Jackson Gulch Reservoir
Quagga Mussel Colonization Potential -- Water-Quality Results Compared from September 2008 - March 2009

USGS science for a changing world

QUAGGA AND ZEBRA MUSSEL SIGHTINGS DISTRIBUTION IN THE WESTERN UNITED STATES 2007 - 2009

■ Red markers indicate presence of quagga mussels ☐ Green markers indicate the presence of zebra mussels

LOCATIONS

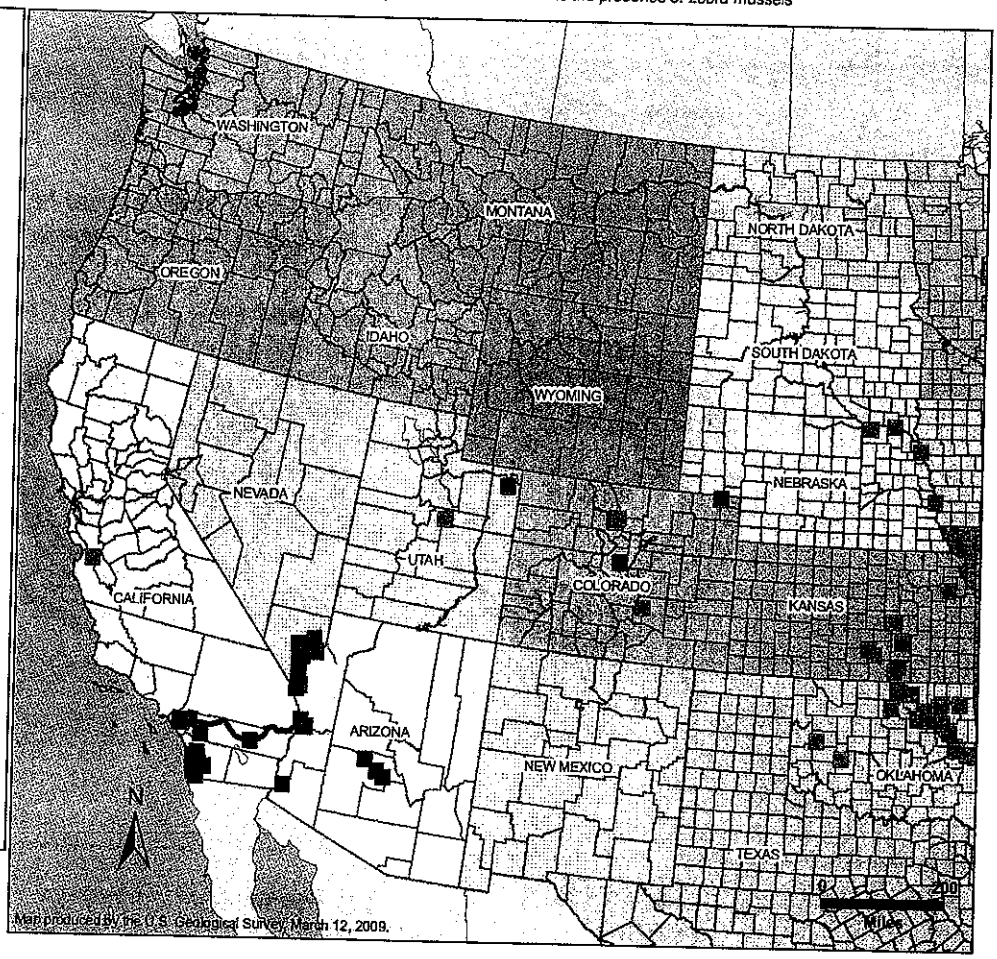
NEVADA
Lake Mead - January 2007
Lake Mohave - January 2007

CALIFORNIA
Parker Dam - January 2007
Colorado River Aqueduct - March 2007
Colorado RA at Hayfield - July 2007
Lake Matthews - August 2007
Lake Skinner - August 2007
Dixon Reservoir - August 2007
Lower Otay Reservoir - August 2007 San Vicente Reservoir - August 2007
Murray Reservoir - September 2007
Lake Miramar - December 2007
Sweetwater Reservoir - December 2007
San Justo Lake - January 2008
El Capitan Reservoir - January 2008
Lake Jennings - April 2008
Olivenhain Reservoir - March 2008
Irvine Lake - April 2008
Rattlesnake Reservoir - May 2008
Lake Ramona - March 2009

ARIZONA
Lake Havasu - January 2007
Central Arizona Project Canal - August 2007
Lake Pleasant - December 2007
Imperial Dam - February 2008
Salt River - October 2008

COLORADO
Pueblo Reservoir - January 2008
Lake Granby - July 2008
Grand Lake - September 2008
Willow Creek Reservoir - September 2008
Shadow Mountain Reservoir - September 2008
Jumbo Lake - October 2008
Tarryall Reservoir - October 2008

UTAH
Electric Lake - November 2008
Red Fleet Reservoir - February 2009



Data Sources: California Dept. of Fish and Game; Arizona Dept. of Game and Fish; Colorado Division of Wildlife; Utah Division of Wildlife Resources; City of San Diego; National Park Service; Imperial Irrigation District; Helix Water District; Irvine Ranch Water District.

SHL W

Southwest Hydro-Logic

Jackson Gulch Reservoir
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Southwest Hydro-Logic

CONVERSION FACTORS AND ABBREVIATIONS USED IN THIS REPORT

CONVERSION FACTORS:

Multiply	By	To obtain
cubic foot per second (cfs)	0.02832	cubic meter per second (m^3/sec)
foot (ft)	0.3048	meter (m)
gallon	3.78	liter (L)
inch	2.50	centimeter (cm)

Degrees Celsius (^oC) may be converted to degrees Fahrenheit (^oF) by using the following equation:

$$^oF = 9/5(^oC) + 32$$

ABBREVIATIONS:

The following terms and abbreviations may used in this report:

feet (ft)
parts per million (ppm)
parts per billion (ppb)
parts per trillion (ppt)
cubic feet per second (cfs)
milligrams per liter (mg/L, same as ppm)
micrograms per liter (µg/L, same as ppb)
nanograms per liter (ng/L, same as ppt)
nanograms per square centimeter per year (ng/cm^2/year)

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CONTENTS

List of Figures

Jackson Gulch Reservoir Quagga Mussel Colonization Potential -- Water-Quality Results Compared from September 2008 - March 2009

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EXECUTIVE SUMMARY

Preliminary conclusions from the September 2008 lake sampling indicate that Jackson Gulch Reservoir is suitable for colonization by zebra and quagga mussels for September water-quality conditions. During February 2009, when samples were collected under the ice, water-quality conditions had changed, indicating lower pH conditions and higher concentrations of acidity. Ice cover on the lake may trap dissolved carbon dioxide, preventing CO_2 from degassing, and keeping it in solution. Higher dissolved CO_2 concentrations create greater acidity. This phenomenon occurs in other cold-region lakes; however, the importance of dissolved CO_2 and acidity for mussel colonization potential has not been fully explored.

During March 2009, water was entering the lake through the Jackson Gulch inlet canal, and the ice had broken free at the edges of the lake. The lake was sampled again under the ice, and the water-quality conditions had gone the other direction towards higher pH values. The reservoir had been frozen for less than three months, which is unusual for a lake located at an altitude of 7,825 feet above sea level. The lake is generally frozen from November to April.

Using the typical water-quality parameters for zebra mussel colonization potential (pH, calcium, dissolved oxygen, and water temperature), data collected seasonally from Jackson Gulch Reservoir were compared. Using these simple measures, Jackson Gulch Reservoir is favorable for mussel colonization during September, unfavorable for colonization during February, and favorable during March. The annual or overall potential has not been determined, and additional sampling needs to be done to characterize the annual conditions.

Calcium carbonate is necessary for zebra and quagga mussels to construct their shells. The extent and direction of departure from equilibrium can be represented by the Saturation Index (S.I.). A positive value for S.I. indicates that the solution is supersaturated, and a negative S.I. indicates that the solution is undersaturated.

Calcium carbonate saturation indices were determined for water samples collected from Jackson Gulch Reservoir. During September 2008, the S.I. values were all undersaturated, indicating that calcite would dissolve under such conditions. During February 2009, the S.I. values were all negative, with S.I. values ranging from -1.2 to -1.3. During March 2009, the S.I. value in the upper sample was positive, indicating that calcite would precipitate under such conditions, which would represent favorable conditions for mussel colonization.

Saturation index values were determined for other lakes where zebra and quagga mussels have been documented. Water from Lake Mead (Nevada), Pueblo Reservoir (Colorado), and Green Lake (Wisconsin) all had supersaturated S.I. values.

From the typical measures of mussel colonization potential (pH, calcium, dissolved oxygen, and temperature) Jackson Gulch Reservoir has low, moderate, and high colonization potential, depending on the parameter and season. Using the S.I. values for calcium carbonate saturation, Jackson Gulch Reservoir had only one sample (upper sample during March 2009) that was supersaturated. These results are not final proof that mussels can or cannot colonize Jackson Gulch Reservoir. However, the S.I. approach is a quantitative method for determining mussel colonization potential. Further sampling and characterization will help to refine the approach.

1.0 WATER-QUALITY RESULTS COMPARED FROM SEPTEMBER 2008, FEBRUARY 2009, AND MARCH 2009

Using water-quality parameters as indicators of suitability, Jackson Gulch Reservoir is generally suitable for colonization by zebra and quagga mussels. During the winter, pH's are lower and suitability is low for that parameter.

During the winter, ice cover on the lake may trap carbon dioxide gases under the ice, which increases acidity, and mussels cannot tolerate acidity. However, the ice cover lasted for less than three months. As soon as the inlet canal brought in water, and the ice broke free at the edges of the lake, conditions returned to being favorable for mussel colonization.

Preliminary conclusions from the September 2008 lake sampling indicate that Jackson Gulch Reservoir is suitable for colonization by zebra and quagga mussels for September water-quality conditions. All of the water-quality parameters used for zebra and quagga mussel colonization potential were within the moderate to high range **(Figure 1)**, indicating that Jackson Gulch Reservoir could be vulnerable to mussel infestation.

During February and March 2009, a hole was drilled in the lake ice, profiles were measured using a water-quality sonde, and samples were collected using a Teflon Kemmerer sampler. Water temperatures were low during February and March 2009, and values were within the low to very low suitability condition for mussels **(Figure 1)**. However, the quagga mussels, in particular, are known for their adaptation to local conditions, and cool water temperatures may not be sufficient to stop mussel infestation at Jackson Gulch Reservoir.

During February 2009, when samples were collected under the ice, lower pH values were recorded **(Figure 1)**. This may be caused by dissolved carbon dioxide (CO_2) being trapped under the ice cover. Higher dissolved CO_2 concentrations creates higher acidity, and mussels cannot tolerate acidity. During March 2009, the Jackson Gulch inlet canal was discharging water into the reservoir. The flowing water mixed the reservoir and raised the lake level, releasing the ice cover at the edges of the lake. The pH values recorded during March 2009 returned to conditions favorable for mussel colonization **(Figure 1)**.

Dissolved oxygen concentrations remained in the moderate to high range for colonization potential during September 2008, February 2009, and March 2009 **(Figure 1)**. Calcium concentrations remained in the high colonization potential for all sampling events **(Figure 1)**.

Under the ice cover of the lake, pH and acidity conditions may not be favorable for mussel colonization. However, the ice cover lasted less than three months, and it is unknown how long the mussels can tolerate low pH or high acidity conditions.

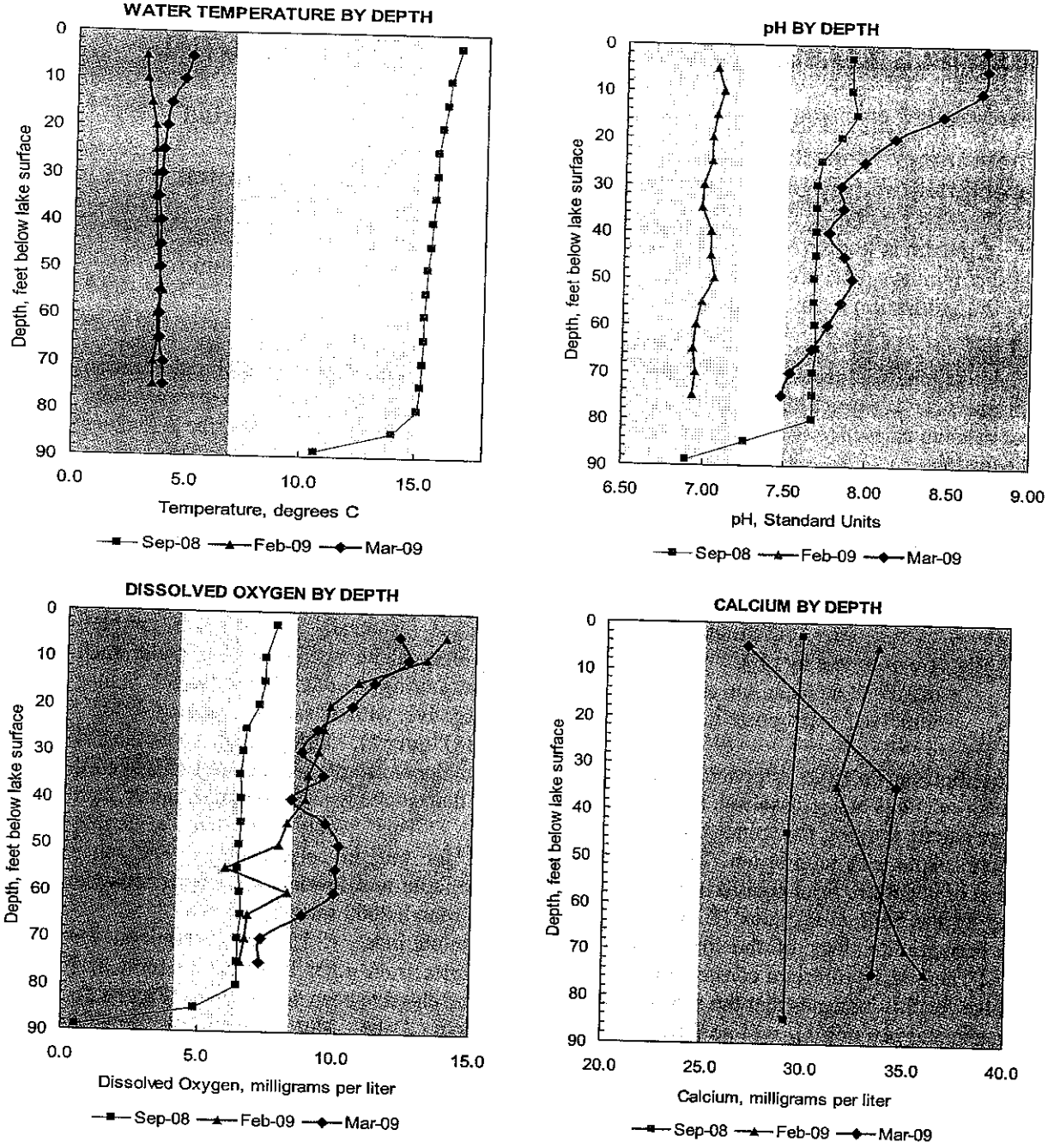

Figure 1. Water temperature, pH, dissolved oxygen, and calcium in water from Jackson Gulch Reservoir, September 2008, February 2009, and March 2009, showing ranges of zebra mussel colonization potential.

2.0 CALCIUM CARBONATE SATURATION INDEX -- A POSSIBLE MEASURE FOR MUSSEL COLONIZATION POTENTIAL

Zebra and quagga mussels need calcium carbonate to construct their shells. The pH-driven mechanisms of calcium carbonate precipitation may be a key indicator of mussel colonization potential.

Calcium is known to be an important factor for mussel colonization potential, and pH values also are known to be a factor. These parameters are interrelated by the saturation index of calcium carbonate, or calcite.

Calcium carbonate is necessary for zebra and quagga mussels to construct their shells. The solution of calcium carbonate (calcite) follows the chemical equation:

$$CaCO_{3(s)} + H^+ = Ca^{2+} + HCO_3^- \quad (1)$$

where:
$CaCO_{3(s)}$ = calcium carbonate solid,
H^+ = hydrogen ion concentration (represented by pH),
Ca^{2+} = dissolved calcium ion, and
HCO_3^- = dissolved bicarbonate ion.

This reaction can go either direction, from left to right where calcite is being dissolved; from right to left where calcite is being precipitated; or in the middle where calcite is at equilibrium. The extent and direction of departure from equilibrium can be represented by the Saturation Index (S.I.), or the difference between the logs of the ion activity product (IAP) and the equilibrium constant (K). A positive value for S.I. indicates that the solution is supersaturated, and reaction *(1)* will go from right to left, precipitating calcite solid. A negative S.I. indicates that the solution is undersaturated, and reaction *(1)* will go from left to right, dissolving calcite. S.I. is dependent on temperature, and calcite solubility increases with lower temperatures.

Zebra and quagga mussels, with their shells made of calcium carbonate, probably could not last for a long time in undersaturated conditions because their shells would dissolve in undersaturated conditions. From the literature on zebra and quagga mussels, no authors have presented the concept of S.I. as a limiting factor, and the effects of S.I. on mussel colonization potential has not been proven experimentally. Most papers and reports simply describe pH values and calcium concentrations as possible limiting factors for mussel colonization potential.

Calcium carbonate saturation indices were determined for water samples collected from Jackson Gulch Reservoir (**Figure 2**). During September 2008, the S.I. values were all undersaturated (especially in the lower sample), indicating that calcite would dissolve under such conditions. During February 2009, the S.I. values were all negative, with all samples ranging from -1.2 to -1.3 (**Figure 2**). During March 2009, the S.I. value in the upper sample was positive (**Figure 2**), indicating that calcite would precipitate under such conditions. This would represent favorable conditions for mussel colonization. The other samples (middle and lower) were undersaturated during the March 2009 sampling event.

Saturation index (S.I.) was determined for water samples from other lakes where zebra and quagga mussels have been documented (**Figure 2**). Water from Lake Mead (Nevada), Pueblo Reservoir (Colorado), and Green Lake (Wisconsin) all had supersaturated S.I. values. Lake Mead and Pueblo Reservoir do not freeze in the winter; however, it is unknown whether Green Lake freezes.

The monitoring at Jackson Gulch Reservoir began in September 2008; therefore, it is unknown what the S.I. values would be throughout the year. The question remains, how long can adult mussels survive in the winter with undersaturated calcite S.I. values?

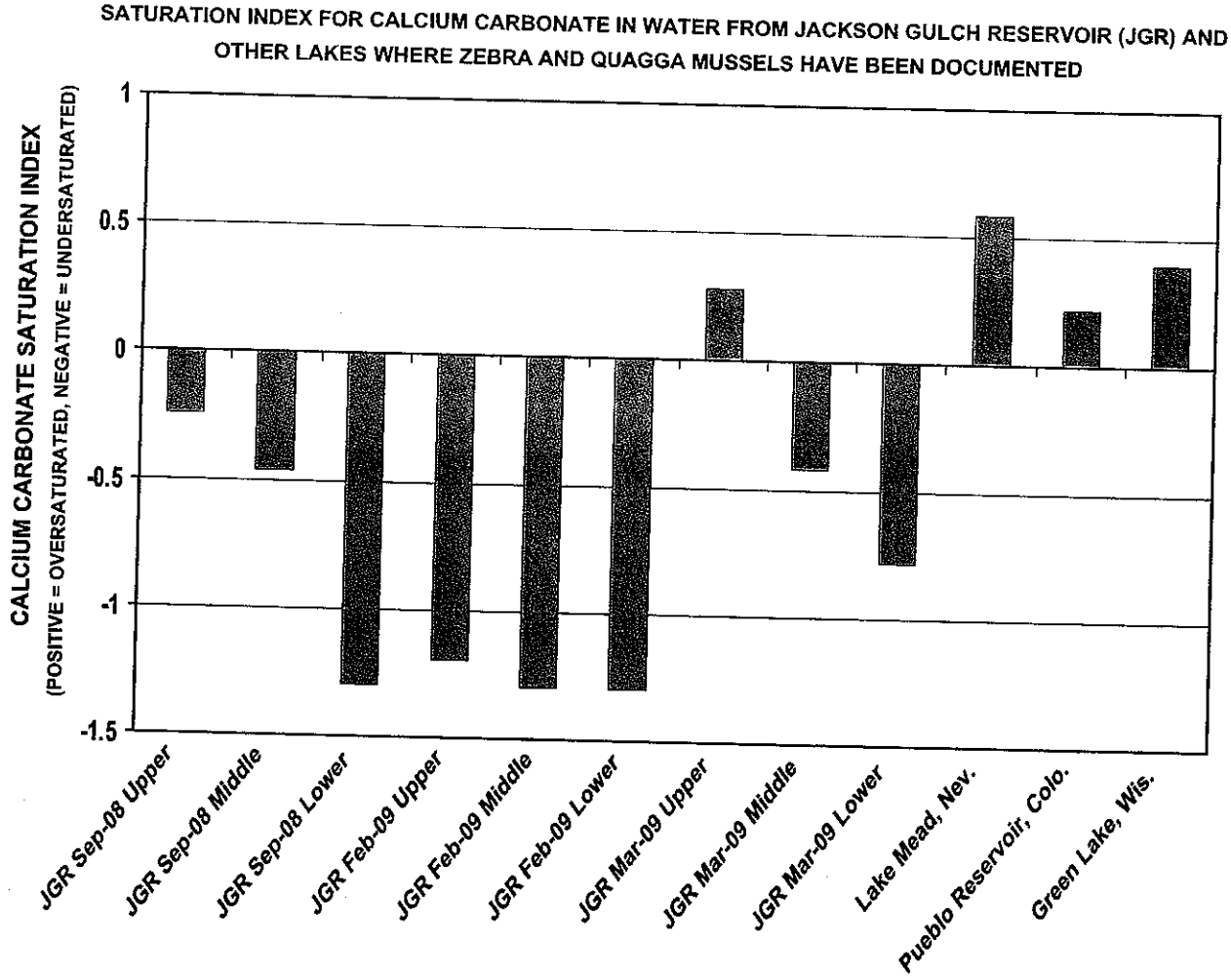

Figure 2. Calcium carbonate saturation index values in water from Jackson Gulch Reservoir and other lakes where zebra and quagga mussels have been documented.