RAC AGENDA – September 2016

1. Welcome, RAC Introductions and RAC Procedure
   - RAC Chair
2. Approval of Agenda and Minutes — **ACTION**
   - RAC Chair
3. Wildlife Board Meeting Update — **INFORMATIONAL**
   - RAC Chair
4. Regional Update — **INFORMATIONAL**
   - DWR Regional Supervisor
5. 2017-2018 Fishing Guidebook and Rule R657-13 — **ACTION**
   - Randy Oplinger, Coldwater Sport Fisheries Program Coordinator
6. OIAL Archery Hunt Strategies — **INFORMATIONAL**
   -DWR Regional Wildlife Manager

Region Specific Items – to be presented in the specified region only.

CRO. Jordanelle Reservoir Fishery Management Plan — **INFORMATIONAL**
- Chris Crockett, Aquatics Manager

SER & SRO. Lake Powell Fishery Management Plan — **INFORMATIONAL**
- Richard Hepworth, Aquatics Manager

Meeting Locations

CR RAC – Sept. 6th 6:00 PM
DNR - Boardroom
1594 W. North Temple, SLC

NR RAC – Sept. 7th 6:30 PM
Weber State University
Shepherds Bldg., Ogden

SR RAC – Sept. 13th 7:00 PM
Beaver High School
195 E. Center St,. Beaver

SER RAC – Sept. 14th 6:30 PM
John Wesley Powell Museum
1765 E. Main Street, Green River

NER RAC – Sept. 15th 6:30 PM
Wildlife Resources NER Office
318 North Vernal Ave, Vernal

Board Meeting – September 29th 9:00 AM
DNR - Boardroom
1594 W. North Temple
Salt Lake City, UT

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State of Utah

DEPARTMENT OF NATURAL RESOURCES

MICHAEL R. STYLER
Executive Director

Division of Wildlife Resources

GREGORY J. SHEEHAN
Division Director

MEMORANDUM

Date: August 25, 2016

To: Regional Advisory Council Member and Wildlife Board

From: Craig Walker, Warmwater Sport Fisheries Program Coordinator
Randy Oplinger, Coldwater Sport Fisheries Program Coordinator

SUBJECT: 2017-2018 Fishing Regulation Proposals

Statewide Rule Changes

Permit the use of corn as bait at Cutler Reservoir, Electric Lake, Fish Lake, Flaming Gorge, Lake Powell, Stateline Reservoir, Strawberry Reservoir, and Utah Lake

CRO

Jordanelle Reservoir:
Remove the words "…only 1 may be over 12 inches."
Remove the words "Bass may not be filleted, and the heads may not be removed in the field or in transit"
Utah Lake tributaries west of I-15:
Add the wording "No limit on northern pike. Anglers must not release any northern pike they catch. All northern pike must be immediately killed."
Add Riverfront Pond to the list of Community Fishery Waters

NERO

Add Big Sandwash and Red Fleet Reservoir to list of waters where yellow perch are permitted as bait
Add rule stating that burbot can be used as bait at Flaming Gorge Reservoir
Brough Reservoir:
Remove the words: "Limit 1 trout over 22 inches."
Remove the words: "All trout 22 inches or smaller must be immediately released."
Remove the words: "Artificial flies and lures only."

SRO

Donkey Lake (Boulder Mountains):
Add: "Limit 16 brook trout"
Annabella Lake (Monroe Mountains):
Add: "Limit 8 trout from Aug. 15 through Dec. 31."
Add: "Limit 4 trout from Jan. 1 through Aug. 14."
Big Lake (Monroe Mountains):
Add: "Limit 8 trout from Aug. 15 through Dec. 31."
Add: "Limit 4 trout from Jan. 1 through Aug. 14."
Deep Lake (Monroe Mountains):
Add: "Limit 8 trout from Aug. 15 through Dec. 31."
Add: "Limit 4 trout from Jan. 1 through Aug. 14."

NRO
Cold Springs Lake:
Remove the words: "CLOSED Jan. 1 through 6 a.m. on the Saturday before Memorial Day."
Add Smith Family Park Pond to list of Community Fishing Waters

R657. Natural Resources, Wildlife Resources.
R657-13. Taking Fish and Crayfish.
R657-13-1. Purpose and Authority.

(1) Under authority of Sections 23-14-18 and 23-14-19 of the Utah Code, the Wildlife Board has established this rule for taking fish and crayfish.

(2) Specific dates, areas, methods of take, requirements and other administrative details which may change annually and are pertinent are published in the proclamation of the Wildlife Board for taking fish and crayfish.

R657-13-12. Bait.

(1) Use or possession of corn, hominy, or live baitfish while fishing is unlawful, except as authorized by the Wildlife Board in the Fishing Guidebook.

(2) Use or possession of tiger salamanders (live or dead) while fishing is unlawful.

(3) Use or possession of any bait while fishing on waters designated artificial fly and lure only is unlawful.

(4) Use or possession of artificial baits which are commercially imbedded or covered with fish or fish parts while fishing is unlawful.

(5) Use or possession of bait in the form of fresh or frozen fish or fish parts while fishing is unlawful, except as provided below and in Subsections (7) and (8).

(a) Dead Bonneville cisco may be used as bait only in Bear Lake.

(b) Dead yellow perch may be used as bait only in: Big Sand Wash, Deer Creek, Echo, Fish Lake, Flaming Gorge, Gunnison, Hyrum, Johnson, Jordanelle, Mantua, Mill Meadow, Newton, Pineview, Rockport, Starvation, Utah Lake, Willard Bay and Yuba reservoirs.

(c) Dead white bass may be used as bait only in Utah Lake and the Jordan River.

(d) Dead shad, from Lake Powell, may be used as bait only in Lake Powell. Dead shad must not be removed from the Glen Canyon National Recreation Area.

(e) Dead striped bass, from Lake Powell, may be used as bait only in Lake Powell.

(f) Dead fresh or frozen salt water species including sardines and anchovies may be used as bait in any water where bait is permitted.

(g) Dead mountain sucker, white sucker, Utah sucker, redside shiner, speckled dace, mottled sculpin, fat head minnow, Utah chub, and common carp may be used as bait in any water where bait is permitted.

(h) Dead burbot, from Flaming Gorge Reservoir, may be used as bait only in Flaming Gorge Reservoir.

(6) Commercially prepared and chemically treated baitfish or their parts may be used as bait in any water where bait is permitted.

(7) The eggs of any species of fish caught in Utah, except prohibited fish, may be used in any water where bait is permitted. However, eggs may not be taken or used from fish that are being released.

(8) Use of live crayfish for bait is legal only on the water where the crayfish is captured. It is unlawful to transport live crayfish away from the water where captured.

(9) Manufactured, human-made items that may not be digestible, that are chemically treated with food stuffs, chemical fish attractants, or feeding stimulants may not be used on waters where bait is prohibited.

(10) On any water declared infested by the Wildlife Board with an aquatic invasive species, or that is subject to a closure order or control plan under R657-60, it shall be unlawful to transport any species of baitfish (live or dead) from the infested water for use as bait in any other water of the State. Baitfish are defined as those species listed in sections (5)(b),(5)(c),(5)(f) and (8).

KEY: fish, fishing, wildlife, wildlife law
Date of Enactment or Last Substantive Amendment: December 8, 2014
Notice of Continuation: October 1, 2012
Authorizing and Implemented or Interpreted Law: 23-14-18; 23-14-19; 23-19-1; 23-22-3

Utah Bowmen's Association

Once-in-a-lifetime Hunt Proposal

Proposal: Provide a Once-in-a-lifetime "Archery-Only" hunt experience.

Provide (2) options:

Option 1 – Keep once-in-a-lifetime permit as drawn. No proposed change.

Option 2 – Exchange permit for an "Archery-only" permit with new hunt dates.

Provide "Archery-Only" early, split and/or late season dates for the archery-only hunt.
Species:

- Moose – 7 days early, 21 days late.
- Bison – 21 days early.
- Rocky Mtn. Goat – 10 days early, 14 days coincide with current hunt, 7 days late.
- Desert Bighorn Sheep – 21 days late.
- Rocky Mtn. Bighorn Sheep – 21 days late.

Hunt Benefits:

- Provides an "Archery-Only" hunt experience.
- Potential fewer hunters in field during current hunts.
- Current draw process and draw benbenodds are not affected.

Discussion Items:

- DWR aerial surveys.
- Forest Service road closures.
- Interstate hunt agreement with Nevada.
- Henry's and Book Cliffs rifle deer hunt.
- Potential decrease in success rate.

Jordanelle Reservoir Fishery Management Plan

Jordanelle Reservoir Working Group

April 2016

Table of Contents

Jordanelle Working Group

By design, the Jordanelle Reservoir Working Group consisted of individuals representing different interests, constituents and angler types. In order to meet the diverse desires of various anglers, specifically along the Wasatch, representatives were selected from individuals who responded to an online Jordanelle survey and others associated with Jordanelle Reservoir. Specifically the working group consisted of representatives from Utah State Parks, Sportsman for Fish and Wildlife, Retail interests, B.A.S.S., Salt City Bass, Rocky Mountain Anglers, Trout Unlimited, Utah Anglers Coalition, Blue Ribbon Fisheries Advisory Council, Utah Division of Wildlife Resources, trophy anglers and general anglers.

Working Group Members

Laurie Backus – Jordanelle State Park
Paul Birdsey – DWR Cold Water Sportfish Coordinator
Matt Carollo – Trophy anglers (Brown Trout)
John Fairchild – DWR Central Region Supervisor (Facilitator)
Mike Fisher – Retail Industry (Sportsman's Warehouse Fisheries Manager)
Nick Granato – Trophy anglers (tiger muskie)
Ashley Green – DWR Habitat Section Chief (Recorder)
Brent McNee – B.A.S.S. and Blue Ribbon Fisheries Advisory Council
Mike Ptaschinski – Salt City Bass, panfish anglers
Jerry Schlief – Rocky Mountain Anglers, Walleye anglers
John Schultz – Trout Unlimited, Utah Anglers Coalition, Blue Ribbon Fisheries Advisory Council
Mike Slater – DWR Central Region Aquatics Program Manager (Chair)
Ken Strong – Sportsman for Fish and Wildlife, general anglers, Blue Ribbon Fish Advisory Council
Jackie Watson – DWR Blue Ribbon Fishery Biologist CRO

Jordanelle Working Group Purpose and Mission Statement

The purpose of the Jordanelle Reservoir Fishery Management Plan Working Group was to assist the Utah Division of Wildlife Resources (UDWR) in updating and developing a Jordanelle Reservoir Fishery Management Plan that provides a quality fishing experience.

Vision Statement

The fishery at Jordanelle Reservoir attracts anglers from the Wasatch Front (and Back) who: 1) Enjoy the family fishing and overall recreational experience provided by Jordanelle State Park, 2) Value the trophy fishing opportunities available at the reservoir, and 3) Pursue a diverse array of species using a variety of fishing techniques.

Current Condition of Jordanelle Reservoir

Jordanelle Reservoir is an impoundment of the Provo River and has been managed as a state park since its opening in 1995. The reservoir is located in Wasatch County, approximately 11 miles upstream of Deer Creek Reservoir and 10 miles north of Heber City, Utah on HWY 40. The reservoir stores 360,500 acre feet of water and covers 3,300 surface acres.

Jordanelle Reservoir has been managed as a two-tier, Rainbow Trout *Oncorhynchus mykiss* and Smallmouth Bass *Micropterus dolomieui*, basic yield fishery since initial management plan development in 1993. Rainbow Trout have been stocked annually since 1993. Other fish species collected from Jordanelle Reservoir include Brown Trout *Salmo trutta*, Bonneville Cutthroat Trout *Oncorhynchus clarkii utah*, Utah Chub *Gila atraria*, Utah Sucker *Catostomus ardens,* and illegally introduced Yellow Perch *Perca flavescens*.

Currently several issues with the Jordanelle fishery have prompted the need for a revised management plan, hence the establishment of a working group. Return of stocked Rainbow Trout to the creel and monitoring gillnets has been low, with catch rates decreasing since about 2004. In the 2013 creel Rainbow Trout catch rates were 0.12 fish/hour and in gillnets 0.75 fish/hour, both below statewide targets. Catch rates of Smallmouth Bass have increased in the creel and are stable in monitoring activities. However, Smallmouth Bass growth rates after age 2 fall below the 25^{th} percentile for North American lentic waters (Wiley and Watson 2014) and anglers are dissatisfied with the lack of large individuals. Finally, angler use has decreased dramatically from 65 hours/acre in 2003 to 12 hours/acre in 2013 (Hepworth et al. 2004, Wiley 2014).

Goals for Management of Jordanelle Reservoir

1. Enrich trophy angling opportunities
2. Promote a family fishery
3. Ensure a quality recreational experience for boaters and anglers
4. Manage Jordanelle fishery for compatibility with native species management
5. Manage Jordanelle as a destination fishery
6. Ensure no new species are illegally moved in or out of Jordanelle

Objectives and Strategies Associated with Management Goals

Goal 1: Enrich trophy angling opportunities

Objective 1: Increase forage base

Targets Develop monitoring protocol for forage species with target catch rates; manage for 8:1 forage to predator ratio

Strategies

- Ensure forage species are established and available prior to predator introductions
- Introduce Kokanee Salmon
  - Determine annual stocking densities
- Consider introduction of native species and other cyprinid species
  - Mountain Whitefish
  - Redside Shiner
  - Fathead Minnow
- Determine reproductive status of Utah Chub in Jordanelle Reservoir
  - Design sampling protocol focused on young of year and juvenile Utah Chub to determine if successful reproduction is occurring
  - If there is a lack of successful reproduction, determine why. If successful reproduction does occur, determine what is happening to juvenile Utah Chub
- Explore options for increasing success of forage species
  - Reservoir habitat enhancements

Objective 2: Increase size structure of Smallmouth Bass

Targets From electrofishing surveys: mean annual proportional size distribution (PSD) 20-60 ((# of individuals ≥ 11"/ # of individuals ≥ 7")*100); mean annual PSD-Preferred 10-20 ((# of individuals ≥ 14"/ # of individuals ≥ 7")*100); mean length 9 inches at Age 3; relative weight (W_r) 90-100 (values that indicate healthy condition and acceptable predator/prey ratio)

Strategies

- Increase harvest of Smallmouth Bass
  - Encourage harvest of individuals under 12 inches
  - Implement appropriate regulations for increased harvest
  - Educate public on fish consumption advisories for mercury
- Introduce predator to reduce number of small individuals
  - Determine appropriate timing and density for stocking wipers
  - Conduct wiper diet study
- Establish stable and appropriate forage for Smallmouth Bass >Age 2

Objective 3: Maintain and/or increase size structure of Brown Trout

Targets From gillnet surveys: Establish target annual mean values of PSD using previously collected data and available literature; relative weight (W_r) 90-100

Strategies

- Establish stable forage
  - Introduce Kokanee Salmon
  - Protect spawning Kokanee population via statewide regulation of catch and release September 10-November 30
- Ensure new species introductions do not negatively impact Brown Trout population

  - Research stocking densities and timing of all new species for compatibility with Brown Trout
  - Research potential competition between Brown Trout and new species, mitigate if necessary

Objective 4: Expand fishery to include trophy apex predator

Strategies

- Develop stable forage (see Goal 1 Objective 1)
- Introduce tiger muskie as a trophy apex predator
  - Determine appropriate timeline and density for introduction
  - Implement appropriate regulations for tiger muskie
- Monitor diet of introduced tiger muskie and populations of prey species
  - Stable isotope analysis of tiger muskie
  - Catch rates and condition of prey species
- Consider potential reservoir habitat needs and improvements specific to tiger muskie

Goal 2: Promote a family fishery

Objective 1: Increase opportunities for shoreline angling

Strategies

- Explore viability of fishing platforms and docks
- Support and facilitate shoreline access via trails in the Ross Creek area
- Support and facilitate shoreline access via trails in the Crandall Point area
- Educate public on where shoreline angling is available within park boundaries
- Support and facilitate non-motorized boat access on north shore, include shoreline angling opportunities with this project
- Create brochure "Techniques for Successful Shoreline Angling at Jordanelle Reservoir"
  - Enter proposal for Blue Ribbon Fisheries Advisory Council funding in WRI database

Objective 2: Increase Rainbow Trout catch rates

Targets From 2019 angler survey: Catch rate 0.25 fish/hour (doubles current catch rate); average total length 15 inches; achieve statewide catch rate goal of 0.30-0.50 fish/hour by 2026

Strategies

- Adjust Rainbow Trout size at stocking and timing of stocking to improve survival and growth
  - Differentially spray mark stocked Rainbow Trout for three consecutive years to evaluate stocking strategy

Objective 3: Expand species for additional opportunities, i.e., shoulder seasons

Strategies

- Highlight shoulder season fishing opportunities for Brown Trout
  - Determine densities of potential supplemental stocking
- Introduce splake
  - Determine timing and stocking densities
- Host ice fishing events to highlight splake fishery once established
- Educate anglers on splake fishing times and techniques
  - Clinics, seminars, and social media posts

Objective 4: Increase awareness of angling opportunities

Strategies

- Provide updated information regarding new management plan to the Central Region RAC
- Provide information of angling opportunities at Jordanelle
  - Media coverage (TV, radio, and newspaper)
    - Changes to Rainbow Trout stocking strategy
  - Update State Park signage
  - Utilize social media and stakeholder websites
- Media coverage of all new species stocking
  - Kokanee, wiper, splake, tiger muskie
- Highlight ice fishing opportunities at Jordanelle
  - When appropriate focus media coverage on splake fishery

Goal 3: Ensure a quality recreational experience for boaters and anglers

Objective 1: Reduce spatial competition between recreational boaters and anglers

Strategies

- Increase wakeless area at Upper Provo River mouth near Rock Cliff
- Determine viability of potential wakeless area at the north end of the reservoir
- Create hands-on or computer based educational clinics on boating etiquette and safe boating practices
- Include DWR conservation officers in enforcing boating and wakeless regulations
  - Explain the purpose of wakeless areas and safe boating distance during contact
  - Promote tolerance
- Educate anglers on opportunities for various shoulder season species
  - Fall - Brown Trout
  - Spring, fall, and winter - splake
- Encourage anglers to fish shoulder seasons
  - Outreach efforts through social media, park signage, and brochure
  - Media coverage to highlight shoulder seasons and reduced crowds

Objective 2: Increase watchable wildlife opportunities

Strategies

- Partner with State Parks staff and Strawberry project biologists to document Kokanee Salmon spawning activity beginning September 2018
- After spawning is documented begin advertising Kokanee viewing opportunities near Rock Cliff the following year
  - Distribute flyers at Strawberry Reservoir Kokanee days
  - Media (TV, radio, newspapers)
  - Social media and websites
- Partner with State Parks to host viewing events with media coverage
- Update and reprint "Discover Utah Wildlife, Spawning Run-Kokanee Salmon" Kokanee lifecycle posters for distribution at Jordanelle State Park

Goal 4: Manage Jordanelle fishery for compatibility with native species management

Objective 1: Reduce risk of negative impacts on native species

Strategies

- Collaborate with native aquatics staff, conservation teams, and June Sucker Recovery and Implementation Program to gain approval of Jordanelle Management Plan
- Generate a stakeholder contact list
  - Notify stakeholders in advance of new species introductions
- Annually present progress to appropriate groups until Jordanelle fishery is established
  - Changes, if any, to management plan
  - Status of Jordanelle fishery

Objective 2: Increase awareness of native species in the drainage

Strategies

- Develop outreach with native species emphasis
  - Columbia Spotted Frog, Bonneville Cutthroat, Southern Leatherside Chub, June Sucker

Goal 5: Manage Jordanelle as a destination fishery

Targets From 2019 angler survey: Angler hours increased from 12 hours/acre to 18 hours/acre, with a goal of 35 hours/acre by 2026.

Objective 1: Increase diversity of species that anglers can target

- Improve size, condition, and return of current sport fish species
  - Rainbow Trout, Smallmouth Bass, Brown Trout
- Introduce new sport fish species to increase diversity
  - Kokanee Salmon, wipers, splake, tiger muskie

Objective 2: Reestablish Blue Ribbon designation

- Obtain most recent Blue Ribbon Fisheries Advisory Council ranking of Jordanelle Reservoir
  - Review scores to determine if issues outside of this management plan need to be addressed
- Recommend Jordanelle for Blue Ribbon consideration by 2019

Goal 6: Ensure no new species are illegally moved in or out of Jordanelle

Objective 1: Promote responsible angling and recreational practices

Strategies

- Utilize DWR Outreach Section to educate the public about changes to the Jordanelle fishery and the importance of not moving fish
  - Potential statewide illegal transport campaign
- Increase DWR Law Enforcement efforts at Jordanelle in regards to illegal introductions both AIS and fish
- Implement appropriate regulations on future illegally introduced fish species

Objective 2: Achieve compliance with AIS rules

Strategies

- Continued outreach activities
- Provide consistent experiences for boaters on a statewide scale
- Operation and maintenance of permanent decontamination station
- Ongoing coordination between DWR and State Parks to implement the AIS plan
- Explore options to increase funding for AIS management
- Consider increase in Jordanelle State Park staff

Discussion

This Jordanelle Management Plan is a guideline for future management of Jordanelle to achieve the developed vision statement. Biotic and abiotic conditions (e.g., unsuccessful introductions or fluctuating water levels) may alter how management proceeds. For this reason the management plan and any associated timelines will need to be adaptable to observed conditions. DWR will continue to work closely with the established working group as needed throughout the development of this fishery. The Jordanelle Work Group will be reconvened annually for progress updates. Additionally, we propose formal review of this management plan five years after implementation, likely 2021.

This plan will be presented to all appropriate stakeholders including Central Utah Water Conservancy District, Bureau of Reclamation, Utah Reclamation Mitigation Conservation Commission, Central Regional Advisory Council and irrigation companies.

References

Hepworth, R. D., D. J. Janetski, and D. E. Wiley. 2004. Jordanelle Reservoir angler survey and fish population sampling 2003. Utah Division of Wildlife Resources, Springville, UT.

Wiley, D. E. 2014. Jordanelle Reservoir angler survey. Utah Division of Wildlife Resources, Springville, UT.

Wiley, D. E. and J. M. Watson. 2014. Age and growth of Smallmouth Bass in Jordanelle Reservoir, 2013. Utah Division of Wildlife Resources, Springville, UT.

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DEPARTMENT OF NATURAL RESOURCES

MICHAEL R. STYLER
Executive Director

Division of Wildlife Resources

GREGORY J. SHEEHAN
Division Director

MEMORANDUM

Date: August 23, 2016

To: Regional Advisory Council Member and Wildlife Board

From: Richard Hepworth, Aquatics Manager Southern Region

SUBJECT: Lake Powell Management Plan

The attached management plan was developed by a diverse group, made up with anglers and agency people dedicated to ensuring the fishery at Lake Powell remains one of Utah's most utilized and appreciated resources.

<u>Highlights:</u>

Mission Statement: *Adopt an aquatic resource management plan that will provide management agencies direction to: 1) Maintain a quality sustainable sport fishery, 2) Ensure all actions are compatible with native species, and 3) reduce the impact of recent and future aquatic invasive species infestations.*

Goals:

1. Maintain current fishery for as long as possible.
2. Adjust fish assemblages as forage changes due to mussel impacts on food web.
3. Maintain angler satisfaction and use.
4. No negative impact to native species.

1594 West North Temple, Suite 2110, PO Box 146301, Salt Lake City, UT 84114-6301
telephone (801) 538-4700 • facsimile (801) 538-4709 • TTY (801) 538-7458 • *www.wildlife.utah.gov*

Edited June 15, 2015

Lake Powell Fishery Management Plan

The development of a long-term plan for the management of the fishery at Lake Powell should consider the following: public desires and values, economic and political factors, needs and responsibilities of state and federal agencies, welfare of Native Fish, as well as opinions and recommendations of interested groups. During spring 2015, UDWR conducted an internet on-line survey to gather information about public desires and perceptions regarding the fishery in Lake Powell (Appendix A). Among many other questions, the on-line survey asked respondents if they would be willing to serve on a committee to develop a Lake Powell Fishery Management Plan. Committee members were selected from respondents who indicated a willingness to serve and were asked to represent public anglers on the committee. Other committee members were selected from local businesses, Blue Ribbon Fishery Advisory Council, US Fish and Wildlife Service, and National Park Service at GCNRA. The Lake Powell Advisory Committee was comprised of the following individuals:

Dale Hepworth	Blue Ribbon Fisheries Council
(Ray Schelble)	Blue Ribbon Fisheries Council
Dale Ryden	USFWS – Grand Junction CO
Scott Vanderkooi	Glen Canyon Adaptive Management
Matt Madsen	Angler
Chuck Benedict	Arizona Game and Fish – Flagstaff
Paul Ostapuk	SRP – Navajo Generating Station
Darrin Hintze	Angler
Brad Cutler	Angler
Kevin Campbell	Angler - Fishing Guide
UDWR Representation	
Wayne Gustaveson	Lake Powell Project Leader
Georg Blommer	Lake Powell Biologist

The purpose of the committee as outlined by UDWR was to:

- Provide public, state and federal government agencies, business interests and agency input to the Lake Powell Fishery Management Plan.
- Determine a Mission Statement.
- Develop a plan for future management of Lake Powell fisheries.
- Set goals and objectives for the fishery.
- Make recommendations to achieve goals.
- Consider all interests – find common ground.

The Lake Powell Advisory Committee met two times (16 hours) during February and March 2015 and developed the mission statement, goals, objectives and tools/actions for Lake Powell.

History:

Lake Powell was formed when Glen Canyon Dam, on the Colorado River located on the UT/AZ border, was closed in 1963. Water began to back up behind the dam continually until 1980 when the lake reached full pool. The lake was then 186 miles long with over 2000 miles of shoreline. Depth at the dam was 561 feet. Since that time water level has fluctuated depending on spring runoff from wet winters and dry seasons. Full pool elevation is 3700 feet (MSL). Recently the lake surface elevation has fluctuated between 3580 and 3660 feet (MSL).

The fish community consists of largemouth bass (Micropterus salmoides) and black crappie (Pomoxis nigromaculatus) which were stocked in 1963 as the dam was closed. Rainbow trout (*Oncorhynchus mykiss*) were stocked at the same time but could not reproduce on the silty river bottoms of inflowing rivers. Trout are now seen occasionally as they migrate downstream but are no longer a major component of the fishery. Walleye (*Stizostideon vitreum),* channel catfish (Ictulurus punctatus), bluegill (Lepomis macrochirus), green sunfish (Lepomis cyanellus), and carp (*Cyprinus carpio)* were present in the tributaries when the dam was closed. These species populated the lake and are still present in the fish assemblage. Striped bass (Morone saxatilis) were introduced in 1974 as part of the original sport fish management plan. Smallmouth bass (Micropterus dolomieu) were stocked in 1982 to augment the largemouth bass population which declined as the lake filled, and fluctuated, eliminating terrestrial vegetation in the fluctuation zone. Smallmouth bass and striped bass are now the most common sport fish species found in the lake.

Forage fish include threadfin shad (Dorosoma pentenense) which were stocked in 1967 and 1968 and have provided excellent forage to game fish since that time. In 2000, gizzard shad (Dorosoma cepedianum) were found in the headwaters of the San Juan arm. They escaped from Morgan Lake on the San Juan River and were unintentionally introduced at that time (Brooks, et. al 2000, Mueller et. al 2001, http://nctc.fws.gov/resources/course-resources/haccp/HACCP-Manual.pdf). Since then they have populated the entire lake, migrated up and down the Colorado River and provided needed forage for sport fish within Lake Powell.

Native fish were found in the Colorado River before the dam was closed. These species did not thrive in the new flat water environment with increased predation, loss of migratory pathways and clear water. At the present time razorback suckers (Xyrauchen texanus) maintain a small but steady population. Other native fish that were found in the Colorado River prior to impoundment include Colorado River pike minnow (Ptychocheilus Lucius**),** bonytail (Gila elegans**),** humpback chub (Gila cypha), and flannelmouth sucker (Catostomus latipinnis**).**

Background

In fall 2012, quagga mussel veligers were found in Wahweap Bay and the main channel near the dam. During spring 2013 adult quagga mussels were detected attached to moored boats and docks at Antelope Point Marina and Wahweap Marina. Lake Powell was declared to be infested with mussels. The logical conclusion is that mussels were transported into Lake Powell by boaters who did not successfully clean mussels from their vessels before launching in Lake Powell. Once established mussels cause many problems including a reduction in sport fishery, esthetic deterioration with dead mussel scattered along the lakeshore and change in lake water chemistry and food web.

LAKE POWELL FISHERY MANAGEMENT PLAN

Lake Powell Advisory Committee Mission Statement

Adopt an aquatic resource management plan that will provide management agencies direction to: 1) Maintain a quality sustainable sport fishery, 2) Ensure all actions are compatible with native species, and 3) reduce the impact of recent and future aquatic invasive species infestations.

Goals:

1. Provide unique and diverse fishing opportunities.
   Objectives: Maintain current fishery for as long as possible as mussel infestation increases
   a. **Lake Powell Fishery**
      - Maintain the overall angler catch rate of 1.0 fish/hour
      - Maintain angler use at 200,000 angler days (800,000 angler hours) per year measured by creel surveys.
   b. Striped Bass
      - Maintain striped bass angler catch rate of 0.75 fish/hour over the next 6 years
      - Maintain a quality striped bass population that exceeds 1.0 (Kfl) as measured by gill net surveys
   c. Largemouth bass
      - Maintain largemouth bass angler catch rate of > 0.1 fish/hour for anglers targeting largemouth bass
      - Maintain largemouth bass quality with average size >300 mm (>350 mm in years when submerged brush provides good habitat) with a relative weight (Wr) >75

- Maintain largemouth bass recruitment when lake is filling and new terrestrial vegetation is covered by increasing lake levels

d. Crappie
- Maintain crappie catch rate at 0.5 fish/hour (anglers targeting crappie) during April and May in years when terrestrial brush is inundated.

e. Smallmouth Bass
- Maintain smallmouth bass size at >300 mm as measured by gill net surveys
- Maintain smallmouth bass angler catch rate at > 0.5 fish/hour

f. Walleye
- Increase walleye angler harvest to exceed 100,000 fish annually
- Maintain walleye angler catch rate >0.1 fish/hour

g. Channel Catfish
- Increase angling pressure on channel catfish by increasing number of anglers that target catfish
- Increase angler catch rate >0.1 catfish/hour
- Increase annual channel catfish harvest to exceed 40,000 annually.

h. Recognize cyclic nature of fishery
- Forage and habitat change as water levels fluctuate. There is no control of amount of water that comes down the tributaries to Lake Powell.
- (plot water levels with habitat conditions and fish populations)

2. Adjust fish assemblages as forage changes due to mussel impacts on food web

a. Evaluate stocking additional fish that can utilize quagga mussels.

Redear sunfish (molluscivore)

Other species consider and rejected: White bass, yellow bass, blue catfish, sculpin, round gobies, pumpkinseed, rainbow smelt, and white suckers.

Evaluate changes to forage abundance – triggers.

b. Assess potential impacts of illegal introductions and consequences if no intentional stocking occurs

c. Evaluate stocking of native species
1. Pikeminnow, razorback sucker, bonytail, and flannelmouth sucker
2. Crayfish

3. Maintain angler satisfaction and use

Objectives:

a. Maintain current angler satisfaction above 75% (good to excellent) for year.
- Determined by annual Survey monkey questionnaire

b. Ensure angler use at Lake Powell is at or above 800,000 angler hours/year

4. Native species within the greater Colorado River system should not be negatively impacted by proposed management action recommended by the plan.
   Objectives:
   a. Identify factors that lead to upstream and downstream movement of fish from Lake Powell.
   b. Reduce movement of sport fish leaving Lake Powell.
   c. Increase harvest of walleye in LP to >200,000 fish. (current Catch/yr=10,000-84,000)
   d. Investigate options for barriers on Colorado and San Juan Rivers.
5. Understand impacts AIS have on the Lake Powell sport fishery (Recreation Aspects) and look for opportunities to minimize impacts.
   Objectives:
   a. Reduce impacts of mussels and other aquatic invasive species (AIS)
   b. Address reduced esthetics associated with quagga mussels in Lake Powell
6. Improve public outreach
   Objectives
   a. AIS issues
   b. Fishing changes. Inform anglers of cyclic nature, what's good/bad.
   c. Social media: WaynesWords.com, UT DWR website and on-line survey.
   d. Recreational opportunities
   e. Illegal introductions
   f. How many people contacted, new contacts
   g. Evaluating message that people get
   h. Refer to UT and AZ Invasive Species Management Plans
   i. Containment of QM
   j. Notify boaters of AIS procedures

7. Additional Research Needs
   Objectives:
   a. Food web dynamics
   b. Walleye: movement, etc.
   c. Literature research - Life history and potential impacts of new introductions
   d. Risk assessment for natives

Tools/Actions:

Goal #1. Provide unique and diverse fishing opportunities

A. **M**aintain current fishery for as long as possible as mussel infestation increases

1. Striped bass:
   a. Assess mussel manipulation of food web and quantify plankton abundance
   b. Note changes in population abundance

c. Plot changes in fish health and robustness through time

2. Largemouth Bass:
   a. Determine population strength and recovery following a filling episode when new terrestrial vegetation is flooded during the spring filling cycle.
   b. Monitor crayfish and sunfish forage availability to largemouth bass
   c. Evaluate the possibility of seeding areas during low water years with native vegetation that may provide habitat for fish as the lake refills
3. Crappie
   a. Ensure that crappie follow the same pattern of rejuvenation as largemouth bass as new vegetation is flooded during the spring filling cycle.
4. Smallmouth Bass:
   a. Smallmouth bass are not dependent on terrestrial brush inundation, rather they need adequate forage for growth and maturation.
   b. Monitor plankton, shad, crayfish and sunfish forage availability to ensure nutrients are adequate
5. Walleye:
   a. Walleye are dependent on shad forage for population health.
   b. Study young of year gizzard shad abundance to determine if adequate forage is available to sustain walleye numbers.
   c. Evaluate movement patterns of walleye in the northern lake to determine if walleye are entering the Colorado River during specific times.
6. Channel Catfish:
   a. Determine if catfish continue to grow and develop in areas of high mussel infestation
   b. Catfish may eat mussels but must crush the shell to receive nutrition. Determine catfish food habits and growth in the mussel era.
7. Stock native fish to see if they can better compete with sport fish in the new fish assemblage
   a. Razorback and flannelmouth suckers may be able to survive by eating some mussels
   b. Colorado Pike Minnow may be able to compete as a sport fish.
   c. Additional evaluation and monitoring of native fish will determine additional steps.
8. Stock redear sunfish or other fish/crayfish that utilize quagga mussels
   a. Redear are a proven molluscivore that grow large in Colorado River reservoirs
   b. They may add an additional species to draw anglers as other Lake Powell fish species decline in numbers.
   c. Larval/young redear sunfish (less than 2 years old) may be the only forage fish that divert food energy to bass and walleye as the food web changes from pelagic to benthic.
9. Maintain close contact with situation at Lake Mead, Mohave and Havasu
   a. These reservoirs were infested with mussels 7 years prior to Lake Powell and will provide dependable information on the future of Lake Powell fisheries.
   b. Fisheries in these downstream reservoirs remain strong. If they collapse the same course of action would be expected at Lake Powell.
10. Lake Level manipulations to increase fish habitat and reduce mussel numbers
    a. Flood events occur to move sediment in the river below Lake Powell

    b. There may be timely actions taken to lower the lake and kill mussels in conjunction with sediment flood events.

11. Live Bait Options
    a. Consider using live shad from Lake Powell as live bait to increase walleye harvest
12. Need muscle samples from native species for stable isotope study. Will they utilize QM?
13. Fishing opportunities on Colorado River
14. Fish Barrier on Colorado River
15. Coordination consistency with NPS and AZ, UT on interpretation/outreach, local business
16. Angler satisfaction survey every 2 years.

Outreach:

1. Outreach important for Walleye Harvest
2. Catfish underutilized – Outreach
3. Better utilize social media
4. Harvest important tool – SMB

Monitoring and Evaluation:

1. Plan Revision (Time Line): Draft in one month, 3 months for final draft for agency review (60 day review period for comments).
2. Evaluation of plan – every 6-10 years
3. Annual Monitoring
4. Describe what is going on monitoring/research in reservoir and native spp.
5. Better communications between stakeholders, sharing data/information
6. Crayfish

Discussion

Goal 1. Provide unique and diverse fishing opportunities.

Historically, Lake Powell has provided a unique fishery with many warm water fish species sharing the lake with striped bass. The fish assemblage has worked well as long as adequate open water forage fish have been available to feed the many hungry mouths that depend on shad for sustenance. At the present time, striped bass are the most sought after species by sport fish anglers, followed by smallmouth bass, largemouth bass, walleye, crappie and channel catfish. Bluegill and green sunfish are present but targeted by fewer anglers.

Now, following mussel infestation, the two most threatened species are threadfin shad and striped bass. Threadfin shad rely completely upon plankton to support the forage fish population. Mussels siphon water and nutrients constantly and, in some infested lakes, plankton that pelagic fish need has been eliminated causing a crash in forage fish numbers. If that happens in Lake Powell, striped bass that rely almost completely on shad may be severely reduced in number, size and condition. Removal of the most important sport fish and its primary prey will dramatically alter the sport fishery.

Based on the results of mussel infestations in the lower Colorado River reservoirs (Lakes Mead, Mohave and Havasu) there remains hope that mussels will be less destructive to pelagic fish than they were in the Great Lakes. In Lake Huron, for example, the most popular open water sport fish (chinook salmon) and pelagic forage fish (alewives) were almost eliminated from the lake following mussel infestation. The process took 12 years from mussel arrival to loss of the primary sport fish (1992-2004) (James Johnson, Alpena Fishery Research Station, Lake Huron MI, personal communication, 2013). If that same timeline occurs in Lake Powell striped bass may be eliminated by 2024.

If that same timeline is used in Lakes Mead, Mohave and Havasu (2005-2017) striped bass would be eliminated by 2017. So far, there is a glimmer of hope, because fishing remains good in these waters in 2015. Mussels do not thrive in warm water. Lake Havasu has a surface temperature of 31 C (88F) in summer which resulted in a die-off of mussels in the upper 5.5 m (18 feet) of the lake during summer stratification (Russ Engel, AZ Game and Fish, personal communication 2015) . Unfortunately, Lake Powell typically registers a summer surface temperature of 28.5 C (83F) which may allow more mussels to survive the heat.

Based on the evidence provided by other infested fisheries, it is likely that Lake Powell will maintain the current fishery until 2022. Close contact will be maintained with fisheries managers in the lower Colorado River reservoirs to see if any deviation from the expected conclusion of mussel infestation will be realized. If so the management plan will be modified accordingly.

The first goal of providing unique and diverse fishing opportunities is being well accomplished now by the current fishery that has a wide variety of species and fishing opportunities. Hopefully the first objective of maintaining current fisheries for as long as possible will be realized. There are many regular anglers that return to the lake each year to experience the amazing fishery. New anglers come each year because of the notoriety generated by fishing success, beauty of the lake and remoteness of the area.

Maintaining the status quo of the current fishery would ensure the popularity of Lake Powell for generations to come. That would lead to the accomplishment of the bullet points listed under the first goal and objective.

Long term sampling will continue to quantify population fluctuation of the various fish species. Electrofishing sampling indicates the rate of success of the annual spawn and determines which species had good survival. This survey classifies bass and sunfish well but not the other species (Blommer G. L. and W. Gustaveson. 2012)

Annual gill net sampling is a good indicator of population strength of all species. Gross changes in species composition and abundance can be quantified as was done with the gizzard shad in 2000-2005 when shad abundance increased from no fish to the most abundant fish in the survey (Figure 1).

Gizzard shad occupied Lake Powell after escaping from Morgan Lake and following the San Juan River downstream to their new home. Lake Powell was completely colonized by gizzard shad by 2005. Then gizzard shad went upstream and colonized inflowing rivers and tributaries. Annual gill net sampling will also be able to determine a change in population abundance that may occur if striped bass numbers drastically decline due to impacts of mussel infestation.

Threadfin shad abundance and the annual crop of gizzard shad are measured by midwater trawl and hydroacoustic sampling. Adult gizzard shad abundance is also identified with annual gill net sampling. If mussels have a devastating impact on either species, annual sampling will show that result.

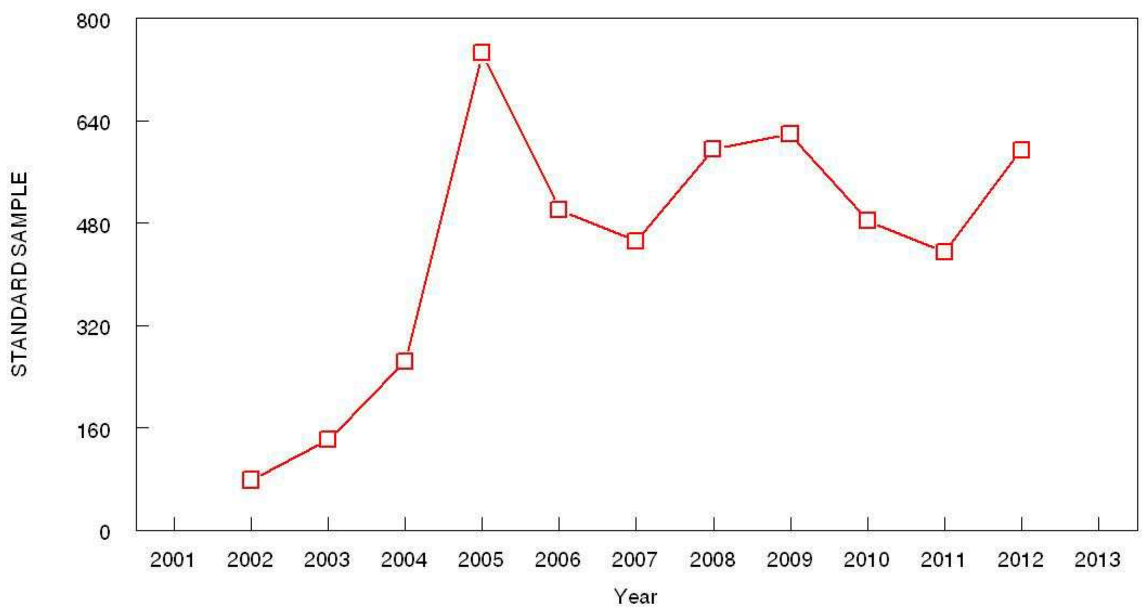

Figure 1. Total catch of Gizzard Shad from the annual gill-net survey, Lake Powell, UT, 2002-2012.

Striped bass have shown a unique life history in Lake Powell. They exhibit a "boom and bust" cycle. Reproduction is extremely successful due to the high oxygen level on the substrate. In most other lakes in the U.S. only a few striped bass eggs hatch due to low oxygen levels that results from high biological oxygen demand.

The many young stripers produced grow well by feeding on open water plankton. Stripers can grow to about 350 mm (14 inches) on plankton alone. It is more common for young stripers to switch to larval shad forage as soon as shad are available in early summer. With shad as forage, stripers will then mature at 3-4 years of age. With maturity comes an ontogenetic metabolic change which requires adult stripers to seek cooler water. Adults are forced to leave the warm surface layer where their forage resides and live near the thermocline where forage is limited.

In some years the shad population is abundant which allows adult stripers to perform quick feeding forays into shallow water where shad are quickly consumed. Then adults dive back into deep water to digest their catch. But in most years there are not enough shad in open water to make the adult feeding journeys into warm water successful. Adults then are confined in the deep water with low forage while juvenile stripers frolic on the surface feeding on the limited shad supply. Adult stripers decline in physical condition while juvenile fish excel (Figure 2).

In most fisheries maintaining a population of a certain length is a reasonable goal. In Lake Powell the goal is to maintain a healthy striped bass population (K(fl) greater than 1) regardless of size. Stripers are over populated in most years so there are plenty of fish to catch. The main goal is to keep these fish healthy and balanced with available forage.

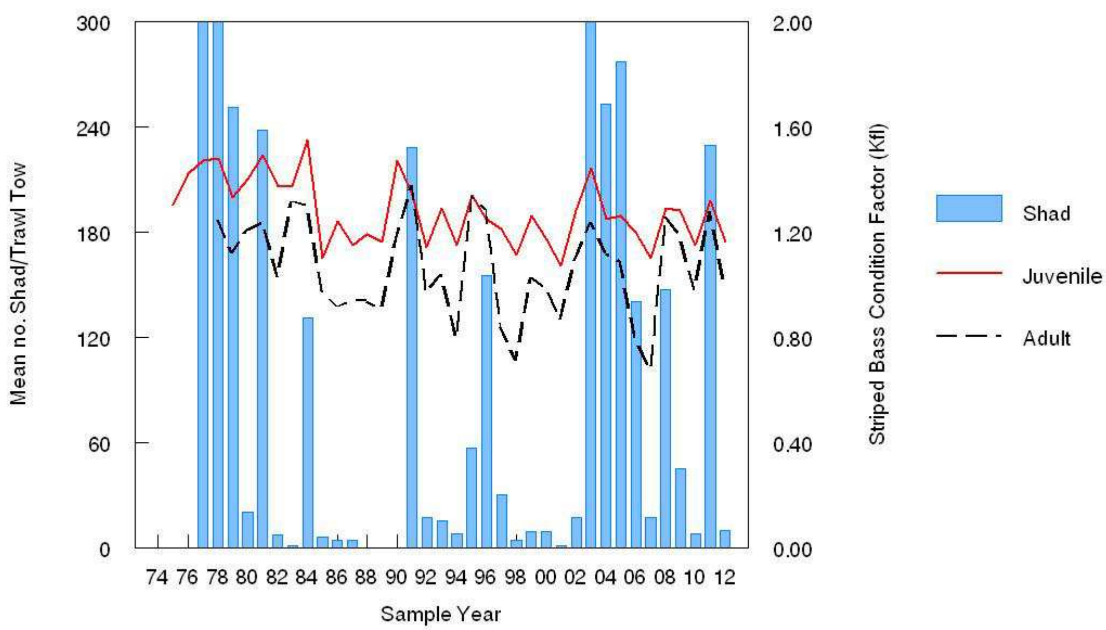

Figure 2. Pelagic shad abundance compared to juvenile and adult Striped Bass condition (Kfl), Lake Powell,UT, 1976-2012.

Walleye and gizzard shad numbers have dramatically increased in the Colorado River and tributaries above Lake Powell. The walleye population in Lake Powell doubled in size after gizzard shad were established (Figure 3) and have remained in high numbers since. Walleye have responded to an increase in forage that favors their habits of feeding near the bottom around cover. Gizzard shad seek out the same areas and have provided the means for walleye numbers to increase, particularly in the more productive northern lake.

The committee suggested that the larger walleye population could be better utilized by anglers if live bait were allowed. In other parts of the country where walleye fisheries are highly regarded the majority of fish are caught on live minnows. Live bait is not currently allowed in Lake Powell but dead shad captured in the lake can be used. That regulation could be expanded to allow use of live shad caught in Lake Powell without negatively impacting the fishery. The only negative is the precedence established in Utah where live bait is not allowed in any water. The favorable point to allow live bait is that walleye that negatively impact native fish could be captured in higher numbers.

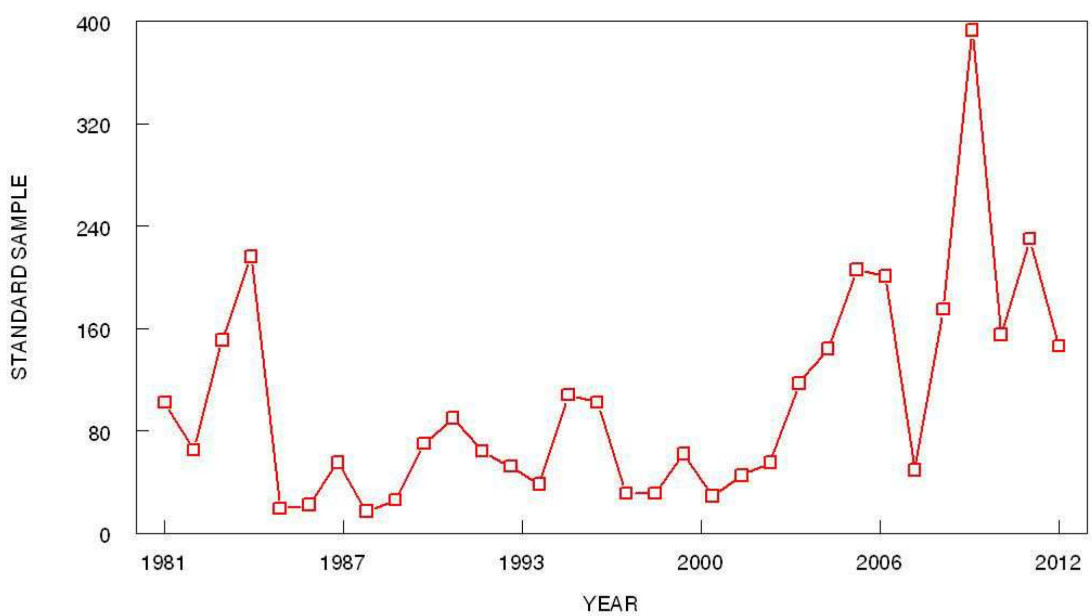

Figure 3. Total catch of Walleye from the annual gill-net survey, Lake Powell, UT, 1981-2012.

Objective 2:

Adjust fish assemblages as forage changes due to mussel impacts on food web

Watching the rapid expanse of invasive mussels, which began in Wahweap and Antelope Point Marinas, and now spreads further uplake has made it unlikely that Lake Powell fisheries can be maintained in the present form over the next few decades. It is not likely that just waiting to see what happens in the future will provide a positive outcome.

The shining star of Colorado River reservoirs now is Lake Havasu where fishing success has improved despite mussel infestation. Striped bass fishing success is not strong in Lake Havasu but largemouth bass fishing is at a peak. The reason is two-fold. Clear water with little lake level fluctuation has allowed aquatic weed growth to increase at greater depths (12.3 m, 40 feet) in the stable lake environment. Second, the population of redear sunfish, present since 1949, has grown in size and number following quagga mussel invasion which provided an abundant mussel food source upon which redear sunfish can thrive (Russ Engel, AZ Game and Fish, personal communication 2015).

Redear sunfish are successfully redirecting food web energy from old pelagic food web to the new benthic food web [nutrients>mussels>redear>bass] with young redear sunfish being the critical link in the chain. Bass get their nutrients from preying on redear sunfish that are growing to record size on the abundant diet of quagga mussels. World record redear sunfish are causing lots of excitement, while drawing new anglers to Lake Havasu despite the quagga mussel infestation.

It was the committee recommendation that redear sunfish be introduced into Lake Powell. Quagga mussels are making great advances each year. They now (2015) occupy at least 64 km (40 miles) of main channel plus many miles of side canyons that meet the channel. It is hoped that the fishery will be able to maintain the present quality and numbers of sport fish. However, the billions of mussels now in the lake have few natural predators and will advance unchecked without pressure from molluscivores. Redear sunfish can put some predatory pressure on mussels and at least slow the advance in shallow coves with weed growth where redear sunfish would reside. That could preserve some cove environments which would be used by important sportfish including, largemouth and smallmouth bass, walleye and crappie.

The success of redear sunfish in Lake Havasu has made local anglers aware of the potential of similar results in Lake Powell. It is vital that a discussion of redear sunfish introduction plans be given to all anglers so that some do not get impatient and perform an illegal introduction without approval. At that point redear sunfish would not be able to be identified as a positive fish but rather an illegal invader. Any new fish species must be stocked with proper authorization to be used successfully as a result of this management plan.

Other mussel-eating fish were considered but eliminated due to migratory and/or predatory tendencies that would add uncertainly to native fish survival. The list of rejected candidates includes: white bass, yellow bass, blue catfish, sculpin, round gobies, pumpkinseed, rainbow smelt, and white suckers.

However, it would be wise to evaluate the possibility of restocking native fish in Lake Powell after a reservoir wide occurrence of mussels, to see if they would have a greater chance of surviving in the reservoir with a new food web that might favor natives over sport fish. Flannelmouth and razorback suckers may be able to derive sufficient nutrition from preying on quagga mussels. Their success would depend on their ability to crush the shell and eat the mussels while rejecting the shell fragments.

Habitat in Lake Powell varies as water levels fluctuate. The long history of largemouth bass population fluctuation depends entirely on amount of brush habitat in the water. As the lake filled initially water level continually advanced from 1963-1980. After the reservoir filled in 1980, reservoir water levels fluctuated near full pool. Without new brush to provide cover, largemouth numbers declined and stayed low until new brush grew on the newly exposed shore and was then flooded again when the lake level increased once more (Figure 4).

The lack of inundated terrestrial vegetation can be offset by an increase in aquatic vegetation. As mussels remove the plankton and nutrients from the water, visibility will increase. As light penetrates deeper in clear water there will be more opportunities for aquatic weeds to grow. More spawning and nursery cover will provide an opportunity for centrarchids to expand their numbers at the same time pelagic shad and stripers are declining. If this change occurs then the introduction of redear sunfish would be the key to success in the new Lake Powell fishery that would develop.

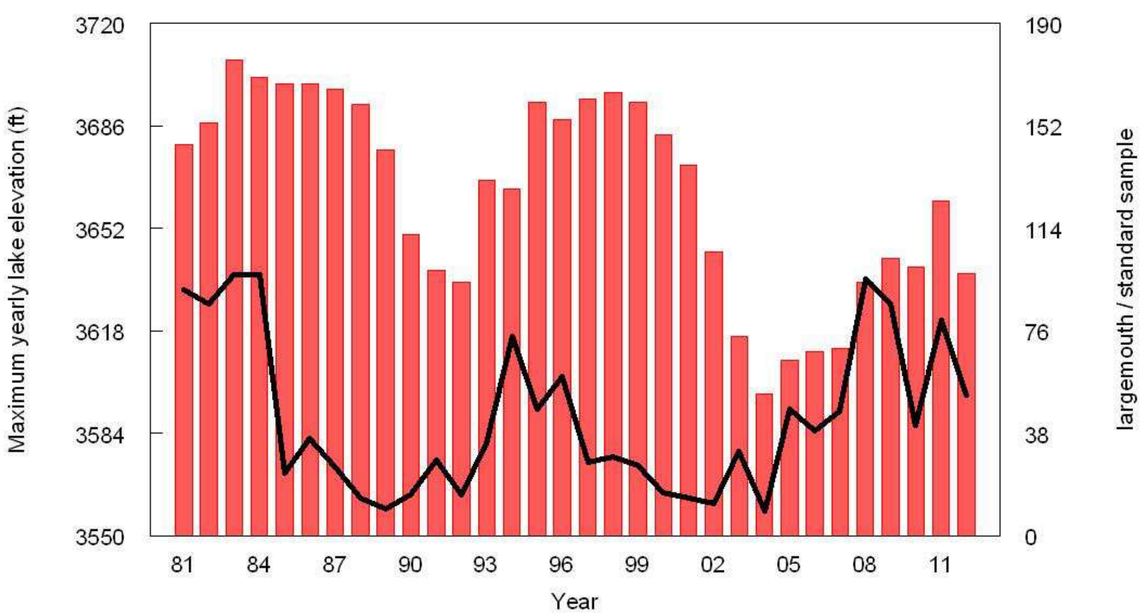

Figure 4. Relationship between maximum yearly water elevation (bar) and the number of Largemouth Bass collected from the annual gill-net survey (line), Lake Powell, UT, 1981-2012.

Objective 3:

Maintain angler satisfaction and use.

In a recent survey anglers were asked to rank their satisfaction level when fishing at Lake Powell. The average rank exceeded 75% placing satisfaction levels in the good to excellent range. Fishing success varies with daily weather conditions and seasonal changes. The variety of species allows some species to be active during summer heat, winter cold and all stages in between. Spring and fall provide the best fishing success. Bass spawning coincides with warming air temperatures in the spring. Walleye are very active in May with crappie spawning in April. Striper surface feeding action (boils) is often found in the heat of the summer, while spooning for deep water stripers is found in cold weather. Catfish and sunfish are easy to catch all summer long. Fishing at Lake Powell appeals to many anglers with a wide variety of interests.

Every third year angling demographics are collected in a creel census survey. Angler use has recently varied between 500,000 to 1,900,000 angler hours annually (Figure 5). Current pressure assessment techniques estimated angler hours at 800,000 for 2012. The popularity of the existing fishery should ensure that similar hours are expended in 2015. Our goal is to maintain that minimum level of fishing pressure and angler satisfaction as long as the existing fish assemblage remains intact.

Current regulations allow very liberal harvest limits. Striped bass and walleye can be harvested without limit. Largemouth bass (5) and crappie (10) are protected with low limits because their numbers fluctuate up and down depending on the availability of brush more than angler harvest. Smallmouth limits (20) are high to convey the message that some harvest is recommended. As conditions change due to mussel infestation these limits should be reevaluated. Obviously, if striped bass numbers crash then it would be wise to impose a new limit due to the change in conditions.

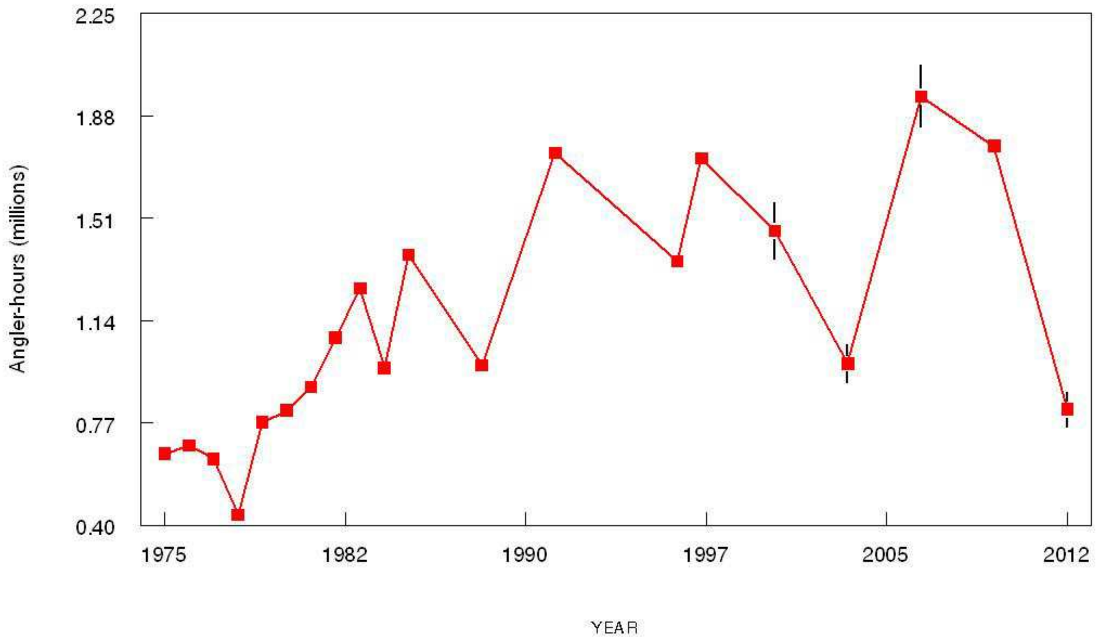

Figure 5. Total hours spent fishing, 1975-1997 estimates are for 12 months. 2000-2012 estimates with SE are for 7-months only, Lake Powell, UT.

Objective 4:

Prevent negative impact on native species while implementing the Lake Powell Management Plan.

Logically the large numbers of predatory species in Lake Powell would make the lake hostile territory for native fish seeking to spawn in calm water as is their nature. Slow moving razorback larvae would be an easy target for many lake predators in clear water without brushy cover.

During spring 2015, light traps were used to assess razorback sucker spawning success near the Colorado River inflow in Lake Powell. Razorback larvae are light sensitive and come readily to the lighted traps at night. Shad share the same phototropic attraction. Light traps results accounted for 95% shad and 3% razorback larvae along with a few other native fish caught in the traps. Razorbacks were well outnumbered but the heavy population of shad is the preferred forage of sport fish in Lake Powell. It is possible that the heavy presence of shad can act as a defense mechanism or disguise to mask the presence of native species. If spawning also occurs in turbid water there is a good chance that certain areas of Lake Powell would provide an opportunity for limited native fish survival. That appears to be the case, as some razorback suckers without PIT tags are found each year in the flat, predator filled waters of Lake Powell. In Spring 2015 17 razorback suckers without PIT tags were found among the total of 250 fish captured.

It was noted in discussion of the first goal that gizzard shad arrival allowed walleye numbers in the lake to soar (Figure 3). It is suggested that walleye harvest by anglers be increased to prevent their negative impact on native species. Actions that may help reduce walleye numbers include the lack of creel limit on a highly desired food fish. It was also suggested that live bait be legalized. Live bait is an extremely effective method for catching walleye which would increase harvest and reduce walleye numbers. More reports than ever before are appearing on social media and in fish reports on how to locate and target walleye in Lake Powell. If the average angler is made aware of techniques and fish location the number of walleye that could be harvested would increase dramatically. That action is already under way. Our goal is to increase walleye harvest to exceed 200,000 annually.

Another stated goal is to stock redear sunfish. Life history studies indicate that reader sunfish are not migratory showing similar habits as bluegill in staying near brushy habitats and spawning in aggregations near favored shallow weedy locations. Redear prefer clear water over turbid which would separate them from surviving razorbacks in Lake Powell. Redear prefer to eat mussels which would prevent adults from preying on larval native fish.

Investigate options for barriers on Colorado and San Juan Rivers.

There is evidence that walleye numbers have increased in the Colorado River above Lake Powell in the past decade. These walleye may be harmful to native fish recovery in the river. The first step is to investigate the circumstances leading to increasing walleye abundance. Walleye may be entering the river to spawn and then remaining when/if adequate food is found. It may be that gizzard shad are migrating upstream and walleye are following. The reason for walleye emigration must be determined before a solution can be put in place. If they leave during the spawn a short term seasonal barrier (electric) may be feasible. If they leave the lake to follow shad a year round barrier may not be possible in the high fluctuating flows and low summer flows that mark the river flow pattern. If shad are the culprit it is possible that the increase in quagga mussels may cause a drastic decline in shad abundance and remove the reason for walleye to enter the river. It is critical to understand the reason walleye are going upstream before a solution can be determined.

It is important for native fish recovery teams and Lake Powell biologists to work together in determining how sport and native fish can best coexist in the lake and river.

Objective 5.

Minimize the impacts AIS have on the Lake Powell recreation and sport fishery.

Quagga mussel colonization began in southern Lake Powell when veligers were found in the fall of 2012. Now in spring 2015, the shoreline of Wahweap Bay is thoroughly covered with adult mussels below elevation 3595 MSL which has been underwater during the past 2 years. Boats pulling onto shore to camp in Wahweap Bay for the night may have mussels attached to the hull by morning as mussels move slightly from rocks to the boat hull which dislodged them. Anchor ropes will have mussels attached as the anchor is retrieved. Measures have been put in place to inspect each boat as it leaves the lake to ensure that attached mussels are not transported to a new water body. The end result is a degraded boating experience compared to the lake before infestation.

As the lake fills the heavy infestation of mussels will be covered and disappear from view only to reappear as the water level declines later in the summer and fall. Then mussels will die as water level declines and they are left on hot rocks exposed to sunlight. In heavily infested areas the stench of dying mussels may be enough to cause visitors to avoid the area. Mussels may even be in such high numbers on beaches that walking barefooted will be treacherous due to the sharp shells that litter the area. Chemical changes due to mussels may lead to outbreaks of blue green algal blooms that destroy the beauty of the shoreline and the water in the bloom area.

There are few options to reduce mussel impact. If lake level could be controlled, it would be possible to maintain the water at the present level and adjust it up to hide mussels from view by flooding the shoreline, or down to kill mussels by desiccation. But there is no control of inflowing water which comes from snow melt in the Rocky Mountains.

Some waterfowl have been seen preying on mussels along the shoreline. But these are mussels that are dying from lowering water levels. There are no true mussel eating fish in Lake Powell. Introduction of redear sunfish would be a positive force in mussel reduction in shallow weedy coves where these sunfish could thrive. The mussel food source is so abundant that redear sunfish could use a wide variety of habitats. Redear sunfish would be the only sport fish with an unending food supply allowing them to go anywhere in the lake where mussels were found. Piscivorous predation cannot stall lakewide mussel colonization but it could turn some microhabitats into good fishing holes where anglers can enjoy fishing for bass and sunfish.

Before redear sunfish could be stocked a risk assessment would have to be completed to address possible impacts, migration and movement, reproductive characteristics, food habits and tolerance to turbidity. Redear sunfish eat mussels but are there other factors that are limiting to their survival or to other fish species in the new environment that is Lake Powell after mussel colonization? It is also important to know what impact toxic accumulations (mercury, selenium, etc.) in mussels will have on redear sunfish that utilize mussels as their primary food source.

Inform public of consequences of illegal versus legal introduction of redear sunfish.

Objective 6.

Improve Public Outreach

Social media provides direct contact with the public. Broadcasting information about mussels lets the public know what actions are being taken to confront mussel impacts head-on. The worst choice would be to say nothing and then try to react to public response. Media releases tend to direct the conversation rather than reacting to a plethora of comments from an uninformed and irate public.

Regular visitors to Lake Powell have witnessed the rapid change in mussel numbers in Wahweap Bay. Most visitors that access the lake at Bullfrog or Halls Crossing ramps or only launch in the summer months do not fully understand the great change that is occurring. It is imperative that all are informed of the events so they can be prepared for and buy into the new boating requirements and procedures that must be performed before leaving the lake. It is most important that they know how to prevent spreading mussels into other waters that are not currently infested.

Reservoir fisheries in the lower Colorado River were infested 7 years prior to the infestation being discovered in Lake Powell. That time gap provides an opportunity to understand mussel impact in these lower river lakes and apply that knowledge to Lake Powell while there is still some time for positive action. We know that Colorado River reservoir fisheries are still performing well. That gives time to assess events occurring in Lake Powell and know that there will be a time lag before fisheries decline. How much time lag will be identified by what happens in the downstream reservoirs.

Social media is the best way to get the word out. Many anglers already use http://**www.wayneswords.com** to get fishing and boating information prior to coming to the lake. That website is updated daily and will continue to provide current, timely and accurate information on mussel issues. The Utah DWR website, http://wildlife.utah.gov, is the best source of information on mussel knowledge, decontamination and mussel certification for all Utah waters. Both of these options require individuals to actively seek the information by clicking on their personal device.

It is also possible to send unsolicited information to those who have boats and were required to provide their email address when registering their boat; or to anglers who provided their contact information when buying a fishing license. Well written brief messages that show impacts and changes with graphic pictures would peak the interest of those that may be completely unaware or may not be actively seeking this information. Pleasure boaters have different goals and ideas than anglers when planning a family outing for skiing and swimming. A message specifically designed for wake boarders, or Sea Dory campers, or sail boat captains could be sent to the subgroup after parsing the boating information and determining within which group a specific boat owner belongs.

The best way to gain respect with a specific group is to be able to successfully predict expected changes. Tell wake boarders that canyon walls in Bullfrog Bay will be pristine in 2015, but that mussels will be visible in large numbers in 2018. Then when they see these changes occur they will seek after more information in the future. They need to know how to protect other waters from mussels silently hitch hiking on wake board boats with ballast tanks. There is a specific message that will be accepted by each group. We just have to find the group and write the message.

Quagga mussels are destructive to boat hulls and engines. Many are unaware of the new dangers to water intakes and cooling systems. Owners of large boats that are likely moored or stored should be informed of the dangers of long term storage on mussel infested water which may lead to rapid mussel coverage of the entire hull and motor. Significant damage can now occur in less than one boating season. Those that have historically stored boats on the water at Lake Powell need to be advised that these boats must be removed and serviced quarterly to prevent mussel damage. It is critical to give boaters this message now so they will maintain their trust and respect for UDWR.

At this point there must be a partnership with Utah DMV who is responsible for boat registration. Utah DWR is well aware of the dangers of quagga mussels to boats but that may not transfer directly to boaters who deal only with DMV. We owe the boaters that opportunity to be informed about mussel impacts.

Objective 7:

Identify Additional Research Needs

Food web dynamics will change as mussels colonize the lake. A decrease in plankton is expected as billions of mussels constantly siphon plankton and nutrients from the water. Less plankton will inhibit growth and survival of all fish now in Lake Powell. The end result is a change in the current fish assemblage.

Research is ongoing by UDWR and specifically the Lake Powell Fisheries Project. Long term annual sampling will help identify changes in fish assemblage and plankton abundance. It is critical that this work continue to identify changes in aquatic resources as soon as possible so that corrective action can be taken if possible.

For instance, walleye numbers have increased in the northern lake and in the inflowing river. It is not known if these walleye have escaped from Lake Powell by swimming upstream or if walleye have moved downstream to the higher shad forage areas. More research is needed to determine the origin of walleye, particularly in the Yampa River. Stable isotopes can provide a definitive signature to identify origin of invading fishes. That work needs to go forward to help us understand the magnitude of upstream travel of walleye and other fishes that may be emigrating upstream from Lake Powell.

Anglers fishing in Lake Powell are given information on how to be more successful in catching walleye. Walleye may be one of the fish that remains in the lake after complete mussel infestation. Creating more walleye anglers will help keep the population under control and give anglers a reason to come fishing at Lake Powell after striped bass diminish in abundance.

Native fish are low in number in Lake Powell. It is unknown what impact mussel infestation may have on them. If native suckers are able to successfully eat mussels their population could increase. A risk assessment for each native fish now found in Lake Powell should be conducted.

Continued literature review concerning life history of all species in Lake Powell is needed to determine how they have responded in other waters after mussels infestations have occurred.

TRIGGERS:

Mussels have continually advanced uplake since 2012. When the infestation reaches Bullfrog (MM 95) and mussels are visible along the shoreline at low water levels, action will be required to slow down mussel advance and maintain fish habitat in coves. Redear sunfish stocking may be the only option to slow mussel advance in specific habitat types. It may take at least two years before the hatchery system is able to produce redear sunfish. This information needs to be provided to the public to prevent illegal "bait bucket stocking" from occurring.

Assess potential impacts of illegal introductions and consequences if no intentional stocking occurs.

Plankton decline as measured by standard sampling in mussel infested locations would determine when the food web alteration begins. This information should require a review of the plan and direct action when possible.

Forage fish abundance as measured by trawl and hydroacoustic sampling would signal a decline in shad numbers. Absence of shad from open water sampling over 3 consecutive years would signal the expected loss of shad as forage. The next step would be the demise of pelagic sport fish such as striped bass.

Species decline as measured by annual electrofishing and gill netting would mark the beginning of species shift. Striped bass and shad would be the most likely to decline. Share this information so visitors will know what to expect as the changes occur. Review plan and implement new directions.

If angler satisfaction drops below 50% then review plan. Use social media to inform anglers and help them understand the shift in species that will occur and how to utilize the newly developing fishery.

Evaluate stocking of native species (Pikeminnow, razorback sucker, bonytail, flannelmouth sucker) and implement that after species shift is observed.

Crayfish are important prey species for bass and walleye. Monitor stomach contents of all fish to determine dietary abundance. Explore possibilities of adding more crayfish (Orconectes virilis) if crayfish numbers in stomach contents decline.

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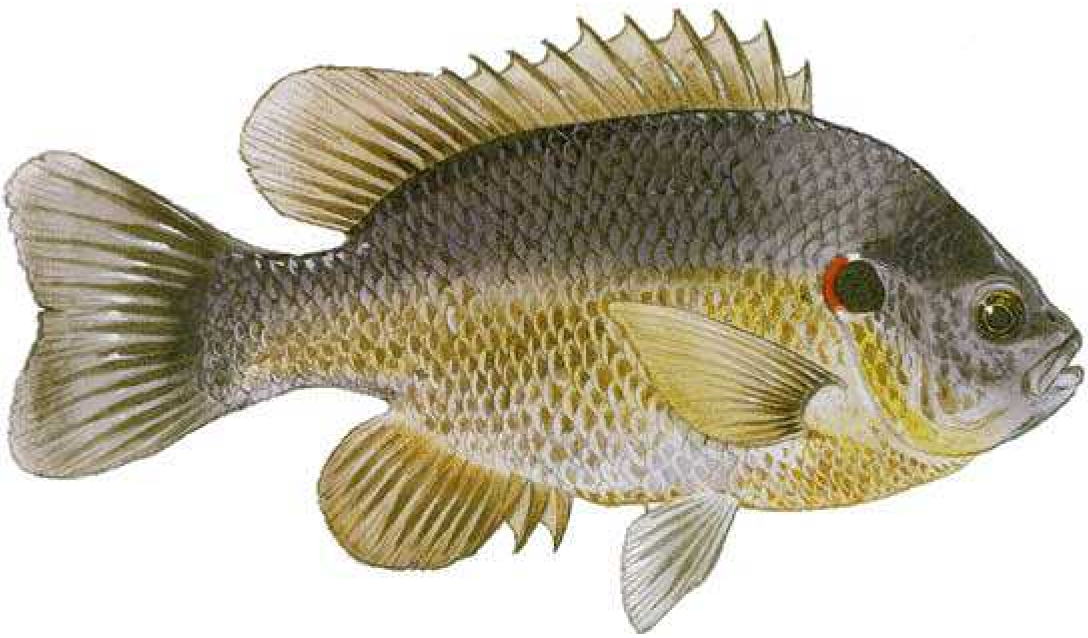
Assessment of the Risk of Escapement of Redear Sunfish from Lake Powell



Prepared by:

Randy Oplinger[1] and Richard Hepworth[2]

[1] Fisheries Research Biologist, Utah Division of Wildlife Resources, Fisheries Experiment Station, randyoplinger@utah.gov

[2] Southern Region Aquatics Program Manager, Utah Division of Wildlife Resources, richardhepworth@utah.gov

Purpose: The purpose of this document is to review the life-history and ecology of redear sunfish *Lepomis microlophus* with the goals of determining whether the species can become established within tributaries of Lake Powell and to determine the potential that redear sunfish have for predating on and competing with native fishes.

Introduction:

Redear sunfish *Lepomis microlophus* are a centrarchid species that are popular among anglers. They are native to the Mississippi River drainage from Missouri and southern Illinois ranging south into Florida, and west into Texas (Trautman 1957). They have also been successfully introduced into many areas including Michigan (Towns 2003), Arizona (Minckley 1993), and California (Wang 1986). Similar to most sunfish species, redear sunfish form spawning colonies and males construct nests. The males guard the nests and offspring and spawning is known to occur throughout the summer months. Redear sunfish are known to specialize on feeding on mollusks (Minckley 1982) but are known to feed on other invertebrate taxa as well (Minckley 1982).

Lake Havasu, Arizona is known as a "world-class" redear sunfish fishery and produced the largest redear to ever be caught by an angler in 2014. Redear sunfish have been in the reservoir since the 1940's (Minckley 1973). Trend netting data on redear sunfish within the reservoir is not available (Karp and Thomas 2014) but angler reports indicate that the size of redear sunfish has increased since quagga mussels invaded the reservoir in 2007 (Karp and Thomas 2014). Redear sunfish have been shown to feed heavily on quagga mussels (Magoulick and Lewis 2002) and it has been suggested that redear sunfish could be an effective biocontrol agent on quagga mussels (Wong et al. 2013). Redear are not the only fish species that feeds on quagga mussels, however. Magoulick and Lewis (2002) noted that both blue catfish *Ictalurus furcatus* and freshwater drum *Aplodinotus grunniens* also feed on the mussel. Common carp *Cyprinus carpio* have also been shown to feed on quagga mussels (Marsden 1997). Culver et al. (2014) found that not all individual redear sunfish feed on quagga mussels and that bluegill *Lepomis macrochirus* feed more consistently on the mussel. Karp and Thomas (2014) found that the average reduction in quagga mussel density in enclosures containing redear sunfish ranged from 0-25.3% with a less than 1% reduction in 6 of 13 enclosures. In Lake Havasu, a minority of redear sunfish consume quagga mussels, but those that do consume mussels tend to consume them in large numbers (C. Karp, Bureau of Reclamation, personal communication). French and Morgan (1995) found that redear sunfish prefer to feed on rams-horn snails *Helisoma anceps* over zebra mussels *Dreissena polymorpha*.

Quagga mussels are very efficient filter feeders and can attain very high densities. For example, it has been estimated that there are 950 trillion quagga mussels in Lake Michigan and that the mussels can filter the entire volume of the lake every 9-12 days. Increases in quagga mussel abundance in Lake Michigan were associated with decreases in chlorophyll-α and phytoplankton biomass, and increases in water clarity (Fahnenstiel et al. 2010). In addition, selective filtration by quagga mussels promoted blooms of less desirable species such as cyanobacteria (Vanderploeg et al. 2001). Quagga mussels can selectively filter rotifers (Mills et al. 1993) and can indirectly decrease the abundance of larger zooplankters through bottom-up mechanisms (i.e., removal of phytoplankton; Mills et al. 1993). Ultimately, quagga mussels sequester nutrients that are available in the pelagic zone and the availability of pelagically derived nutrients decreases while the availability of benthically derived nutrients increases (Higgins and Vander Zanden 2010). Most of these benthically derived nutrients are quagga mussels themselves but the establishment of quagga mussels has been associated with changes in the community composition of other benthic invertebrates (Ricciardi et al. 1997). Overall, these changes can affect fish species or life stages that consume zooplankton. For example, Strayer et al. (2004)

analyzed 26 years of data on the effects of zebra mussels on the Hudson River and found a 28% decrease in abundance and a 17% decrease in growth of pelagic fishes and a 97% increase in abundance and 12% increase in growth of littoral fishes. Salmon and alewife *Alosa pseudoharengus* populations in Lake Huron declined after the establishment of quagga mussels (Michigan DNR 2010). In contrast, the establishment of quagga mussels had little effect on threadfin shad *Dorosoma petenense* in Lake Mead (Loomis et al. 2011). Little research on the effects of quagga mussels on piscivorous fish has been conducted but it is anticipated that the establishment of quagga mussels would adversely affect predators that rely on planktivorous prey.

Lake Powell is one of the most popular fisheries in Utah. Lake Powell consistently receives > 800,000 angler hours of fishing effort every year. Quagga mussels were first discovered in Lake Powell in 2013. The Utah Division of Wildlife Resources (UDWR) is concerned that the establishment of quagga mussels will decrease the quality of Lake Powell as a fishery. Most of the sportfish within Lake Powell rely on zooplankton for at least portions of their life-histories. It is assumed that quagga mussels will behave similarly in Lake Powell as other lakes and will remove phytoplankton via filtration, having bottom-up effects on zooplankton and fish. The UDWR, however, is considering the stocking of redear sunfish into Lake Powell. It is anticipated that if stocked, redear will consume some quagga mussels, which will help reduce these bottom-up effects and will in-turn benefit other sportfish in Lake Powell. Redear sunfish themselves may also become a popular sportfish. The tributaries to Lake Powell, however, provide important habitat for many imperiled, native fishes. There are concerns that if redear sunfish are stocked into Lake Powell that they may emigrate from the reservoir into these tributaries where they could possibly predate on or compete with these native fishes. The purpose of this review is to summarize what is known about redear sunfish with the goal of determining whether tributaries to Lake Powell provide the physical conditions required to support redear sunfish. In addition, we summarize the potential competitive and predation effects that redear sunfish could have on native fishes.

Part 1: Assessment of the Habitat Suitability of Lake Powell Tributaries for Redear Sunfish
Analysis:

The most comprehensive source for information on the life-history and ecology of the redear sunfish is Twomey et al. (1984). In their paper, Twomey et al. (1984) reviewed the literature on the redear sunfish and developed a model determining whether riverine habitats are suitable for the species. The model presented by Twomey et al. (1984) contains four components and ten variables and is outlined in Table 1. Each variable is scored between 0.0 and 1.0 and Twomey et al. (1984) provides guidelines on the scoring of each variable. The lowest overall score determines the suitability of a habitat to redear sunfish with 0.0 representing un-suitable habitats, 0.0-0.1 representing "poor habitats", 0.2-0.4 representing "fair habitats", 0.5-0.7 representing "good habitats" and >0.8 representing "excellent habitats".

In this analysis, we apply the Twomey et al. (1984) model to the major tributaries of Lake Powell (the Colorado, Green, and Escalante Rivers). Data for all ten variables listed in Table 1 is not available but the Twomey et al. (1984) model can be applied to the tributaries using available turbidity, temperature, water velocity, and vegetation data.

Table 1: Overview of the four components and ten variables in the Twomey et al. (1984) model describing the suitability of habitats to redear sunfish.

Component	Variable
Food	Percent Vegetated Area in Pool Habitats
Cover	Percent Habitat > 2 m in Depth
Water Quality	Minimum Dissolved Oxygen Maximum Salinity Maximum Turbidity Maximum Summer Water Temperature pH
Reproduction	Percent Vegetated Area in Pool Habitats Average water velocity Mean Weekly Water Temperature

Turbidity:

The literature indicates that redear sunfish perform best when turbidity is less than 25 mg/L ; although redear sunfish have been reported to survive in ponds with turbidities as high as 174 mg/L (Childers 1967). Embryonic development appears to be impaired at turbidities > 174 mg/L (Buck 1956). The critical threshold for long-term survival and reproduction is likely between 75 and 100 mg/L (Buck 1956) and it is not likely that redear sunfish would persist long-term in waters with turbidities that exceed this critical threshold.

The tributaries to Lake Powell are known to be turbid. Data from United States Geological Survey (USGS) stream gaging stations near Lake Powell are shown in Table 2. These data indicate that average turbidities in the region exceed what redear sunfish can tolerate. There were two point samples taken in the Little Colorado River (83 and 95 mg/L; Table 2) that had turbidities within the range that redear sunfish can tolerate (< 174 mg/L; Buck 1956). The remaining samples (55 samples in total between 1950 and 1957) were well in excess of what redear sunfish can tolerate.

Table 2: Average suspended sediment concentration (in mg/L) at sites near Lake Powell. Data are point samples taken either by the Utah Department of Environmental Quality (DEQ) or the United States Geological Survey (USGS)..

River	Data Source	Site Name	Years Data Collected	# of Samples	Average Turbidity (mg/L)	Turbidity Range (mg/L)
Colorado	DEQ	Green R Ab Cnfl/Colorado R	1983-2015	158	842	8 - 18,120
	DEQ	Colorado R AB Dark Canyon	1998-2014	50	753	16-2,925
	DEQ	Colorado R. Bl Big Drop #3 Rapids	1990-2015	98	777	8-10,840
	DEQ	Colorado R Ab Cnfl/Green R	1983-2015	160	644	4-9,999
	USGS	Colorado River near Cisco, UT	1980-1984	60	847	12-2,854
San Juan	DEQ	San Juan R Ab Lake Powell	1997-2014	52	1,048	2-16,260
	DEQ	San Juan R At Mexican Hat US163 XING	1980-2009	162	1,656	2-33,780
Escalante	DEQ	Escalante River Below Cnfl/Calf Creek	1976-1978	17	71	5-310

The Twomey et al. (1984) model assumes that habitats with turbidities > 200 mg/L are not suitable for redear sunfish. Data from Table 2 and Figure 1 indicate that turbidities in the Colorado and

San Juan Rivers typically exceed this level and thus are not suitable for the species. Less sampling has been performed in the Escalante River but the sampling that has been performed indicates that this river could have turbidities that are low enough to support redear sunfish.

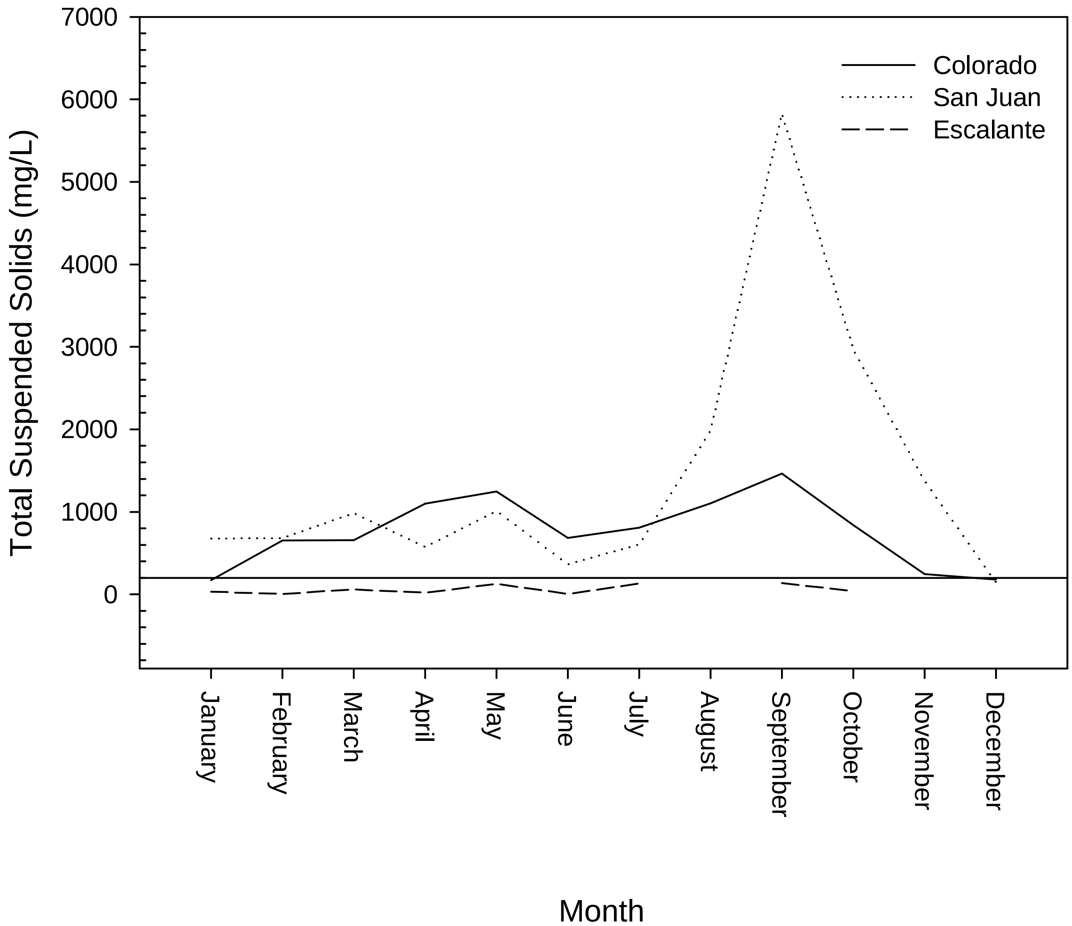


Figure 1: Mean monthly turbidities in the Colorado (solid line), San Juan (dotted line) and Escalante (dashed line) Rivers. Values based on the same data presented in Table 2. The horizonal reference line represents the critical turbidity threshold established in Twomey et al. (1984; 200 mg/L).

Water Temperature:

Redear sunfish reproduce at temperatures ranging between 18.3 and 32°C (Childers 1967; Clugston 1966). Swingle (1949) reports that the optimal temperature range for reproduction is 21-24°C. Temperatures of 24-27°C are optimal for growth (Emig 1966). Disease becomes a problem in redear sunfish at temperatures below 14°C and growth ceases at temperatures below 10°C.

Temperature data from the Colorado and San Juan Rivers near Lake Powell are presented in Table 3 and Figure 2. There was not sufficient data to characterize temperature from the Escalante River. If redear sunfish were to escape into the Colorado River below Lake Powell, they would likely encounter water temperatures that are probably too cool for reproduction and growth (Table 3). The cool temperatures in this stretch of the Colorado River can be attributed to the hypolimnetic release of water from the Glen Canyon Dam. Temperatures in the upstream tributaries are likely warm enough to support some reproduction and growth but are still cooler than ideal. In contrast, water temperatures in the Colorado River upstream of Lake Powell provide "optimal" temperatures for reproduction for 2 months out the year and approximately 3 months of "optimal" temperature occur in the San Juan River. Water temperatures in the Colorado River are too cool to support "optimal" growth whereas one month of "optimal" growth could occur in the San Juan River. There are two temperature variables in the Twomey et al. (1984) model; maximum average summer temperature and mean weekly water temperature during the spawn. Data from the San Juan River indicates that temperatures in the river are warm enough to be suitable for redear sunfish. In contrast, the Colorado River provides "poor" to "fair" habitat (suitability scores of 0.0-0.2; Twomey et al. 1984). There is very limited data from the Escalante River from the summer of 1977 (3 point samples) that indicate that water temperatures in the river can reach 25-29^{o}C. Thus, it appears that temperatures in the Escalante River could be warm enough to support the growth and reproduction of redear sunfish.

Table 3: Average temperatures at various sites along the Colorado and San Juan Rivers. Data are point samples taken either by the Utah Department of Environmental Quality (DEQ) or the United States Geological Survey (USGS).

River	Data Source	Site Name	Years Data Collected	# of Samples	Average Temp (^{o}C)	Temp Range (^{o}C)
Colorado	DEQ	Green R Ab Cnfl/Colorado R	1983-2015	136	17.9	0.0-29.5
	DEQ	Colorado R AB Dark Canyon	2000-2014	33	11.8	0.0-28.1
	DEQ	Colorado R. Bl Big Drop #3 Rapids	1990-2015	79	19.0	4.5-29.5
	DEQ	Colorado R Ab Cnfl/Green R	1983-2015	131	18.6	0.0-29.2
	USGS	Colorado River near Cisco, UT	2006-2015	120	11.9	0.3-23.7
	USGS	Colorado River at Lees Ferry, AZ	1986-2015	240	10.0	8.3-11.6
San Juan	DEQ	San Juan R Ab Lake Powell	1997-2014	40	13.4	0.0-29.0
	DEQ	San Juan R At Mexican Hat US163 XING	1980-2009	167	14.7	0.0-30.9
	USGS	San Juan River near Bluff, UT	1980-2014	408	12.2	1.5-24.8

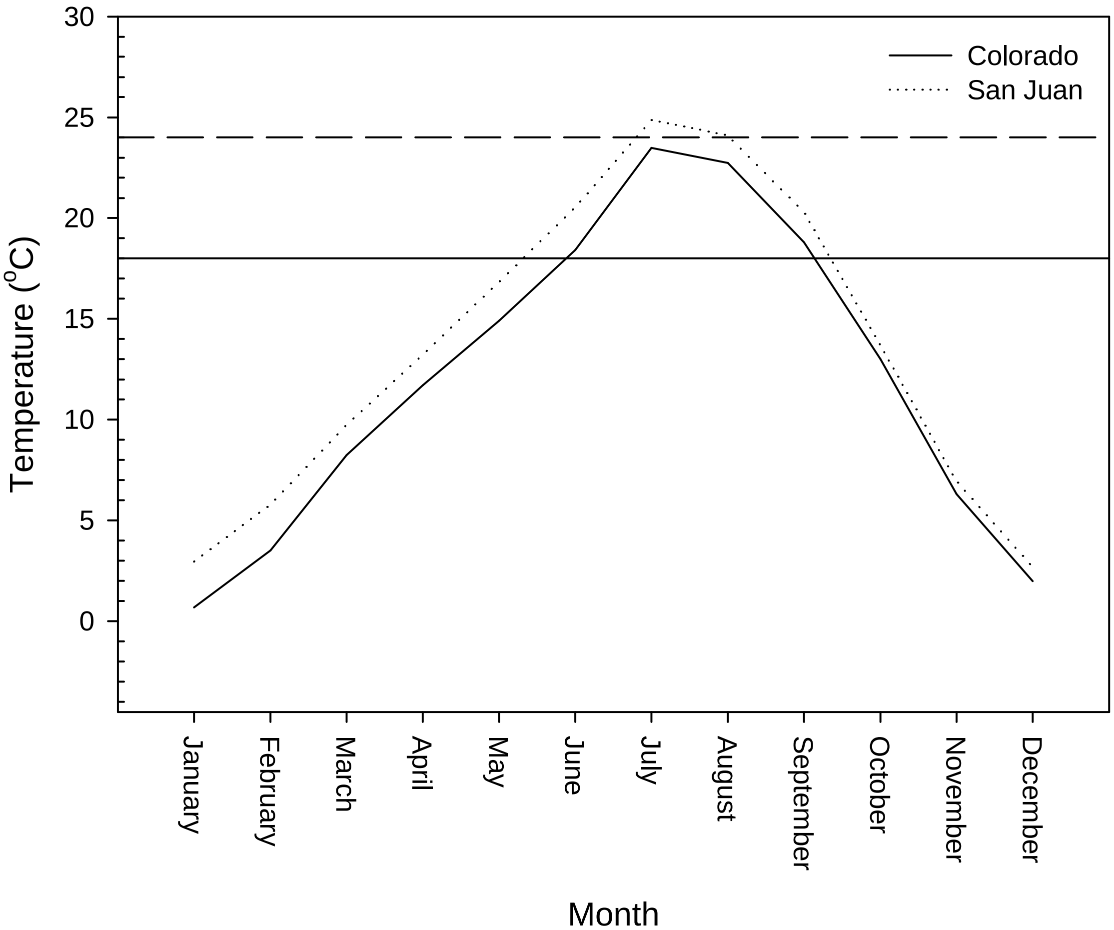


Figure 2: Mean monthly water temperatures along the Colorado (solid line) and San Juan Rivers (dotted line) near Lake Powell. Data from the Colorado River below Glen Canyon Dam (Lees Ferry Data from Table 3 is excluded). The lower (solid) reference line denotes the minimum spawning temperature for redear sunfish and the upper (dashed) reference line denotes the minimum temperature considered "optimal" for redear sunfish growth.

Water Velocity:

When encountered in riverine habitats, redear sunfish prefer low gradient, low velocity stretches (Smith 1979; Shields et al. 2000). They also appear to avoid main-channel habitats and prefer side-channels and backwaters (Bailey et al. 1954). Data from Illinois indicates that redear sunfish are seldom encountered in main river channels and instead prefer backwaters (M. Mounce, Illinois Department of Natural Resources, personal communication). Studies along the longitudinal profile of large rivers shows that redear sunfish only reside on low gradient, downstream portions (Brown and Ford 2002; Kiernan et al. 2012). Redear sunfish appear to be less tolerant to riverine conditions as other species and when they are found in rivers they tend to occupy pool habitats (Travnichek et al. 1995). Rypel (2011), however, found that the growth of redear in low velocity rivers was comparable to their growth in impoundments. It appears that the velocity tolerance of redear sunfish has not been tested but Schaefer et al. (1999) performed experiments on the morphologically similar bluegill and found that the maximum time that a bluegill can tolerate a sustained water velocity of 30 cm/s was 83 s.

There are several sources that provide water velocity data within tributaries to Lake Powell. Magirl et al. (2009) measured water velocity in Cataract Canyon and reported a maximum velocity of 520 cm/s with velocities in pools ranging between 150 and 200 cm/s. When looking at the Colorado River as a whole, Magirl and Andersen (2010) report that water velocities within pools range between 50 and 200 cm/s. There is limited water velocity data from the San Juan River but data from the August 2016 release from the Gold King Mine in Colorado indicated that water in the Utah portions of the San Juan flowed at an average velocity of 92 cm/s. Discharge at this time was 115% of average (USGS stream gage at Bluff, Utah), indicating that the water velocity at this time may have been slightly above average. The average velocity of lower portions of the Escalante River have been reported as 73 cm/s in riffles and 38 cm/s in pools (Stumpf and Monroe 2012). Water velocities below Glen Canyon Dam have been reported to range between 103 and 179 cm/s (Graf 1997).

Most velocity data from tributaries are based on estimates made at a single point in time and may fluctuate with season. Unfortunately, USGS stream gages generally do not report water velocities. Leopold and Maddock (1953) describe a method to estimate velocity with stream discharge data using the formula $v = aQ^b$, where v = velocity and Q = discharge. The coefficients a and b are based on various river metrics (width, depth, etc.) but in the desert southwest, the average values for a and b are 0.32 and 0.26, respectively (Leopold and Maddock 1953). This formula allows for additional estimates of water velocity to be made and these estimates are presented in Table 4.

Twomey et al. (1984) reports that sites with velocities greater than 10 cm/s are not suitable for redear sunfish. It is apparent from the data that velocities in tributaries to Lake Powell are well in excess of what Twomey et al. (1984) reported that the species can tolerate. With that said, the velocities reported here are averages and there are microhabitats (side channels, backwaters, etc.) in the system that likely have slower velocities that are suitable for redear sunfish. As a whole, however, water velocities in tributaries to Lake Powell exceed what is preferred by redear.

Table 4: Estimated water velocities along the Colorado, San Juan, and Escalante Rivers near Lake Powell. Data are point samples taken either by the Utah Department of Environmental Quality (DEQ) or the United States Geological Survey (USGS). Data calculated based on monthly average discharges from USGS stream gaging stations. Discharge was converted to velocity using the formula provided in Leopold and Maddock (1953).

River	Data Source	Site Name	Years Data Collected	# of Samples	Average Velocity (cm/s)	Velocity Range (cm/s)
Colorado	DEQ	Green R Ab Cnfl/Colorado R	1984-2015	93	322	198-526
	DEQ	Colorado R. Bl Big Drop #3 Rapids	1990-2015	69	371	233-714
	DEQ	Colorado R Ab Cnfl/Green R	1984-2015	91	297	174-513
	USGS	Colorado River near Cisco, Ut	1980-2015	420	307	266-407
	USGS	Colorado River at Potash, UT	2014-2015	12	302	260-440
San Juan	DEQ	San Juan R At Mexican Hat US163 XING	1990-2009	92	221	141-361
	USGS	San Juan River near Bluff, UT	1980-2014	417	224	204-278
Escalante	USGS	Escalante River near Escalante, UT	1980-2015	420	58	53-70

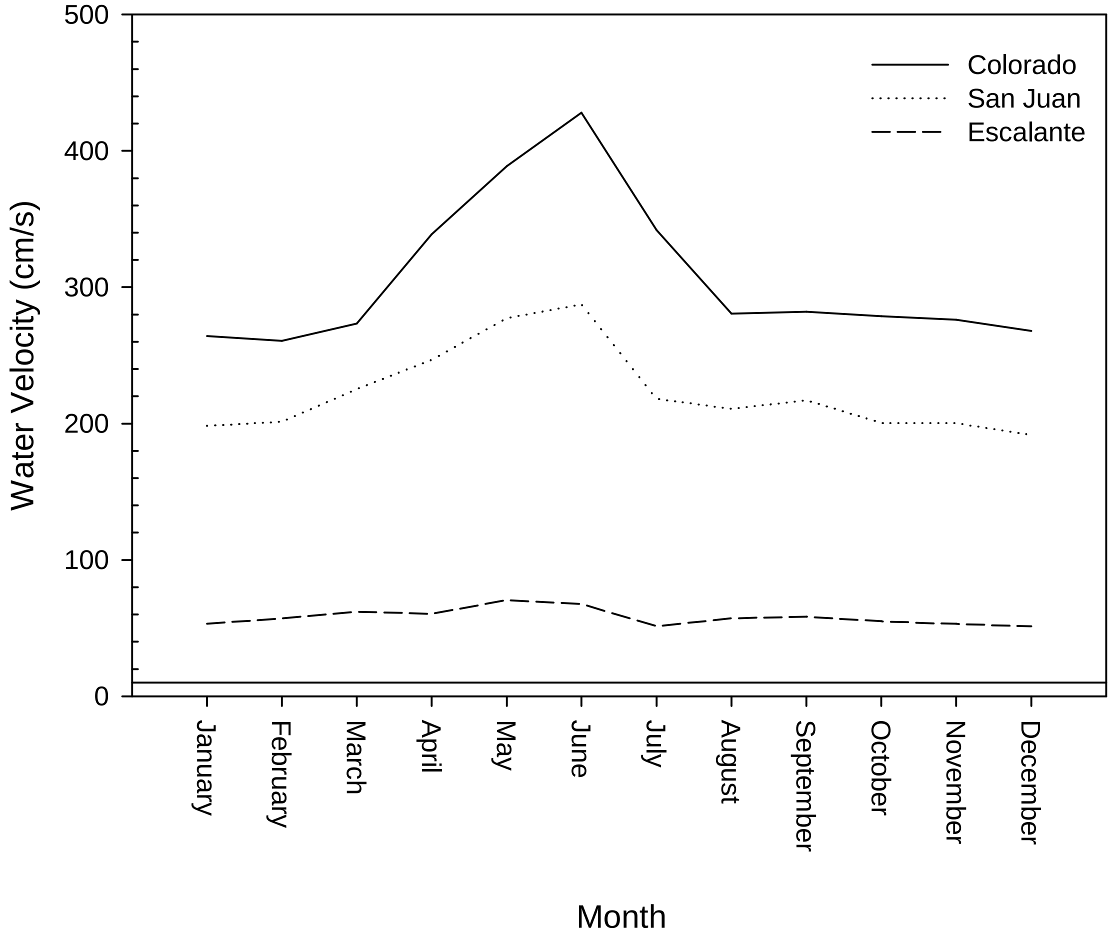


Figure 3: Average monthly water velocities along the Colorado (solid line), San Juan (dotted line), and Escalante (dashed line) Rivers near Lake Powell. The solid horizontal line at 10 cm/s represents the maximum water velocity tolerated by redear sunfish. Data calculated based on monthly average discharges from USGS stream gaging stations. Discharge was converted to velocity using the formula provided in Leopold and Maddock (1953).

Vegetation:

Data from Illinois (M. Diana, Illinois Natural History Survey) indicates that redear sunfish are associated with vegetated habitats. In riverine systems, redear are more likely to occupy pools and backwater areas with vegetation than those without vegetation (M. Mounce, Illinois Department of Natural Resources). Vegetation is considered important nursery habitat for redear and likely provide habitat for many preferred prey species (Trautman 1957). Redear sunfish condition is best in moderately vegetated habitats (Colle and Shireman 1980). Vegetation, however, is not considered absolutely necessary for the species (Twomey et al. 1984).

Unfortunately, there is very little data on macrophytes in tributaries to Lake Powell. It has been documented that macrophytes do occur within these rivers, however (McKinney et al. 1996). This paucity of data makes it difficult to apply the Twomey et al. (1984) model. Regardless, there is enough information to assume that quantities of vegetation within the tributaries are sufficient to provide "fair" to "excellent" habitat to redear sunfish (habitat is "fair" to "excellent" anywhere were percent area containing vegetation is <80%).

Application of Twomey et al. (1984) Model:

The final habitat suitability score from the Twomey et al. (1984) model is the lowest score of the food, cover, water quality, and reproduction components (Table 1). There is not sufficient data to score all ten variables within the model (Table 1). Regardless, turbidities in the Colorado and San Juan Rivers are high enough to score the water quality component as zero in those two rivers.Water velocities are high enough to score the reproduction component as zero in all three rivers assessed. This means the overall score for the tributaries is a zero, which indicates that the tributaries do not provide suitable habitat for redear sunfish (Twomey et al. 1984).

Part 2: Analysis of Bluegill and Green Sunfish Population in Tributaries

Another method of estimating the performance of redear sunfish in tributaries to Lake Powell is to evaluate how two closely related fish, the bluegill and the green sunfish perform in these habitats. Both species are currently found in Lake Powell and have been introduced into other habitats in Utah. Rypel (2011) evaluated the riverine/lacustrine performance of fourteen sunfish species and determined that green sunfish are better adapted to riverine life than bluegill and redear sunfish are not as adapted to riverine life as green sunfish but are more similar in adaptation to green sunfish than bluegill. The work by Rypel (2011), however, was performed in low gradient, warm, coastal river systems that provided nearly ideal physical conditions for all the species evaluated. Tyus and Saunders (2000) noted that pond habitats are better suited for both bluegill and green sunfish than riverine habitats. Bluegill are more tolerant of turbid conditions and high water velocities than redear sunfish (Stuber et al. 1982a). Considerable diet overlap between bluegill and redear sunfish has been noted (Desselle et al. 1978; VanderKooy 2000). Collar et al. (2009) synthesized the results of centrarchid diet studies and found that ~16% of the diet of green sunfish consisted of fish whereas few fish (0.1% of diet) were found in the stomachs of bluegill (n = 3290 individuals) and no fish were found in the stomachs redear sunfish (n = 164 individuals). Age-0 bluegill utilize both pelagic and littoral habitats whereas age-0 redear sunfish only occupy littoral areas (Dimond and Storck 1985). Redear were found to spawn earlier and at lower temperatures than bluegill and ultimately, fall abundance of age-0 bluegill outnumbered age-0 redear sunfish by 57 to 1 (Dimond and Storck 1985). Regardless, mitochondrial DNA evidence (Harris et al. 2005), morphological data, and habitat preference data (Stuber et al. 1982a; Twomey et al. 1984) all suggest that redear sunfish are more closely related to bluegill than green sunfish (Harris et al. 2005).

Both bluegill and green sunfish have been documented in tributaries to Lake Powell, albeit at low densities. Gerig and Hines (2013) sampled Utah portions of the San Juan River on eight occasions during 2012 and collected one green sunfish and no bluegill during their sampling. Sampling during 2013 documented no green sunfish and no bluegill (Hines 2014). Data from annual reports submitted to the San Juan River Recovery Implementation Program from 1998-2014 indicate that green sunfish are occasionally encountered in the river (0-5 fish collected/year) and that bluegill have not been collected within the river.

Valdez (1990) sampled the Cataract Canyon portion of the Colorado River in 1985-1988 and documented the collection of one adult bluegill in 1987. No additional bluegill were collected during the other years sampled. Numbers of green sunfish collected varied from zero in 1985 to 13 in 1986 (Valdez 1990). Some of the catch included young of year individuals. Green sunfish never constituted more than 0.10% of the total fish catch (Valdez 1990). Data from 2008-2011 shows that green sunfish and bluegill were not captured in Cataract Canyon during this time period (Badame and Lund 2010; Breidinger and Badame 2011, and Breidinger and Badame 2012). Similar samples taken in 2004 also indicated that both species were absent from Cataract Canyon (Valdez et al. 2005). Karp and Tyus

(1990) sampled the Green and Yampa Rivers within Dinosaur National Monument and caught few green sunfish (<0.01% of total catch) and no bluegill. Breen et al. (2011) referred to data from samples taken from the Colorado River near Moab, Utah between 1986-2009 and noted that green sunfish were present in samples during 12 of the years of sampling and that bluegill were present during 3 years of sampling. Trammel et al. (2004) did not note the collection of bluegill in the Colorado River near Canyonlands National Park but did note that green sunfish constituted up to 0.1% of the catch. Breen et al. (2016) reported the results of standardized seine surveys between 1986 and 2015 and found that that green sunfish constituted up to 0.24% of the catch in the lower Green River and 0.29% of the catch in the lower Colorado River (between Cisco Landing and the junction with the Green River). No bluegill were reported in the sampling (Breen et al. 2016). Staff from the UDWR's Moab Field Office report that collection of 11 green sunfish and 4 bluegill in 2013, 3 green sunfish and 1 bluegill in 2014, and 1 green sunfish and 1 bluegill in 2015 during standardized sampling in the Colorado River between Moab and the confluence with the Green River (D. Elverud, personal communication).

In general, redear sunfish appear rare in large, turbid river systems, even in their native range. McClelland and Sass (2008) reported data collected from 27 sites spanning 280 miles of the Illinois River. Samples were collected yearly between 1957 and 2007. Redear sunfish were not collected in most years and were rare (<0.01% of catch) in the years that they were collected. Winemiller et al. (2000) reported the collection of redear sunfish in oxbow lakes but not the main stem of the Brazos River, Texas. Slipke and Maceina (2005) found that redear sunfish were more common in backwaters than the main stem of Alabama rivers.

Part 3: Assessment of the Predation Risk that Redear Sunfish Pose to Native Fishes

Life History Characteristics of Endangered Colorado River Fishes:

There are four endangered fish species that occupy tributaries to Lake Powell: the humpback chub *Gila cypha*, bonytail chub *G. elegans*, Colorado pikeminnow *Ptychocheilus lucius*, and the razorback sucker *Xyrauchen texanus*. Historically, humpback chub inhabited the swift and turbulent waters in canyons of the Colorado River and three of its tributaries: the Green and Yampa rivers in Colorado and Utah, and the Little Colorado River in Arizona. Today, five self-sustaining populations of humpback chub occur in the Upper Colorado River Basin. Two to three thousand adults occur in the Black Rocks and Westwater Canyon core populations in the Colorado River near the Colorado/Utah border. Several hundred to more than 1,000 adults may occur in the Desolation/Gray Canyon core population in the Green River. Populations in Yampa and Cataract canyons are small, each consisting of up to a few hundred adults. The largest known population of humpback chub is in the Lower Colorado River (LCR) Basin in the Grand Canyon -- primarily in the LCR and its confluence with the main stem of the Little Colorado River. In 2009, the U.S. Geological Survey announced that this population increased by about 50 percent from 2001 to 2008. The agency estimates that the number of adults is between 6,000 and 10,000, with the most likely number being 7,650 individuals.

The bonytail chub is among North America’s most endangered fish species. No reproducing populations are known in the wild. Recognizing that fewer bonytail were being seen in the Colorado River and no young, biologists captured 34 adults from Lake Mohave from 1976 to 1988, and 16 from 1988 to 1989. These fish were held in fish hatcheries. The young of these Lake Mojave fish, and the few remaining adults in hatcheries and in the wild, make up the entire known population of bonytail in the world. Because there are so few bonytail in the wild, their preferred habitat is still unknown. Their large fins and streamlined body enable bonytail to swim in swift river flows. Young bonytail chubs typically eat aquatic plants, while adults feed mostly on small fish, algae, plant debris, and terrestrial insects.

Young Colorado pikeminnow feed on insects and plankton, whereas adults feed mostly on fish. Today, two wild populations of Colorado pikeminnow are found in the Upper Colorado River Basin – one in the upper Colorado River system and one in the Green River system. The San Juan River Basin Recovery Implementation Program continues to stock Colorado pikeminnow to develop a separate, self-sustaining population. The Colorado pikeminnow is adapted to warm rivers and requires uninterrupted passage and a hydrologic cycle characterized by large spring peaks of snowmelt runoff and lower, relatively stable base flows.

To complete its life cycle, the razorback sucker moves between adult, spawning, and nursery habitats. Spawning occurs during high spring flows when razorback sucker migrate to cobble bars to lay their eggs. Larvae drift from the spawning areas and enter backwaters or floodplain wetlands that provide a nursery environment with quiet, warm, and shallow water. Research shows that young razorback sucker can remain in floodplain wetlands where they grow to adult size. As they mature, razorback sucker leave the wetlands in search of deep eddies and backwaters where they remain relatively sedentary, staying mostly in quiet water near the shore. Historically, the razorback sucker was widespread and abundant in the Colorado River and its tributaries. Today all populations of razorback sucker are supplemented with stocked fish except for the Lake Mead population. Lakes Mead and Mohave are the only population with wild fish.

Potential Threats Associated with the Introduction of Redear Sunfish to Endangered Native Fishes:

1. *Predation:* Redear sunfish are highly molluscivorous (Ledford and Kelly 2006; Etnier 1971; Desselle et al. 1978; Wong et al. 2013), in one case zebra mussels were primary prey of 100% of adult redear sunfish (Magoulick and Lewis 2002) and usually comprise 50-100% of their total diet (French 1993). Additionally, redear sunfish have been used in hatchery and fish rearing situations to control snail populations without the threat of predation on production fish (French and Morgan 1995). Redear sunfish possess morphological characteristics specifically designed for feeding on snails and other mollusks. Within the Colorado River between Lake Havasu and Lake Mohave, redear sunfish diet is made up of crayfish and invasive mussels (Personal Communication Richard Wydoski, Bureau of Reclamation). The upper and lower pharyngeal teeth and molariform teeth enable them to close their upper and lower teeth together to crush shells and mollusks (French 1993). Redear sunfish are not designed to prey on other fish species. Collar et al. (2009) reviewed the literature and did not document the occurrence of fish in the diets of redear sunfish and also found that the morphology of the redear mouth is not conducive to piscivory. Thus, if redear sunfish become established within tributaries to Lake Powell, it is not likely that they will predate on native fishes.
2. *Competition with Native Fishes:* Redear sunfish are considered to be specialist mollusk feeders. Regardless, a broad range items have been documented in the diets of redear sunfish. Desselle et al. (1978) found that mollusks made up <10% of the diet of young redear sunfish. Chironomidae constituted up to 96% of the diet of 50-99 mm fish, but less than 1% of the diet of larger fish (Desselle et al. 1978). Minckley (1982) found that mollusks constituted 59% of the diet of redear sunfish sized from 85-305 mm total length. Fisher Huckins (1997) found that percentage of snails in the diets of redear sunfish increased with size and that smaller redear sunfish tended to feed more heavily on soft-bodied invertebrates.

Magoulick and Lewis (2002) analyzed the diet of 236 redear sunfish and found zebra mussels in all fish. The molluscivorous behavior of redear sunfish appears to be inconsistent. Some studies find that mollusks make up a significant portion of the redear diet whereas other find that mollusks make up a small portion of the diet. Regardless, it is clear that redear sunfish will consume mollusks when available but it appears that there is enough plasticity in the diet of redear sunfish to allow the species to adapt to consumption of alternative prey..

Kaeding and Zimmerman (1983) analyzed the diet of a wide size range of humpback chub and found that approximately 70% of the chub's diet consisted of immature chironomidae, simulidae, and "other dipterans". Stone and Gorman (2006), however, note that humpback chub shift to piscivory at around 180 mm total length. Comparatively, little diet data is available for bonytail chub. They have been reported to primarily feed on terrestrial insects, small fish, and algae (Joseph et al. 1977). More is known about the diet of the Colorado pikeminnow. Muth and Snyder (1995) found that small (< 20 mm total length) pikeminnow primarily consumed zooplankton. The authors did note considerable diet overlap between Colorado pikeminnow and green sunfish (< 40 mm total length; Muth and Snyder 1995). Holden and Wick (1982) also note that small pikeminnow consume zooplankton and consume increasing numbers of insects until they are 100 mm total length. From there, fish become part of the pikeminnow diet and pikeminnow become almost entirely piscivorous by the time they are 200 mm total length (Holden and Wick 1982). In contrast, razorback suckers are primarily planktivorous in lentic systems (Marsh 1987) and consume benthic and drifting macroinvertebrates in lotic systems (Marsh et al. 2015).

It appears that there could be some diet overlap between redear sunfish and the native fishes. Young humpback chub and Colorado pikeminnow have diets that are similar to young-of year redear sunfish. In lotic systems, redear sunfish typically stay in littoral habitats and thus likely would have less diet overlap with razorback suckers. The lack of diet data from bonytail chub makes it difficult to assess diet overlap with redear sunfish. Young of year Colorado pikeminnow, humpback chub, and razorback suckers are known to use backwater habitats. These habitats are likely the same habitats that redear sunfish would use and this habitat overlap may increase competition for food between redear and the native species. Bluegill and green sunfish likely have similar diet overlap with the native species. Adult redear sunfish are primarily mollisicivores but there is enough diet plasticity in the species to allow redear to feed on other prey items (Desselle et al. 1978). The lack of mollusks in the tributaries to Lake Powell (Shannon et al. 2003; Cross et al. 2010) may force redear to become generalist feeders, which may increase their diet overlap with the native species.

3. *Habitat degradation:* Redear sunfish have shown indirect impacts on vegetation in Tennessee (Ruiz et al. 1999). Reductions in gastropods have improved vegetative growth in ponds and lakes. In Lake Powell and the Colorado River system these impacts will be negligible due to the low numbers of gastropods in these systems. Dreissenid mussels pose a much greater risk to habitat degradation in these systems.
4. *Hybridization:* Redear sunfish cannot hybridize with any of the native fish in the Colorado River System. Redear sunfish will only hybridize with other *Lepomis* species (Scribner et al. 2001).

Conclusions:

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