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Great Salt Lake, Utah

Introduction

Great Salt Lake, the shrunken remnant of prehistoric Lake Bonneville, has no outlet. Dissolved salts accumulate in the lake by evaporation. Salinity south of the causeway has ranged from 6 percent to 27 percent over a period of 22 years (2 to 7 times saltier than the ocean). The high salinity supports a mineral industry that extracts about 2 million tons of salt from the lake each year. The aquatic ecosystem consists of more than 30 species of organisms. Harvest of its best-known species, the brine shrimp, annually supplies millions of pounds of food for the aquaculture industry worldwide. The lake is used extensively by millions of migratory and nesting birds and is a place of solitude for people. All this occurs in a lake that is located at the bottom of a 35,000-square-mile drainage basin that has a human population of more than 1.5 million.

Frequently Asked Questions and Answers about Great Salt Lake

• How large is the lake?

At the average water-surface altitude of 4,200 feet, the lake is 75 miles long by 28 miles wide and covers about 1,700 square miles. At this altitude, the maximum depth is about 33 feet. At its lowest altitude in 1963 (4,191 feet), it was less than one-half the size it reached at its historic high peak during 1986–87 (4,211 feet).

• How was the lake formed?

The lake is a remnant of Lake Bonneville, a large Pleistocene-age lake that covered about 20,000 square miles (slightly smaller than West Virginia at 24,000 square miles) and was a maximum of 325 miles long by 135 miles wide, with a maximum depth of 1,000 feet. Lake Bonneville existed from about 30,000 years ago to 16,000 years ago. Four ancient shorelines of Lake Bonneville are visible on the Wasatch Mountains to the east.

Altitude (feet)	Lake-level name	Years before present
4,500	Stansbury	23,000–20,000
5,090	Bonneville	16,000–14,500
4,740	Provo	14,500–13,500
4,250	Gilbert	11,000–10,000

(Curry and others, 1984)

• When did the lake first appear?

Although as early as 30,000 years ago there were alternating periods of saline lakes and playas (salt flats) in the basin, Great Salt Lake is believed to have first formed about 11,000 years ago when the lake rose from a smaller saline body to about 4,250 to 4,275 feet at the Gilbert Level. At this time it was about three times as large as present Great Salt Lake and was salty. The lake was less salty during the Stansbury Level of Lake Bonneville.

• Why is the lake salty?

Because the lake does not have an outlet, water flows into the lake and then evaporates, leaving dissolved minerals behind as residue. On average, 2.9 million acre-feet of water enters the lake each year from the Bear, Weber, and Jordan Rivers. The inflow carries about 2.2 million tons of salt. About 4.3 billion tons of salt are in the lake, and commercial removal of the salt ranges from 1.6 to 2.5 million tons annually.

• What animals live in the lake?

Of the various animals, the most visible and famous is the brine shrimp (Artemia franciscana). Two species of brine flies (genus Ephydra) also are very numerous but do not bite. Numbers of these flies may reach 370 million per mile of shoreline during summer.

Two to five million shorebirds and hundreds of thousands of waterfowl use the lake seasonally. Wilson's Phalarope and Eared Grebes often are present in summer.

• How did brine shrimp get into the lake and when did they first appear?

The shrimp likely arrived as cysts (eggs) on the feet of migratory birds. Brine shrimp cysts and fecal pellets in a deep sediment core have been dated to be 15,000 years old.

• How do brine shrimp live in the extremely salty (hypersaline) environment of the lake?

The body cuticle prevents water loss and salt entry. The shrimp drink large amounts of salt water and the gut takes up the water (and some salt). The branchia, or gills, then excrete the salt back into the water.

• Have there ever been marine organisms or fish in the lake?

In 1899, the U.S. Fisheries Service considered implanting oysters into the mouths of the larger rivers that enter the lake but decided that oysters could not be raised commercially.

In 1986, killifish entered from Timpie Springs on the south end when the lake was at a salinity of about 5.5 percent.

• Why is the north part of the lake purplish-pink?

A railroad causeway separates the lake into a north and south part. Most freshwater enters the south part, and water in the north part evaporates faster than it enters. The north part is always much saltier than the south part. Several species of purple salt-tolerant bacteria and an alga with a red pigment live in the north part and cause the purplish-pink coloration, especially when the salinity is greater than about 25 percent.

• Are there any other large saline lakes?

Excluding Lake Eyre in Australia (3,100 square miles when flooded, but usually dry):

Water body	Salinity (parts per thousand)	Area (square miles)
Caspian Sea (Russia, Iran)	11	170,000
Aral Sea (Russia)	10	25,000
Lake Balkhash (Russia)	2.8	7,115
Great Salt Lake (Utah)	*140	1,700
Salton Sea (California)	44	380
Dead Sea (Israel)	220	390

* Measurement for Gilbert Bay, 1995.

Brine shrimp (Artemia franciscana) adults and cysts.

History

Thirty thousand years ago, during the last ice age, Lake Bonneville expanded from a small saline lake to a freshwater lake that covered about 20,000 square miles and was about 1,000 feet deep. About 16,000 years ago, the lake cut a massive outlet at its northern end and discharged a flood that reached the Snake River. A dry period nearly eliminated any remnant of the lake about 500 years later, but increasing

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precipitation raised the water surface to about 50 feet above the present lake level, creating Great Salt Lake.

The Dominguez and Escalante expedition reached Utah Valley, 50 miles south of Great Salt Lake, in 1776. The indigenous Timpangotzis Indians told them of a very salty lake in the valley to the north. The explorers were anxious to return to Monterey and did not investigate this saline lake. In 1824, the French trapper Etienne Provost may have been among the first of the European trappers to see the lake, but other European trappers and explorers also vie for the honors: Jim Bridger, Peter Skene Ogden, and John H. Weber. An early scout and explorer, John C. Fremont, is credited with making the first scientific measurement of lake altitude in 1843 (4,200 feet).

The Stansbury expedition entered Salt Lake Valley to make maps and describe the area in 1849 under the direction of the U.S. Government. The expedition succeeded in mapping the entire shoreline of the lake by 1850. All of the larger islands in the lake except Fremont Island were named for members of this exploration party: Stansbury Island (Howard Stansbury), Carrington Island (Albert Carrington), Gunnison Island (J.W. Gunnison).

Clarence King, a geologist with the U.S. Government survey of the Fortieth Parallel, surveyed the lake from 1869 to 1870. Additional geologic and geographic surveys in the vicinity of Great Salt Lake were completed in the next few years by F.V. Hayden, George M. Wheeler, and Grove C. Gilbert as part of the great exploration of the West done by the U.S. Army Corps of Topographical Engineers and the U.S. Department of the Interior.

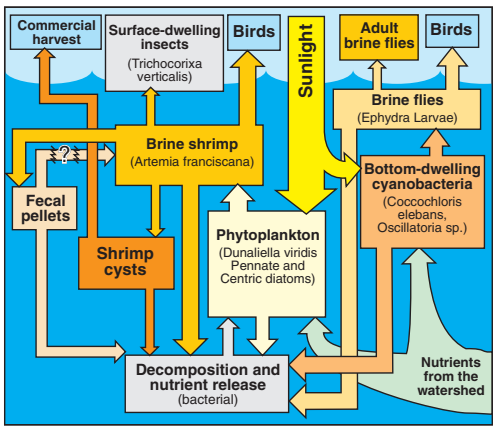
Hydrology and Salinity

Great Salt Lake is divided by a rock-fill railroad causeway constructed in 1959 to replace the wooden trestle built in 1903. During the high water years of 1983–87, additional fill was added to raise the structure and a 300-foot breach was added. Most of the surface inflow from the Bear, Weber, and Jordan Rivers enters the lake south of the causeway, and only a small amount of water flows north through openings in the causeway. Water north of the causeway (Gunnison Bay) often has a salinity of 25 percent or higher; water south of the causeway (Gilbert Bay) has varied from about 6 to 27 percent salinity. The Bear, Weber, and Jordan Rivers contribute about 66 percent of the annual inflow of 2.9 million acre-feet (one acre-foot equals 325,851 gallons, or the amount of water that it would take to cover one acre to a depth of one foot) to the lake, precipitation into the lake contributes about 31 percent, and ground-water inflow about 3 percent.

Union Pacific Railroad causeway viewed from Lakeside, Utah. Gunnison Bay on left, Gilbert Bay on right, January 1998.

Water-budget studies done by the U.S. Geological Survey indicate that rivers contribute about 82 percent of the annual dissolved-solids load of 2.1 million tons and springs contribute 18 percent. Water can leave the lake only by evaporation, which amounts to about 2.9 million acre-feet annually. The lake is saline because evaporation concentrates the dissolved salts in the remaining water. About 4.5 billion tons of salt are in the lake, and commercial removal of salt equals about 2.3 million tons annually. Sodium chloride (table salt) is the most common salt, although small amounts of other salts and elements also are present, including magnesium, potassium, sulfate, and carbonate.

Five commercial enterprises extract salt and other minerals from the lake. Most use large solar evaporation ponds located near Stansbury Island and Bear River Bay to retrieve the salts.



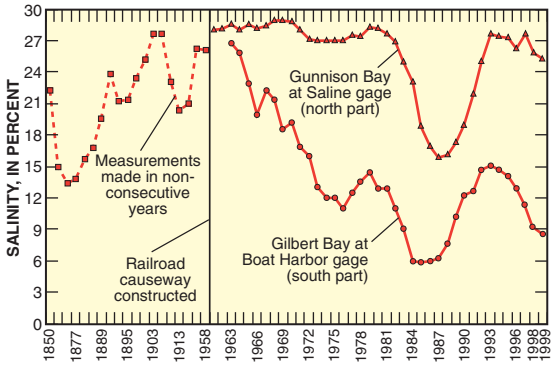
Generalized ecosystem structure and energy flow within Gilbert Bay of Great Salt Lake.

Life in Great Salt Lake

Hypersaline lakes typically support fewer species of aquatic organisms than freshwater lakes because only a few specialized species can withstand the stress of saline water. The total number of species in Great Salt Lake depends on the salinity and is not accurately known because microscopic species have not been well studied. When the salinity is high (28 percent in Gunnison Bay), there may be as few as six species. At lower salinities (6 to 9 percent in Gilbert Bay), the number of species has been estimated at 32. These organisms interact to form a complex and highly productive ecosystem. Algae (25 species reported in 1979) provide the base for the food chain through photosynthesis. They serve as food for brine shrimp and brine flies, which in turn are consumed by birds or by the shrimp harvested for the aquaculture industry. Bacteria, protozoa, and brine flies recycle the organic material to release nutrients and keep energy flowing through the system.

Brine Shrimp

The invertebrate community of Great Salt Lake undergoes large annual variations in timing and abundance of life stages and is dominated by brine shrimp, Artemia franciscana. The variations are partly the result of changes in salinity, water temperature, nutrients, and algal populations. The young artemia, called nauplii, typically appear from over-wintering eggs (hard-walled cysts containing an embryo in dormancy) from late February to early March when water temperatures are between 32 and 41 degrees Fahrenheit. Their appearance follows the winter bloom of phytoplankton that provides food for the developing nauplii by about 1 month. Peak numbers of nauplii typically occur between mid-April and mid-May. The first generation of adults produced by the nauplii reproduces sexually and, if food availability and environmental conditions are suitable, will produce the second generation ovoviviparously (by live birth). If conditions are less favorable, oviparous reproduction produces cysts. Two or three generations of artemia are produced each year. The artemia graze the phytoplankton to near extinction by May. The lack of food causes adult females to begin oviparous cyst production. The maximum number of adults occurs about mid-May and then gradually declines until December, when water temperatures drop below about 37 degrees Fahrenheit and the adults die.



Average annual salinity of Great Salt Lake.

Brine shrimp from Great Salt Lake have been commercially harvested as adults since 1950 and as cysts since 1952. The annual harvest is regulated by the Utah Division of Wildlife Resources and begins October 1. The harvest lasts about 1 to 4 months, depending on the number of cysts available. The cysts are marketed worldwide and used extensively in aquaculture as a food source for larval stages of giant prawns and fish. Reported cyst harvest from 1964 to 1978 ranged from 83 tons in

Base from U.S. Geological Survey digital data, 1:100,000, 1978, 1979, 1980, 1984
Universal Transverse Mercator projection, zone 12

0 10 20 MILES
0 10 20 KILOMETERS

EXPLANATION

- Great Salt Lake, altitude 4,200 feet
- Intermittent water body
- Utah State Park or National Monument
- Waterfowl Management Area (WMA) or other wildlife reserve

USGS has measured lake altitude at or near Boat Harbor gage since 1875, and at Saline gage since 1966.
Great Salt Lake historic maximum altitude 4,211.60 feet, June 3, 1986, and April 1 and 15, 1987
Great Salt Lake historic minimum altitude 4,191.35 feet, October 15 and November 1, 1963

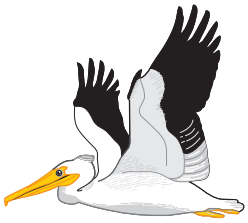
Commercial shrimp-harvesting craft with isolation boom suspended by orange floats.

1966 to 265 pounds in 1968 to about 7,400 tons during 1995–96. (Reported amounts include total unprocessed biomass of which about half is cysts.) Historically, salinity of the lake has been the major factor associated with the abundance and distribution of artemia and the success of the cyst harvest. When salinity of Gilbert Bay varied from 6 to 10 percent from 1982 to 1989, cyst production was poor and most harvesters moved to Gunnison Bay, the north part of the lake, where the salinity was 15 to 17 percent. Since about 1990, reproducing populations of artemia have been limited to Gilbert Bay, although during the 1998–99 season limited harvest efforts resumed in Gunnison Bay.

Brine Flies

Two species of brine flies (or ephydra) live in the lake. Adult flies congregate along the shoreline for breeding and occasionally reach densities of 370 million per mile of beach. Although they do not bite, they often land on people and may be annoying. The larval form of the brine fly (shown above at twice lifesize) feeds on detritus and benthic algae and plays an important role in recycling nutrients within the lake.

Migratory Birds



Great Salt Lake supports from 2 to 5 million shorebirds, as many as 1.7 million Eared Grebes, and hundreds of thousands of waterfowl during spring and fall migration. Because of its importance to migratory birds, the lake was designated a part of the Western Hemisphere Shorebird Reserve Network in 1992. The lake is a major staging area for some shorebirds, such as the Wilson's Phalarope. In July 1986, 387,000 Wilson's Phalarope were estimated in a 1-day aerial survey, and 600,000 were estimated on a single day in July 1991. Studies indicate that at least 5,000 to 10,000 Snowy Plovers nest on the alkaline flats surrounding the lake. The current estimate for breeding American Avocets is 40,000 and for Black-necked Stilts 30,000. Hundreds of thousands of Eared Grebes stage on the lake, fattening on the abundant brine shrimp. One of the world's largest populations of White-faced Ibis nests in the marshes along the east side of the lake. The lake hosts the largest number of breeding California Gulls, including the world's largest recorded single colony. About 150,000 breeding adults have been counted in recent years. The American White Pelican colony on Gunnison Island ranks among the three largest colonies in North America.

The lake and its marshes provide a resting and staging area for the birds as well as an abundance of brine shrimp and brine flies that serve as food. Important wetlands include Bear River Migratory Bird Refuge operated by the U.S. Fish and Wildlife Service; Locomotive Springs, Salt Creek, Public Shooting Grounds, Harold Crane, Willard Bay Upland Game, Ogden Bay, Howard Slough, Farmington Bay, and Timpie Springs Waterfowl Management Areas operated by the Utah Division of Wildlife Resources; Layton Wetlands Preserve managed by the Nature Conservancy; Gillmor Bird Sanctuary managed by the Audubon Society; and the Inland Sea Shorebird Reserve managed by Kennecott Utah Copper. Most of these areas are accessible seasonally for bird watching and some for duck hunting.

Recreation

Motor boating is not popular on the lake because of corrosion problems; however, two marinas provide facilities for sailing: Great Salt Lake Marina on the south end of the lake and Antelope Island State Park on Antelope Island. The more popular of the marinas and headquarters for the Great Salt Lake Yacht Club is located at the south end of the lake where launching is free but facilities are limited to a boat ramp, picnic area, and restrooms. Freshwater boating is available at Willard Reservoir, east of Bear River Bay, and camping facilities are available at Willard Bay State Park. A commercial business operates daily boat trips on the lake from Great Salt Lake Marina in the summer. A per-vehicle fee for use of the Davis County Causeway and Antelope Island State Park provides access to a boat ramp, restrooms, showers, picnic areas, camping areas (by reservation only), an excellent visitor center, miles of horse and bike trails, a resident bison herd, and a café.

Golden Spike National Historic Site marks the spot where the last spike in the transcontinental railroad was driven on May 10, 1869. Facilities include a visitor center, historic locomotives, and interpretive presentations.

Antelope Island, with an area of about 28,000 acres, is the largest of the islands in Great Salt Lake and is publicly owned and accessible by vehicle. Carrington and Fremont Islands, although relatively large, are accessible only by boat and are privately owned. Gunnison and Hat Islands are protected as bird rookeries and have no public access. Stansbury Island is accessible by vehicle but is mostly privately owned.

Bird watching is seasonally popular at most of the wetlands along the east shore. There is no charge for access to State Waterfowl Management Areas. Duck and goose hunting is allowed (with purchased permits) in the fall at all of the State Waterfowl Management Areas.

Additional References

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Gwynn, J.W., ed., 1980, Great Salt Lake, A scientific, historical, and economic overview: Utah Geological and Mineral Survey Bulletin 116, 400 p.

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Stephens, D.W., 1998, Salinity-induced changes in the aquatic ecosystem of Great Salt Lake, Utah: 1–7, in J. Pitman and A. Carroll, eds., Modern and Ancient Lake Systems, Utah Geological Survey Guidebook 26.

— By Doyle W. Stephens and Joe Gardner

Contact Information:

Antelope Island State Park	801-721-9569
Entrance station	801-773-2941
Bear River Migratory Bird Refuge	435-723-5887
Friends of Great Salt Lake	801-583-5593
Website	www.fogsl.org
Great Salt Lake Marina, near Saltair	801-250-1898
Golden Spike National Historic Site	435-471-2209
Great Salt Lake Yacht Club	www.gslyc.org
Inland Sea Shorebird Reserve Website	www.kennecott.com/SD_env_wetlands.html
The Nature Conservancy of Utah	
Layton Wetlands Preserve	801-531-0999
Website	www.nature.org/utah/
Salt Island Adventures (boat cruises)	801-252-9336
Utah Division of Wildlife Resources	801-538-4700
Website	wildlife.utah.gov/index.php
Willard Bay State Park	435-734-9494

This information is provided by the U.S. Geological Survey, which has been researching Great Salt Lake since the G.C. Gilbert exploration of the 1870s. For additional information about Great Salt Lake see our web site at:

http://ut.water.usgs.gov/

Information on technical reports and hydrologic data of Great Salt Lake can be obtained from:

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