucker grow rapidly for approximately the first five or six years of life and then growth slows (McCarthy and Minckely 1987, Tyus 1998, Minckley et al. 1991). Growth of older individuals in extant wild populations is very low (Minckley 1983, Tyus 1988, Modde et al. 1996). Wild growth rates for mature adult fish in Lake Mohave based on PIT tag recaptures were often too small to be accurately measured for both males and females over the time period of 1987-1997 (Marsh and Pacey 1998). This information suggests it will take substantially longer to rear fish to increasingly larger stocking sizes (400-500 mm TL) than it did to reach the target size of 300 mm TL.

Growth in ponds

One of the main strategies for maintaining genetic refugia and self-sustaining populations of razorback sucker in the lower Colorado River basin is to rear razorback sucker larvae in production ponds until they are a suitable size for stocking (USFWS 2004). Pond culture has proven useful to promote rapid growth of juvenile razorback suckers (Kaeding and Osmundson 1989). Marsh (1994) reported that growth rates of razorback suckers reared in golf-course ponds exceeded the best growth rates obtained under intensive culture conditions at federal hatcheries, especially during the first several years of life. Growth rates in these semi-natural ponds are also comparable to estimated growth rates of juvenile wild fish (McCarthy and Minckley 1987). Modde and Haines (2005) reported the greatest growth rates in the largest and deepest floodplains with the greatest amount of submergent vegetation, but excellent growth and survival of fish in a grow-out pond is of little value if there is not an efficient way to collect the fish from the pond (Kaeding and Osmundson 1989).

Temperature

Bulkley and Pimentel (1983) used shuttle boxes in the laboratory to determine a temperature preference for razorback suckers of 23-24°C. In their studies, razorback suckers were found to avoid temperatures below 11.8°C or above 28.6°C. Razorback suckers at Bubbling Ponds Hatchery are more active in the spring and feed better as photoperiod increases even prior to water temperatures rising (Frank Agygos, personal communication). Table 3 briefly summarizes water temperature data from each facility. Detailed, seasonal water temperature profiles are not currently available for many razorback grow-out sites.

Density

Extensive studies have been conducted on commercially important species to evaluate stocking densities and feeding rates that maximize production. For these species, controlled experiments under laboratory conditions have established relationships between temperature, density, and feed ration on growth (Brett 1979) but this information is sporadic or non-existent for razorback suckers (Bays et al. 2005). Fish culturists with experience rearing razorback suckers typically have target stocking densities that they use (Tables 4-5). These stocking densities have largely been determined over time by trial and error. These approximate stocking densities provide a good starting point for more controlled types of replicated pond studies.

Feed ration

Razorback suckers are currently being fed a wide variety of prepared diets (Table 7) that range from a slow-sinking salmon feed manufactured by Silver Cup® to a spirulina and krill-enhanced catfish feed made by Rangen®. Most locations are feeding 2.0-5.0 % body weight per day. Methods for culture of razorback sucker larvae in intensive settings at fish hatcheries are well documented (Figiel 2005) and various larval fish diets have been evaluated (Tyus and Severson 1990, Severson et al. 1992), but no standardized procedures are used for feeding larval fish in intensive settings.

Razorback sucker larvae are also effectively reared in pond environments using natural foods supplemented with larval fish diets and survival is high when no predators are present (Mueller 2006). Growth rates for larval and early juvenile razorback suckers may increase with pond fertilization. Diet and physiological studies on wild razorback suckers indicate that they feed on plankton as well as benthic organisms during their entire life (Marsh 1987). Artificially fertilizing ponds may greatly increase production capacity and growth rates for razorback sucker (Papoulias and Minckley 1992) and warrants further investigation.

Handling stress

Handling stress has been shown to influence growth rates. Paukert et al. (2005) found that growth of bonytail chub was reduced by 26% when compared with controls after being repeatedly captured and handled in hoop nets. Handling effects are likely to be similar for razorback suckers that are repeatedly captured and sorted in a hatchery setting. Razorback suckers that are handled at Willow Beach National Fish Hatchery will commonly not eat for two weeks after handling (John Scott personal communication). This creates a difficult situation for production facilities because fish need to be sorted to ensure large aggressive fish do not interfere with growth of smaller individuals, but frequent handling and sorting causes stress related reductions in growth.

Measuring Growth in Captive Fish

Weight is the traditional measure used to estimate growth or production in aquaculture settings. Groups of fish are typically weighed and an average individual weight is computed (Busacker et al. 1990). Although this method is often logistically the easiest, it may not be the most informative for species with highly variable growth rates like razorback suckers, especially when target lengths must be reached before fish can be stocked. Weight can also be highly influenced by things like stomach fullness or development of gonads (Busacker et al. 1990). Condition factor or relative weight can also be used to assess growth of fish, but these tools may be more robust predictors of fecundity than of growth (Anderson and Neuman 1996). For some species sexes need to be distinguished because males and females may differ in morphology (Anderson and Neumann 1996). Mueller (2006) analyzed growth rates based on PIT tag recaptures of 86 razorback suckers in High Levee Pond and found that differences in growth do not appear to occur until fish are over 450 mm TL at which time growth rate in males slows while females continue to grow at a slightly higher rate. This would indicate that sex may not be an important factor to consider when examining growth rates unless the target grow-out size is above 450 mm TL.

The best measures of growth are often determined from the length and weight of individuals rather than from groups of fish (Anderson and Nuemannn 1996) because individual growth rates give better estimates of confidence and variance (Busacker et al. 1990). Length frequency analysis or recapture of previously marked individuals of a known size is likely to yield the most useful information for razorback sucker growth. The success of any of these methods depends on proper sampling procedures that are representative of the population as a whole (Busacker et al. 1990). Sampling methods that are known to be size-biased such as trammel nets (Mueller et al. 2004) or cast nets should not be used when trying to measure growth rates.

Conclusions

For razorback sucker, survival is largely associated with stocking size. Additional focused research is therefore needed to identify ways to increase growth rates of captive-reared razorback sucker. Growth rate in fish is controlled by many factors including fish size and age, temperature, density, and feed ration, which can all be highly correlated. Growth of razorback suckers is also inherently variable which makes the task of identifying the key factors that affect growth in captivity even more difficult. The focus at most razorback rearing facilities is production, so the types of data that are collected are often insufficient for detailed evaluations of individual rearing practices on growth. Surveys of existing razorback sucker rearing facilities indicate that culture methods vary widely and the types of growth data that are collected are not standardized. Replicated studies with detailed information on rearing location, water temperature, initial stocking size, stocking density, and the sizes of all fish at harvest are needed in order to compare the effects of individual rearing practices on growth. This type of research will ultimately provide both time and cost-savings to production facilities by reducing the amount of time necessary for razorback sucker to reach stocking size, improving overall production efficiency.

Optimum rearing densities for razorback sucker larvae and juveniles remain to be determined. Current stocking densities will be very useful as starting point for more detailed studies and although optimum rearing densities are likely to be site-specific, replicated studies on density will provide a valuable reference for hatchery managers.

Frequency of sorting is another area that needs further research. Frequent handling and sorting can cause stress-related reductions in growth, but not sorting can create dominance hierarchies that further reduce growth rates of subordinate individuals. The effects of sorting on overall fish growth in both pond and intensive culture environments warrant further investigation. Research techniques for these types of experiments are well understood and typically utilize a matrix of replicate ponds per variable (Bays et al. 2005). In every case accurate and complete records of sampling procedures and data collection are needed in order to interpret data and make inferences about growth rates (Busacker et al. 1990).

Additional research is also needed to evaluate long-term survival of stocked fish reared in ponds compared to fish reared in intensive culture facilities. Exercise conditioning and predator-recognition training may also increase survival of stocked fish and be more economically feasible than rearing fish to increasingly larger sizes prior to stocking. The success of traditional fish hatchery programs is measured largely by the number of fish stocked, but hatchery programs for endangered species must measure success in terms of long-term survival and species recovery (Brannon 1993, Anders 1998). A specific list of research recommendations follows.

Specific Research Recommendations

- **Use replicated studies to establish optimum stocking densities for ponds and tanks that can be used as a starting point for site-specific refinement**

- **Determine if sorting/grading improves overall growth rates in both ponds and intensive culture facilities**

- **Investigate the use of artificial fertilizers to improve growth of both juvenile and adult razorback suckers in ponds**

- **Determine if the razorback sucker diet gives better growth rates than cheaper catfish or salmon feeds**

- **Evaluate growth rates and production potential of new intensive culture methods such as large circular tanks**

- **Evaluate long-term survival of fish produced from raceways and circular tanks compared to fish reared in ponds**

- **Evaluate more effective means of treating fish diseases**

- **Evaluate factors other than size that may increase post-stocking survival such as exercise conditioning or predator recognition training**

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Appendices

Appendix 1. Survey Questions

Survey of Razorback Sucker Culture in the
Southwestern United States

The enclosed survey is being distributed by the Arizona Game and Fish Department to razorback sucker culture facilities throughout the Southwestern United States. The purpose of this survey is to consolidate information regarding culture of this species so that appropriate facility improvements can be considered for Bubbling Ponds Hatchery in Arizona. Specifically, we wish to increase growth rate and production efficiency at the hatchery. Information gathered in this survey will be summarized in a final report to U.S. Bureau of Reclamation in Boulder City, NV, and disseminated to all facilities that participate in the survey. A workshop to discuss the findings of this study, as well as to share general information concerning razorback sucker culture, will be organized by the Arizona Game and Fish Department at the conclusion of this study, and all participants will be invited.

Thank you for taking the time to fill out this survey. Please contact Mike Childs if you have questions or would like to discuss the survey.

Mike Childs
mchilds@sedona.net
(928) 639-1346
(928) 634-1279

Facility:_____________________________________ Date:___________________
Contact Phone # _____________________________
ContactPerson_______________________________
Contact Email: _______________________________

1. Water quality ranges at this culture facility.

Season				
	Spring (Mar-May)	Summer (Jun-Aug)	Fall (Sept-Nov)	Winter (Dec-Feb)
Temperature (C)				
PH				
D.O (mg/L)				
PO_4 (mg/L)				
TDS (mg/L)				
Hardness (mg/L) $CaCO_3$				
Pathogens				

2. What is the water source (spring, well, river, etc.) and is the source protected from fish and pathogen introduction?

3. Holding facilities available for razorback sucker.

Type[1]	N	Vol (ft^3)	Flow (gpm)	Max weight 4 inch fish	Max weight 6 inch fish	Max weight 8 inch fish	Max weight 10inch fish	Max weight 12inch fish	Max weight 14inch fish

[1]Type: (EP) denotes earthen pond, (LP) lined pond, (LR) linear raceway, (CT) circular tank, and (AQ) aquarium

4. Do you try to maintain density and flow indices at a constant value? If not, what do you think the ideal density and flow indices are for your facility?

5. Feeding and growth of razorback sucker.

Average Fish Length	Food and Quantity (g food/kg Fish)[1]								Average Growth Rate (in/month)
Larvae									
2 inch									
4 inch									
6 inch									
8 inch									
10 inch									
12 inch									
14 inch									
16 inch									

[1]Food types include: TS (trout starter), T1-5 (trout chow 1 –5), CS (catfish starter), C1-5 (catfish 1-5), RS (razorback starter), R1-5 (razorback 1-5), A (Artemia), K (krill), B (bloodworm); include notes for other food types.6. What factors do you think would be most important in improving growth rate of razorback sucker at your facility? Please discuss factors such as water quality (temperature, oxygen, pH, nitrogen), fish density, flow rate, food type and quantity, photoperiod, reproductive condition, etc., as they pertain to your facility.

7. Do you have problems with razorback stunting (or variable growth rates) at your facility? What factor(s) do you think contribute most to stunted growth of razorback sucker at your facility?

8. Do you think that natural variation in growth rate of razorback sucker can be overcome by manipulating any factors at your facility? If so, at what cost (monetary, loss of genetic diversity, etc.)?

9. Based on your answers to the above questions, what do you think the ideal culture situation would be for razorback sucker if the primary management goal was to improve growth rate (culture container, water conditions, feed, etc.).

10. Do you have any data (electronic format) that you would be willing to share that could be used to compare growth rates of razorback sucker at the various culture facilities in the Southwestern United States? If so, accompanying data on water quality, fish density, etc., would add greatly to such a dataset. This information will be summarized and provided to all razorback culturists who participate in this survey.

11. Please provide a general history of razorback sucker culture at your facility (years of culture, strategies attempted). Please include successes and failures (with details regarding holding conditions, flow, etc.), and provide an explanation for what has worked and what has not.

Appendix 2. Follow-up Surveys

Questions about existing facilities

1. What is the biggest difficulty at your facility in growing subadult razorback suckers to the target size (300 mm)?

2. What diseases are most problematic at your facility?

3. How do you treat for these diseases?

4. Do you have a target stocking density for ponds? What is it?

5. What do you feed your fish?
   How many times a day do you feed?
   What % of body weight?

6. How often do you sort/or grade fish during the year?
   How are the fish graded?

7. How do you harvest fish?
   Drain ponds completely, seine a lowered pond, fyke nets, hoop nets etc.

8. How big are the fish that you normally start with?
   How big approximately are your fish at the end of the first year?
   How long approximately does it take you to grow fish to the target size (300 mm)?

9. Do you have temperature data or growth rate data for your facility and would you be willing to share it.

   OR

10. Approx when does the mean water temp reach 20°C at your facility? Spring - Month. When in the fall does it begin to drop below 20°C.

Hypothetical questions - Opinions as to what you think would work best

1. In your opinion, what would be the best type of facility for growing out subadult RZB. (100 mm to 500 mm).

   Raceways
   Circular tanks
   Ponds
   Other

2. If using ponds, what size pond would be most effective?
   By surface area.
   1/10 acre .5 acre, 1 acre 10 acres etc.

3. What would be the ideal depth?
   Average depth
   Max depth

4. Would the pond be lined or unlined?
5. Would you grade or sort fish and how often?

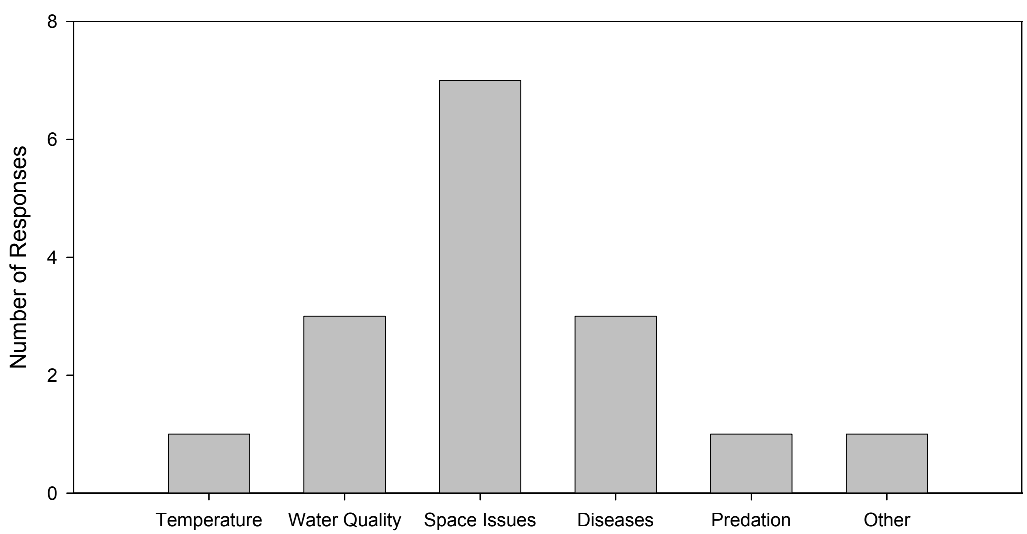
Appendix 3. Tabulated Survey Results

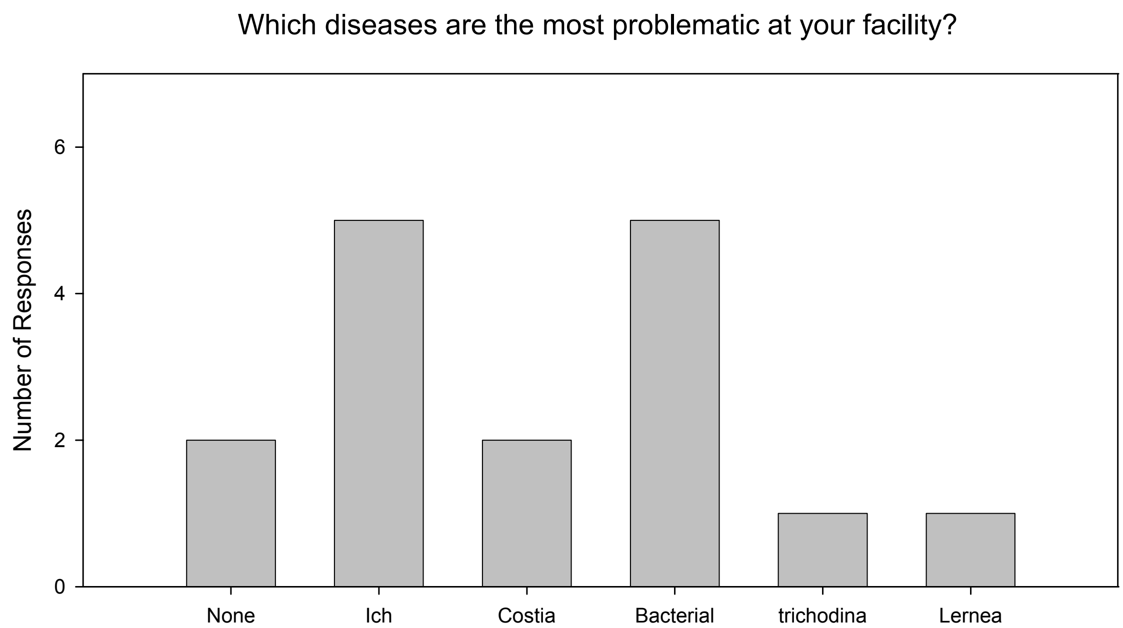
Survey Participants

Name	Facility	Telephone number	Agency
Frank Agyagos	Bubbling Ponds	928-634-4466	Arizona Game & Fish
Dave Billingsly	Bubbling Ponds	928-634-4466	Arizona Game & Fish
Dave Hampton	Dexter	505-734-5910	U.S. Fish & Wildlife Service
Manuel Ulibarri	Dexter	505-734-5910	U.S. Fish & Wildlife Service
Thad Bingham	Grand Junction	970-245-9319	U.S. Fish & Wildlife Service
Brian Scheer	Grand Junction	970-245-9319	U.S. Fish & Wildlife Service
Mike Montagne	Ouray	435-789-0351	U.S. Fish & Wildlife Service
Sam Pollock	Ouray	435-789-0351	U.S. Fish & Wildlife Service
John Scott	Willow Beach	928-767-3456	U.S. Fish & Wildlife Service
Geno Sprofera	Willow Beach	928-767-3456	U.S. Fish & Wildlife Service
Robert Krapfel	Achii Hanyo	928-853-1673	U.S. Fish & Wildlife Service
Deborah Herndon	Lake Mead	702-486-6740	Nevada Dept. of Wildlife
Quent Bradwisch	Wahweep	435-675-3714	Utah Division of wildlife Resources
Annette Morgan	Hualapai ponds	928-769-2255	Hualapai Division of Natural Resources
Joe Marrinan	Mumma	719-587-3392	Colorado Division of Wildlife
Grant Webber	Uvalde	830-278-2419	U.S. Fish & Wildlife Service

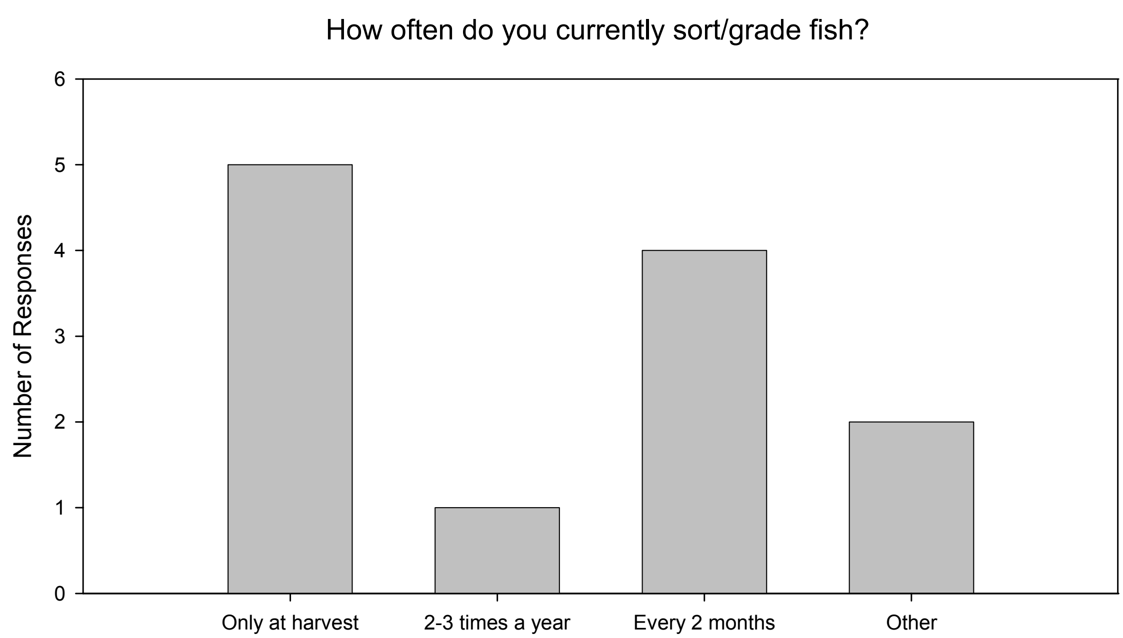
Questions about existing facilities and practices

What is the biggest difficulty at your facility in growing razorback suckers to the target size ?



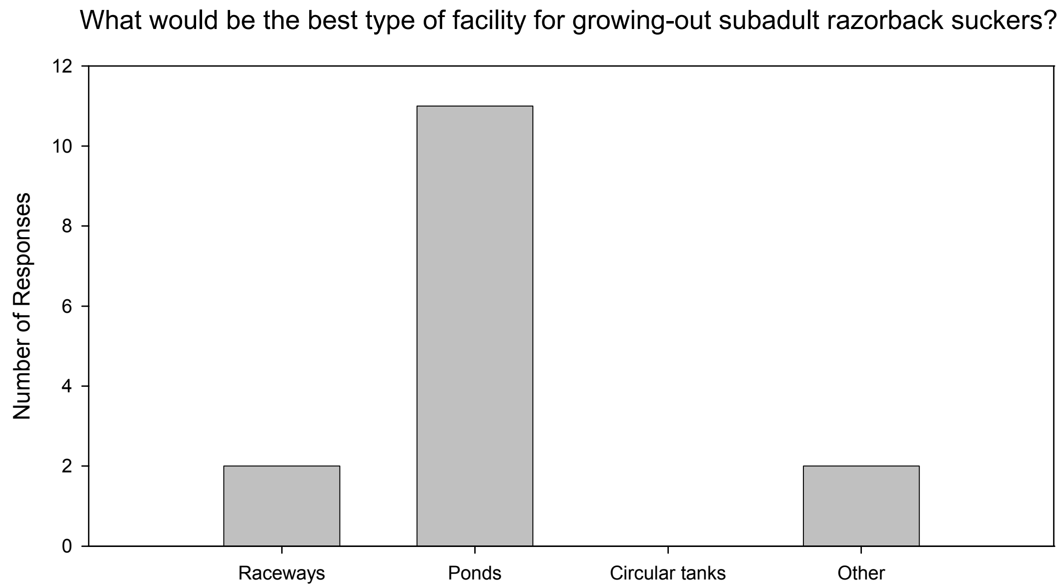


Which diseases are the most problematic at your facility?
Number of Responses
0
2
4
6
None
Ich
Costia
Bacterial
trichodina
Lernea

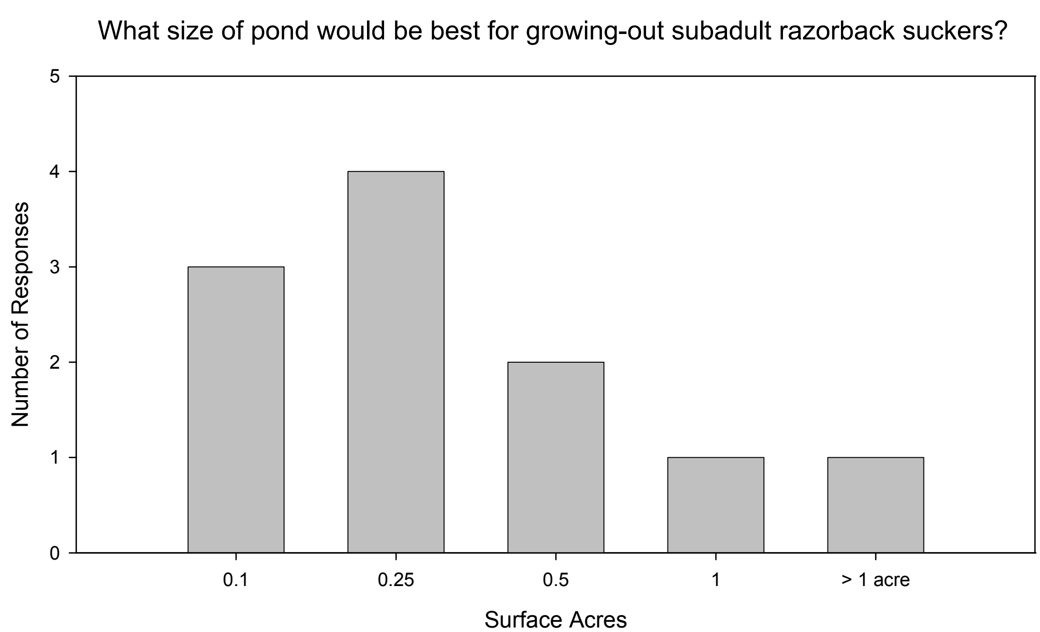


How often do you currently sort/grade fish?
Number of Responses
0
1
2
3
4
5
6
Only at harvest
2-3 times a year
Every 2 months
Other

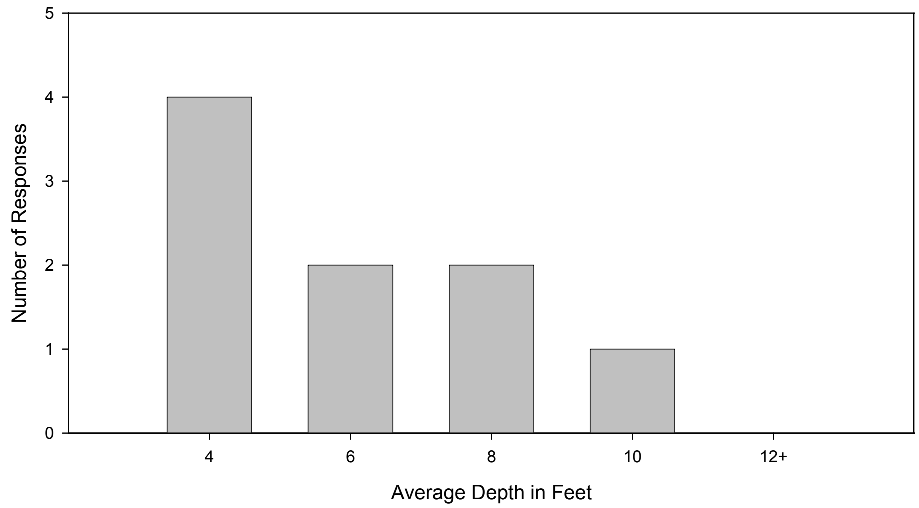
Hypothetical/Opinion Questions



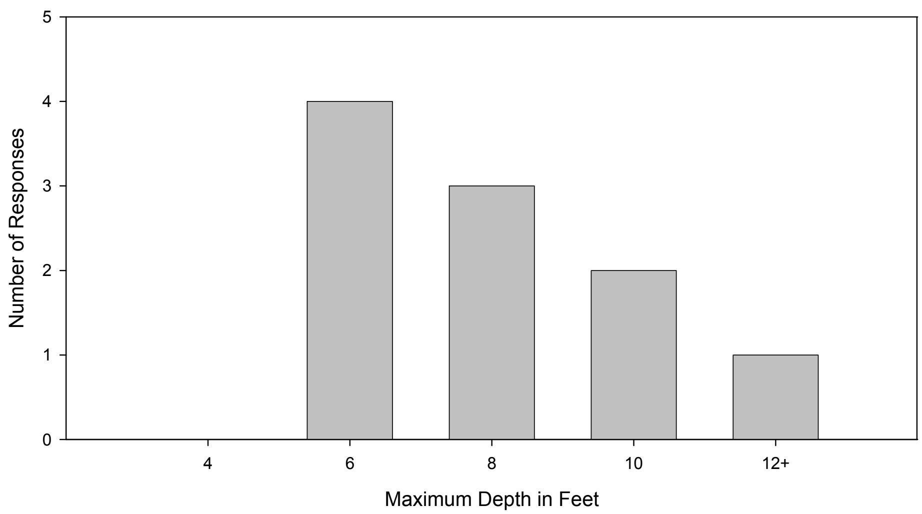
* Other = combination of ponds initially and then grow-out in raceways



What average pond depth would be best for growing-out subadult razorback suckers?



What maximum pond depth would be best for growing-out subadult razorback suckers?



Ideally how often would you sort fish?