Resource Guide
for the Weber State University Botany Department field trip to Antelope Island State Park

Written by Drs. Eugene Bozniak, Stephen Clark, Dawn Gatherum, and Barbara Wachocki.

The Great Salt Lake

Facts: GSL is:

- The 33rd largest lake in the world*
- The 4th largest terminal lake (no outlet to the sea) in the world*
- The largest U.S. lake west of the Mississippi River
- A remnant of Lake Bonneville, a prehistoric freshwater lake that was 10 times larger than GSL.
- About 75 miles long and 28 miles wide and (on average) covers 1,700 square miles
- Has a maximum depth of about 35 feet
- Typically is 3 to 7 times saltier than the ocean
- One of the largest migratory bird magnets in Western North America

* The size of the lake varies because of the amount of inflow and the fact that it is so shallow. At the historic low elevation of 4,191.35 feet in 1963, the lake covered only 950 square miles. The drop of about 8.5 feet in elevation from its historic "average" (1847-2000) surface elevation of 4,200 feet, resulted in a loss of about 44 % in surface area. This would place the size of the lake somewhere about the 12th largest terminal lake in the world rather than 4th. During 1986 and again in 1987, the lake reached an elevation of 4,211.6 feet and had a surface area of around 3,300 square miles. The pumping that took place following the historic high levels reached in 1987 resulted in a large, shallow, saline lake in the west desert as an extension of the Great Salt Lake.

Economic Value of Minerals

The Great Salt Lake contains an estimated 5 billion tons of salt. Each year an additional 2.5 million tons washes in and accumulates due to evaporation. It is estimated that the total value of the salts in the lake reach nearly $90 billion. Yes, $\$90 \times 10^9$. Only in recent decades has this been appreciably touched and currently slightly more is extracted annually from the lake than is wash in. In the last few decades the development of various low-energy solar technologies have combined to make the lake an attractive source of the following: common salt, sodium chloride; potassium sulfate (fertilizer); sodium sulfate (chemicals and medicine); chorine gas (plastics); magnesium sulfate; magnesium metal; and lithium compounds. Industries extracting salt and other minerals from the Great Salt Lake include: Great Salt Lake Minerals and Chemicals, Morton International, Cargill, Akzo Nobel Salts, MagCorp, North American Salt Company, and Mineral Resources International.

Socio-Economic Value of the Biota

The socio-economic value of the marshes sustained by the lake is *incalculable*.

Value of the Wetlands:

The state of Utah is home to some of the most valuable wetlands in the United States. We are in the flyway for many of the migrating bird species and provide critical wetland ecosystems for many plants and animals. The value of wetlands as a national resource cannot be understated. Over ten years ago, President George Bush (Sr.) established a policy of "No net loss of wetlands." Federal Agencies now spend approximately $800 million a year on wetlands protection and development. Constructed wetlands are a demonstrated effective method to improve water quality. Yet in spite of this, the concept of wetlands is poorly understood by the public and is the subject of diverse opinions among wetland scientists. Furthermore, the majority of wetlands studies have focused on environmental and ecological issues. Less effort has been devoted to assessing, collecting and developing the best technical approaches to mitigate, preserve, enhance and create the value and function of wetlands.

Value of the Brine Shrimp:

The brine shrimp industry on Great Salt Lake began during the 1950's with harvesting of adult brine shrimp for fish food in the aquarium trade in the U.S. That expanded to many parts of the world and as the aquaculture industry developed large commercial operations, the need for more brine shrimp developed so in the 1970's the harvesting of cysts commenced. Since the production of brine shrimp cysts is dependent on salinity (if the salinity drops below 10% the cysts lose buoyancy, sink, and are more difficult to harvest) and salinities vary considerably, this industry is faced with many uncertainties. Nevertheless, up to 21 million pounds (gross weight) of cysts in the best years, like 1995-96, 1996-97, and again in 2001-02, are harvested. During other years with much less production much lower quantities are harvested over very few days or weeks.

Other economic value(s):

A very large emerging potential exists for the beta-carotene contained in *Dunaliella salina* during the summer months when large quantities of these cells accumulate in the very concentrated brines of the solar evaporation ponds of the various salt extraction industries located around or within the lake. Pilot-plant operations exploring the feasibility of such extraction has found that the economics is not favorable currently to develop fully, however, the potential is still there.

Physiography

The Central Wasatch Mountains lie directly astride the boundary between two major physiographic provinces: the Basin and Range, and the Middle Rocky Mountains. These provinces are further divided into five smaller physiographic units: (1) Great Salt Lake Valley, (2) Wasatch Mountains, (3) Back Valleys, (4) Eastern Highlands, and (5) Lake Islands. For political purposes the area is defined as Weber, Davis and Morgan Counties, Utah.

Great Salt Lake Valley

The Great Salt Lake Valley extends westward from the base of the Wasatch Mountains. Its western portion is a broad, almost flat plain composed largely of lake bottom deposits from ancient Lake Bonneville, partly modified by young erosion and deposition principally by streams. The eastern portion, that part lying adjacent to the Wasatch Mountains, is steeper and characterized by local faulting, Bonneville-aged beaches, deltas, alluvial fans, and recent cutting by streams.

This plain is bordered by the north-south trending Wasatch Mountains. The valley represents a large down dropped graben, or a tilted half graben, and sediments up to 6000-8000 feet thick are present.

Wasatch Mountains

The Wasatch Mountains are the most conspicuous physiographic feature of north-central Utah. The main ridge of the range lies along a north-south axis through the center of the study area. It contains peaks that rise 5000 feet above the valley floor. The highest peak is Ben Lomond Peak, elevation 9712 feet.

Generally the western side of the range is steeper than the eastern side. However, both sides exhibit areas of gentle slopes and steep inclines, the latter partly due to the presence of faults along which the mountain block were uplifted. This uplift is evidenced on western slopes by numerous triangular facets and fault scarps. Two large east-west canyons, Weber Canyon occupied by the Weber River, and Ogden Canyon, occupied by the Ogden River, are found within the study area. In addition, numerous small canyons have been cut into the slopes on both sides of the range. Some of these contain perennial streams, but most are ephemeral.

The Wasatch Mountains were formed by two separate events with combinations of thrust and normal faults. During the late Mesozoic, compression forces began to build the ancestral Wasatch Mountains by thrust faulting. These compression forces caused mountains to form that contained older Pre-Cambrian metamorphic rocks and Paleozoic sedimentary rocks. These rocks were completely folded and faulted to the degree that old layers are often found on top of much younger ones, as can be readily seen on the sides of Ogden Canyon. These early mountains probably largely eroded. Regional normal faulting then occurred during Tertiary to recent times, lifting the Wasatch Mountains and the Bear River Range to their present positions and down dropping the Great Salt Lake and back valleys. Water and glacial action then shaped the mountains into their present physiography.

Back Valleys

A long northwest-trending depression lies within the Wasatch Range. It is divided into two valleys each with its own drainage system. Ogden Valley, the northernmost of the two, is about 12 miles long and three miles wide. Three perennial streams enter the valley from the north and east. The North Fork of the Ogden River drains the mountains at the northern end of the valley, and is the longest stream within the valley. The Middle Fork of the Ogden River drains the western portion of the Bear River Range. The South Fork of the Ogden River drains the southern part of the same range. Three small, ephemeral streams also enter the valley. These are: Wolf Creek, Bennett Creek, and Hawkins Creek. The valley also contains several small springs. The surface water and much of the ground water that is present in Ogden Valley eventually flows into Pineview Reservoir. Water from Pineview Reservoir flows westward down Ogden River and into the Great Salt Lake Valley, joins the Weber River and flows into the Great Salt Lake.

On the edges of both valleys the terrain begins to steepen. Elevations rise gently along old weakly developed Lake Bonneville terraces and post- Bonneville fans.

Morgan Valley is 15 miles long and three miles wide. The greatest part of this valley is the flood plain of the Weber River. Two major perennial, graded streams enter into this valley. They are Lost Creek and East Canyon Creek. Each of these contain a large reservoir near their upper end. Numerous smaller streams also enter the valley from the west draining the eastern slopes of the Wasatch Mountains, while other streams enter from the east, thus draining a southern portion of the eastern highlands. Both valleys represent down dropped grabens or tilted half grabens that formed during Tertiary to recent extension, both valleys are bordered by normal faults on their east sides, and both valleys are filled with thick deposits of Tertiary to recent sediments and volcanics.

Eastern Highlands

Eastward from the back valleys, foothills rise gently to form rolling, flat-topped mountains of about 8000-feet elevation known as the Eastern Highlands. They are the southern extension of the Bear River Range. The highlands consist of late Precambrian to Tertiary sedimentary rocks and Quaternary colluvium and alluvium.

Lake Islands

Two islands of the Great Salt Lake are located within the three counties. Antelope Island, the largest of the two, is located in Davis County. It is a north-south trending island 15 miles long, and three to four-miles wide. Its maximum elevation is 6400 feet rising some 2200 feet above the surface of the lake. Several small, ephemeral streams and some small springs are located in the bottoms of its shallow canyons.

Fremont Island, named in honor of Captain John C. Fremont, is located in Weber County. It trends northwest-southeast and is three-fourths-mile long and one-fourth-mile wide. Its maximum elevation is 4995 feet. The island has no streams and only one small spring.

Both islands probably originated as uplifted blacks (horsts) during the same time as the present Wasatch Range and the Eastern Highlands were formed.

Antelope Island consists of older Precambrian metamorphic and igneous rocks and late Precambrian to Paleozoic sedimentary rocks mantled locally by a thin layer of Quarternary lake deposits, colluvium and alluvium. Fremont Island consists only of late Precambrian sedimentary rocks with a thin cover of Quaternary lake deposits.

Climate

The area is broadly defined as semi-arid. However, due to great differences in elevation and exposure, considerable variation in mean annual precipitation is found ranging from a semi-arid condition of six inches or less on the islands of the Great Salt Lake to a sub-humid climate of 45 inches along the tops of the Wasatch Mountains.

In general, seasons are characterized by a wet spring (March to May), warm-to-hot, dry summer (June to August), cool, dry autumn (September to November), and cold, snowy winter (December to February).

Summer storms in the low valleys are infrequent while storms of short duration and high intensity are common in the mountains. The greatest recorded storm intensity in Farmington Canyon was 2.04 inches per hour. These summer storms are usually a product of convective thunderstorms although some originate when weak cold fronts moving eastward from the Pacific lift the warm, moist air that has come into our area from the Gulf of Mexico. Prevailing winds are from the south and southwest.

Winter storms generally originate with strong frontal systems moving in from the Pacific Northwest and account for 80 percent of the precipitation with most of this falling as snow at elevations above 7000 feet. Snow records from Farmington Canyon show an average depth of snow pack at 7600 feet elevation of 53.3 inches with a water content of 18.6 inches. Snow depths of 18 feet or more in drifts along the mountain tops are common.

Smaller climatic differences such as those found on north-or south-facing slopes of ridges or canyons, particularly if they are steep, are also important. South-facing slopes have greater insulation, higher ground temperature and drier soils. Air temperatures are generally cooler in the canyon bottoms and on the north-facing slopes, while relative humidity is quite variable.

Moisture content of the snow pack is also quite variable. In general south-facing slopes and areas covered by heavy stands of conifers have a greater percentage of moisture per unit of snow depth than those open areas on north-facing slopes. These small, local climatic differences greatly influence the distribution of plants and communities within the study area.

Plant Communities

Twelve plant communities are defined. Three are limited to the Bonneville Basin. The others are found along the Wasatch Range, the Back Valleys, and Eastern Highlands with some types being present on Antelope Island. Seven hundred and ninety-eight species and/or subspecific taxa are delineated.

Saline Marsh

Immediately adjacent to and/or part of the eastern edge of the Great Salt Lake lies a saline marsh community. Elevations range from 4200 to 4300 feet. The ground is essentially flat and covered throughout much of the year with shallow, brackish water.

Cattails and tules are the dominant emergent vegetation, while pond weeds and smart weeds are to be found floating in most areas of standing, open water. Open flat lands are often covered with goosefoot.

Important plants are: *Scirpus acutus, Scirpus maritimus, Typha domingensis, Typha latifolia, Salicornia rubra, Eleocharis palustris, Carex nebraskensis, Carex aquatilis, Polygonum amphibium, Polygonum convolvulus, Polygonum persicaria, Polygonum punctatum, Potamogeton pectinatus, Conium maculatum, Distichlis spicata, Solanum dulcamara, Polypogon monspielensis.*

Salt Desert Shrub

Upland from and often adjacent to the saline marsh area is a region with a drier, clay, alkaline soil. Elevations range from 4300 to 4400 feet. Greasewood-dominated flats and saltgrass meadows are characteristic of the moist lowland portions of this habitat. Slightly higher and drier sites support a mixture of saltgrass and woody chenopods.

Important plants are: *Sarcobatus vermiculatus, Allenrolfea occidentalis, Atriplex confertifolia, Atriplex patula, Chenopodium album, Kochia scoparia, Distichlis spicata, Bromus tectorum, Cleome serrulata.*

Fire Modified Mixed Grass

Only the foothill areas of Antelope Island and Fremont Island are defined as mixed grass. This community lies between 4200 feet and 4800 feet, and is characterized by dry sandy-rocky soil covered with mostly annual grasses, these probably being perpetuated by recurrent fire.

Important plants are: *Bromus tectorum, Bromus diandrus, Oryzopsis hymenoides, Atriplex confertifolia, Grayia spinosa, Abronia fragrans, Sphaeralcea coccinea, Chrysothamnus nauseosus.*

Big Sagebrush

Sagebrush-dominated plant communities are widespread over much of the area on well-drained, sandy soils from the foothills of the Wasatch Mountains to the high ridges of the Wasatch front range. Big sagebrush, big rabbitbrush, and snakeweed dominate the lower elevations, while black sagebrush and yellow rabbitbrush are found mostly at higher sites.

Important plants are: *Artemisia tridentata, Artemisia arbuscula, Artemisia ludoviciana, Gutierrezia sarothrae, Elymus trachycaulus, Elymus triticoides, Chrysothamnus nauseosus, Chrysothamnus viscidiflorus, Bromus japonicus, Bromus tectorum.*

Juniper

Stands of juniper are infrequent, small in size, and most often found on moderate-to-steep south- or west-facing slopes between 5500 and 6500 feet. Soils in this type are shallow, sandy to rocky, dry, and well drained. Utah juniper and western red cedar are the dominant plants with curl leaf mountain mahogany and gambel oak also frequently found.

Important plants: *Juniperus osteosperma, Juniperus scopulorum, Artemisia tridentata, Quercus gambelii, Sporobolus airoides, Oryzopsis hymenoides, Oenothera pallida.*

Mixed Mountain Brush

This is the largest plant community. It is found on almost all east-, west-, and south-facing exposures at elevations of 4600 to 7500 feet, and on north-facing exposures at lower elevations. Oak, maple, and mahogany are the dominant plants. Soils are generally dry, shallow on the rocky slopes or deep on flat area and in basin. Slopes are moderate to steep.

Important plants are: *Quercus gambelii, Acer grandidentatum, Cercocarpus ledifolius, Acer glabrum, Prunus virginiana, Physocarpus malvaceus, Purshia tridentata, Amelanchier utahensis, Berberis repens, Holodiscus dumosus, Hydrophyllum capitatum, Allium acuminatum.*

Aspen

Aspen communities are usually found in pockets on north-or east-facing slopes at elevations between 6800 and 8000 feet, and in dense stands on flat areas or hillsides at higher elevations. The soils are deep, dark, and rich in organic matter. Quaking aspen is the dominant plant, but a dense understory of snowberry, chokecherry and mixed forbs is often also present.

Important plants are: *Populus tremuloides, Symphoricarpos oreophyllus, Prunus virginiana, Thalictrum fendleri, Geranium fremontii, Geranium richardsonii, Rudbeckia occidentalis, Valeriana occidentalis, Heracleum lanatum, Mertensia ciliata, Aster engelmannii, Delphinium occidentale, Castilleja applegatei, Bromus ciliatus.*

Mixed Conifer

Dense stands of conifers are found on most north-facing slopes in the canyons at elevations of 6000-8500 feet, and on the eastern side of the mountains at higher elevations. Slopes are often steep at the lower elevations and more gentle at higher elevations. Soils are usually shallow, and with a deep layer of litter.

White fir and Douglas fir dominate the lower elevations while alpine fir, Englemann spruce and limber pine are found in higher sites. In general the conifer stands are dense enough to prohibit any substantial development of understory vegetation.

Important plants are: *Abies concolor, Pseudotsuga menziesii, Picea engelmannii, Pinus flexilis, Ribes montiginum, Sambucus caerulea, Heuchera rubescens, Heuchera parviflora, Carex microptera.*

Mountain Meadow

This community is often found in or around shallow basins, broad canyon bottoms, and damp to wet flatlands at elevations of 7000-9000 feet. Soils are usually dark, deep, and damp to wet. Perennial grasses, forbs, and sedges dominate these sites.

Important plants are: *Poa pratensis, Arrenatherum elatius, Elymus trachycaulus, Phleum pratense, Melica bulbosa, Mertensia ciliata, Camassia quamash, Veratrum californicum, Scirpus microcarpus, Zigadenus elegans, Wyethia amplexicaulis, Orthocarpus luteus, Orthocarpus purpureo-albus, Potentilla fruticosa, Lonicera involucrata.*

Subalpine

Subalpine communities are found only along the ridges of the Wasatch Mountains and mountain tops of the eastern highlands at elevations near 9000 feet. Soils are shallow, extremely rocky and normally dry. The vegetation consists mostly of low woody plants, and low perennial forbs and grasses. Trees when present are usually distorted by strong winds.

Important plants are: *Artemisia tridentata, Koeleria macrantha, Elymus spicatus, Oxyria digyna, Saxifraga arguta, Ivesia gordonii, Swertia radiata, Viguira multiflora, Antennaria parvifolia, Sedum debile.*

Alpine

An alpine flora is found only on the tops of the highest mountains at elevations of 9400-9700 feet. These sites are extremely rocky and without well-defined soil. Trees and tall plants are noticeably absent. Dominant plants include sagebrush, small perennial forbs, and some low grasses.

Important plants are: *Artemisia tridentata, Synthris pinnatifida, Draba burkei, Penstemon brevifolius, Lesquerella multiceps, Elymus spicatus, Festuca pratensis, Carex phaeocephala.*

Riparian

A diverse riparian habitat is found throughout the area in all canyons that contain perennial streams at elevations from 4200 to 9000 feet. The diversity of this habitat is in part a function of elevation, hence this type is subdivided into three often overlapping areas: (1) high elevations above 8000 feet, (2) middle elevations between 6000 and 8000 feet, and (3) low elevations below 6000 feet.

<u>High elevation riparian</u>. This community generally originates in a basin or meadow area. It is typified by dense stands of perennial forbs, sedges, perennial grasses, and willows. Soils are wet to damp, deep and dark. Streams are usually small, slow moving and contain silty bottoms.

Important plants are: *Salix bebbiana, Salix geyeriana, Salix scouleriana, Rhamnus alnifolia, Habenaria dilatata, Scirpus microcarpus, Catabrosa aquatica, Mimulus lewisii, Juncus longistylus, Juncus ensifolius, Carex praegracilis, Alopecurus aequatis, Glyceria grandis.*

<u>Middle elevation riparian</u>. At lower elevations the canyons steepen and the volume and velocity of the streams increase. Canyons are often deep and V-shaped. STRAMSIDES and bottoms are often rocky with little soil depth. Streams are usually bordered by tall shrubs such as dogwood. Habitat for grasses, forbs, and sedges is generally reduced.

Important plants are: *Cornus stolonifera, Salix rigida, Acer grandidentatum, Amelanchier alnifolia, Rubus parviflorus, Clematis columbiana, Ranunculus sceleratus, Senecio serra, Cardamine cordifolia, Carex rostrata.*

<u>Low elevation riparian</u>. At lower elevations the streams are generally slower, wider, and often with large flood plains. Here the soils are usually deeper and more productive. Such sites are dominated by cottonwood, birch, and willow, with a mixture of forbs and grasses.

Important plants are: *Populus angustifolia, Betula occidentalis, Salix exigua, Acer negundo, Crataegus douglasii, Alnus tenuifolia, Smilacina stellata, Smilacina racemosa, Steironema ciliatum, Carex lanuginosa, Juncus bufonius.*

History of Botanical Exploration

On September 6, 1843, Captain John C. Fremont on an assignment to connect the interior land surveys made by the Wilkes expedition in 1841 camped on the Weber River Delta in present Weber County. The next morning he set out for an island in the Great Salt Lake, later to be called Fremont Island, but which he referred to as "Disappointment Island." He collected plants there for two days then returned to the Weber River Delta where on September 9, additional plants were collected. These collections were the first to be made the purpose of scientific inquiry from this area. Included were *Atriplex canescens, Atriplex confertifolia,* and *Chrysothamnus nauseosus.* They were later sent to John Torrey of Columbia University.

In 1857 Jane Carrington made a collection of plants from the "Salt Lake Area." These were later given to Elias Durand at the Academy of Natural Sciences in Philadelphia. Using this collection, and those of Fremont and Stansbury, Durand wrote the first local flora for Utah entitled, "A sketch of the botany of the basin of the Great Salt Lake of Utah."

In 1860 Sereno Watson traveling with the King exploration of the fortieth parallel explored the mountains of the study area and the islands of the Great Salt Lake. The results of this effort were published by Watson in 1871 as Part Five of the "Report of the geological exploration of the fortieth parallel." Watson's contribution was of great value and consequence. The number of new species he discovered is staggering.

During this period 1843-1869 other botanists were also in the area. In 1845 Joseph Burke, a collector from England traveled through the area. In 1854, Lieutenant Edwin O. Beckwith while re-surveying Stansbury's old route passed through the area. And, in 1871 John C. Coulter was in Northern Utah. Little is known of their collections (if any) from this area.

The only other botanists who have contributed to an understanding of this flora are Francis W. Pennell, and A. O. Garrett. Francis W. Pennell of the New York Botanical Garden collected several species from this area as recorded in his publication on the "Scrophulariaceae of the Rocky Mountain States." A. O. Garrett, while head of the Biology Department at East High School collected many plants from the southern Wasatch Mountains.

The most recent collections have been made by Dr. Stephen L. Clark, who from 1965 to the present has collected extensively in the area.

Life in the Great Salt Lake

Introduction:

How often have you heard people say........ *"There is no life in the Great Salt Lake!"*? This is even said by people who KNOW about the harvesting of the brine shrimp from the lake itself! It is always a mystery how animals are supposed to survive without a primary producer to provide them with food and oxygen. Well, it is now safe to say that wherever there is natural water, no matter the quality, there will be life in it. In recent years we have discovered life in places we assumed it was impossible. When we did discover life in extreme environments we still resisted the fact that they were *active* and not *passive* (i.e. simply washed into)in such settings. Now we have evidence that living organisms can not only tolerate but prefer extreme environments. Bacteria, and sometimes algae, have been found in extremely: cold water (*psychrophiles*), hot water (*thermophiles*), high acid environments (*acidophiles*), high hydrostatic pressures such as on the ocean floor (*barophiles*), and in high salt concentrations like the Great Salt Lake (***halophiles***). Actually, the salt concentration of the Great Salt Lake is too low to support high populations of certain algae as we shall see later.

Lakes such as the Great Salt Lake that are *hypersaline* are considered to be rather simple ecosystems with a simple *food web* because they contain fewer species than freshwater lakes. There is a very efficient system of energy exchange between the few levels of life in this environment, however.

Primary Producers (Algae and Photosynthetic Bacteria):

The primary producers in the lake are found in one of two habitats: ***planktonic*** (water column) or the ***benthic*** (bottom). The planktonic primary producers are referred to as phytoplankton and dominated by algae and a few bacterial species. Over the years of studies on the lake, roughly a dozen species of algae and a similar number of bacteria have been recorded. The lists compiled by some investigators is longer than that of others, however, few efforts have been carried out to culture the algae to determine if they are truly active or are simply tolerating the brine for a while after having been washed into the lake.

The planktonic algae are dominated by a variety of pennate diatoms in early spring and late autumn when they are apt to reach bloom proportions in numbers. In summer and occasionally in winter two species of *Dunaliella* (green algae) dominate. In the less saline south arm of the lake, *Dunaliella viridis* dominates, imparting a green cast to the water, whereas in the more saline north arm of the lake, *Dunaliella salina* dominates and this species produces beta-carotene in such large quantity that the water becomes quite red in color. However, even the north arm is not saline enough for this species to reach maximum populations. This they do in the solar evaporation ponds of various companies that extract salts from the lake by concentrating brines. You may have noticed the brilliant red color of the solar evaporation ponds of GSL-Minerals & Chemicals as you fly over the lake in summer. Even the entire north arm develops a reddish color in summer due to this alga. Contributing somewhat to the red color of the north arm is the presence of *Halobacterium*, a bacterial species that accumulates a rhodopsin-type of pigment.

Two genera of blue-green algae or cyanobacteria are commonly found in the plankton. These are *Aphanothece* and *Coccochloris*. These two genera along with the *Dunaliella* spp. along with the dozen or so bacterial species found in the south arm, provide the food for the grazing brine shrimp (*Artemia franciscana*). Diatoms, though valuable, are tougher for the brine shrimp to digest because of their thick silica cell walls.

Some of the bacteria found in the south arm belong to the following genera: *Micrococcus, Bacillus, Achromobacter, Flavobacterium, Bacterioides, Serratia* and *Cellulomus.*

The benthic habitat is dominated by blue-green algae (cyanobacteria) and some diatoms with the occasional green alga. These collectively cause the precipitation of calcium-carbonate (limestone) which accumulates as reefs on the bottom of the lake. These primary producers are especially active when the phytoplankton and brine shrimp numbers above decline and the resulting clear water allows light to penetrate to the bottom. The algal mats that develop are important as the food for two species of brine fly (genus *Ephydra*). These small insects spend their larval developmental stage grazing on this benthic community, later form pupae and emerge as adults in early summer. They form dense clouds that hover over the beaches and everything on the beach, including people. Many people are annoyed by the brine fly but they do not bite and are unique to brine environments. You may have noticed large wind-rows of pupae cases from these brine flies on the shore of the lake.

Consumers:

a) Brine Shrimp

In the late 19th century, various investigators identified the brine shrimp as *Artemia salina* or *Artemia gracilis*, however, more recently they have been named *Artemia franciscana* (the same as the one in San Francisco Bay). Brine shrimp (also called *"Sea Monkeys"* by aquarium enthusiasts and aquaculturists) are Crustaceans that have about 15 larval molting stages (their larvae are called *nauplii*) before they become full adults of about 10 mm. The eggs are very thick-walled, can survive for very long periods of time if kept dry, and are called *cysts*. While some species of *Artemia* can produce live young parthenogenically, *Artemia franciscana* has both male and females present. Large numbers of these small cysts are produced which float on the brine and provide the basis of a multi-million dollar industry where these cysts are harvested for use in the aquaculture industry and by aquarium enthusiasts. Adult shrimp feed on the phytoplankton suspended in the water but can also "graze" on the benthic algae (both blue-greens and diatoms) that grow on the limestone reefs. During times of plentiful algal biomass, even fecal pellets contain enough undigested food to make ingestion profitable from an energy budget standpoint. These fecal pellets also provide the nuclei for the precipitation of calcium carbonate that grows into *"oolites"* which forms the majority of the sand grains on the shore of the lake.

b) Brine Flies

Due to our terrestrial nature we notice the huge, coal black clouds of flies on the lake shore. We are often annoyed by their presence and fail to realize just how important they are to the aquatic ecosystem of the Great Salt Lake. These flies and their larvae & pupae support an enormous number of shorebirds. As mentioned above, there are two species of brine flies present. *Ephydra cinerea* and a larger species, *Ephydra hians.* The former is more abundant in the south arm outnumbering its larger counterpart by 100:1.

The adult flies have an average life span of 3-5 days. Eggs are laid continuously through the summer at the surface of the water. The eggs hatch quickly into larvae which graze on the algal and bacterial community on the bottom, on rocks, or on logs. The larvae receive all their oxygen from algal photosynthesis. When the larvae develop into pupae the adult features develop rapidly and the pupae trap air bubbles which cause them to float and be transported to the shore by the wind, hence the enormous windrows of pupae on shore.

c) Corixids

Corixids are predatory aquatic insects referred to as *"water boatmen"* that are common in freshwater. It was first believed that the corixids found in the Great Salt Lake were simply transported to the lake from nearby freshwater marshes but the consensus now seems to be that they are indeed true inhabitants of the lake. The one identified in the lake is *Tricorixia verticalis*. This corixid preys on the brine shrimp as well as the larvae of the two species of brine flies. The ecological impact of this predation is currently being investigated by the Utah Division of Wildlife Resources.

d) Birds

The Great Salt Lake supports between 2 and 5 million shorebirds, mostly migratory. The lake and its associated marshes provide a resting and staging area for the birds, as well as an abundance of food in the form of brine shrimp and brine flies. The importance of the lake ecosystem to migratory birds has been recognized in the last decade and the lake was designated as part of the Western Hemisphere Shorebird Reserve Network in 1992. As an example of the value of the lake to birds the lake serves as: the largest staging concentration of the Wilson's Phalarope (500,000); largest number of American Avocets and Black-Necked Stilts in the Pacific Flyway; and the world's largest assemblage of Snowy Plovers, representing 55% of the entire breeding population west of the Rocky Mts.

Wetlands

Definition:

Wetlands, as the term might suggest, are areas where water covers the soil, or is present either at or near the surface all year or at least for substantial parts of the year, especially during the growing season. Some of our most valuable and productive wetlands are only seasonally wet. Wetlands are an important link between the land and water and are as productive as are rain forests and coral reef ecosystems. Water saturation (hydrology) largely determines how the soil develops and the types of plant and animal communities living in and on the soil. Wetlands may support both aquatic and terrestrial species. Generally, the prolonged presence of water creates conditions favoring specially adapted plants (hydrophytes). Wetlands vary widely because of regional and local difference in soils, topography, climate, hydrology, water chemistry, existing vegetation, and other factors, especially human disturbance.

Wetland Classes:

In general we talk of two broad categories of wetlands: (a) *Coastal Wetlands* and (b) *Inland Wetlands.*

Coastal Wetlands are found along the oceans and closely linked to estuaries where seawater and freshwater mix. Grasses, sedges, and rushes that are salt tolerant take advantage of nutrients flowing into their environment once or twice daily (*tides*) resulting in *tidal salt marshes* that are exceptionally high in total production of organic matter.

Inland Wetlands are found on floodplains along rivers & streams (riparian wetlands), in depressions surrounded by dry land, for example potholes, basins, and playas, along margins of lakes and ponds, and any other low-lying area where groundwater intercepts the soil surface. Inland wetlands include marshes and wet meadows dominated by herbaceous plants and swamps dominated by shrubs and trees. Near the Great Salt Lake we find inland saline and alkaline marshes.

Utah's Wetlands:

It is estimated that Utah has lost approximately 30% of its original wetlands. Less than 1% of Utah's total land area meets the criteria set for wetlands. Of all of Utah's wetlands, seventy-five percent (about 400,000 acres) are part of the "Greater Salt Lake Ecosystem". This ecosystem includes the Great Salt Lake itself, the wetlands that lie adjacent to the lake, and the three rivers that drain into the lake....the Bear, Weber, and Jordan Rivers, their associated tributaries and the wetlands contained in their floodplains.

Immediately adjacent to and/or part of the eastern edge of the Great Salt Lake lies a saline marsh community. Elevations range from 4200 to 4300 feet. The ground is essentially flat and covered throughout much of the year with shallow, brackish water. Cattails and tules are the dominant emergent vegetation, while pond weeds and smart weeds are to be found floating in most areas of standing, open water. Open flat lands are often covered with goosefoot. Important plants are: *Scirpus acutus, Scirpus maritimus, Typha domingensis, Typha latifolia, Salicornia rubra, Eleocharis palustris, Carex nebraskensis, Carex aquatilis, Polygonum amphibium, Polygonum convolvulus, Polygonum persicaria, Polygonum punctatum, Potamogeton pectinatus, Conium maculatum, Distichlis spicata, Solanum dulcamara, Polypogon monspielensis.*

For more details on GSL vegetation, including the Riparian communities near the GSL, consult the vegetation portion of the field trip guide.

Value of Wetlands:

Considerable attention has recently been paid to wetlands values both in this country and elsewhere. Once regarded as useless, disease-ridden environments, wetlands in fact provide values that no other ecosystem can provide, including: natural and waste-water quality improvement, flood protection, shoreline erosion control, opportunities for recreation and aesthetic appreciation, and natural products for our use at little or no cost. Wetlands provide one or more of these values and are worth protecting, even at considerable economic cost.

Water Quality, Hydrology, and Flood Control:

As *surface runoff* water passes through a healthy natural wetland, the wetland plants and animals act as a filter retaining excess nutrients and breaking down some pollutants before this surface flow reaches open water, thereby maintaining high surface water quality. Sediments are also trapped which protects fish and amphibian egg development in lakes and streams. In performing this natural filtration function, wetlands save us a great deal of money.

Artificially *constructed wetlands* are also currently being employed to treat waste-water so that high open water quality is maintained. Constructed wetlands have become routine in waste-water engineering schemes bringing the disciplines of engineering and biology closer together.

In addition to improving water quality through filtration, most wetlands act as a sponge and absorb water when it is available in excess and release it into the groundwater supply slowly. This **positive impact on the hydrology** ensures that we have adequate stream-flow throughout the year. Permanent streams become temporary or seasonal if wetland integrity is not maintained. In riparian systems, this sponge action of wetland plants **prevents floods**. Preserving and restoring damaged wetlands can lead to flood control which otherwise would require very expensive dredging operations and levee construction.

Wetlands at the margins of lakes, rivers, bays and the ocean protect shorelines and stream banks against erosion. **Erosion control** is so important today that many states spend considerable resources to protect sensitive areas along rivers and coasts.

Shoreline Erosion:

Coastal areas are subjected to tremendous erosion when exposed to storm surges. The greater the wetlands are negatively impacted by "development" the greater is the erosion. Wetlands hold soil in place with their roots, absorb the energy of waves, and break up the flow of stream or river currents.

Fish and Wildlife Habitat:

More than one-third of the United States' threatened and endangered species live ONLY in wetlands and nearly half use wetlands at some point in their lives. Estuarine and marine fish and shellfish, various coastal birds, and certain mammals must have coastal wetlands to survive. Most commercial and game fish use coastal wetlands as nurseries for food, shelter, and protection of their young.

Our wetlands are vital to breeding and migratory bird populations as has been discussed in the previous section on *"Life in the Great Salt Lake"*. International agreements to protect wetlands of international importance have been entered into because some species of migratory birds are completely dependent on certain wetlands and would become extinct if those wetlands were destroyed.

Recreation and Aesthetics:

Wetlands have recreational, historical, scientific, and cultural values. More than half of the U.S. Adult population (99 million) hunt, fish, birdwatch, or photograph wildlife in wetlands. School field trips often involve the study of wetlands. Painters and writers often find inspiration to create their art in wetlands. A total of nearly $60 billion is spent annually on the above activities.

Natural Products for Our Economy:

Many of our nation's fishing and shellfishing industries harvest wetland-dependent species; the catch is valued at $15 billion a year. In the Southeast, for example, nearly all the commercial harvest are fish and shellfish that depend on the estuary-coastal wetland system.
Several plants are very valuable from our wetlands. Think of the value of blueberries, cranberries, timber and wild rice to our economy. Many wetland plants and soils provide medicines today and promise to do so in the future.

Protection:

Despite all the above benefits provided by wetlands, the U.S. loses about 60,000 acres of wetlands per year. Additionally, non-native (*alien*) species of plants and animals as well as global warming & climate change contribute to wetlands loss and degradation. What is being done to protect these valuable ecosystems? Several federal and state agencies devote considerable resources to wetlands protection. The EPA has principal responsibility here. They have a number of programs for wetland conservation, restoration, and monitoring. EPA, along with the U.S. Army Corps of Engineers (Corps) establishes environmental standards for reviewing permits for discharges that affect wetlands, such as residential development, roads (e.g. Legacy Highway), and levees. Under Section 404 of the Clean Water Act, the Corps issues permits that meet environmental standards, after allowing the public to comment. The federal government as well as the states, tribes, local governments, and private organizations work together to solve complex environmental problems involving wetlands protection. What are you prepared to do? There are a number of things you can do to help. Consult the internet and your instructor for help.

Fire Ecology

Fire Ecology is the study of how fire affects ecosystems. Impacts of fire differ depending on the type of ecosystem, the intensity of the fire and the time from the last fire. Some ecosystems, such as grasslands and chaparrals (mixture of grasses and shrubs) are prone to frequent fires. Fire also plays a role in other ecosystems, such as coniferous forests and aspen forests, although these are usually less frequent than in grasslands. Native plants growing in areas where natural fires occur have adapted and indeed depend upon fire for survival.

In order for a fire to occur, an ignition source and fuel are required. Naturally occurring fires are started by lightening strikes. Human sources include discarded cigarettes, unattended campfires and deliberately set, controlled burns. If there is a great deal of fuel present (wood and litter), fires tend to burn more intensely and for prolonged periods of time in a given spot. Factors such as fuel moisture, wind, and humidity all play a role in determining if a fire will spread, how quickly, and in which direction.

There are three major types of fires; surface, canopy and ground fires. Surface fires are common in grasslands, where there are no trees and the litter and vegetation is spread fairly evenly over the surface. Grasses provide little fuel and hence, fires move quickly over the surface of the ground. Surface fire are the least intense of the three types, so underground structures (roots, bulbs, etc.) are not affected. The soil surface may become quite hot, but nutrients and microorganisms below the surface are left intact. Canopy fires are more intense and spread through the canopies of adjacent trees. These typically occur in coniferous forests. Due to the fact that there is more fuel involved, the heat generated is greater than that found in surface fires. In the event that there is a great deal of dead wood on the forest floor and the vegetation is very dry, a ground fire can occur. These are the most intense fires, fueled by a great deal of wood. These also occur in coniferous forests. In ground fires, the heat is so intense that underground structures are lost, many soil microorganisms die, and organic matter and soil nutrients such as nitrogen can actually become volatilized and lost to the air. Intense fires alter the soil structure, pH, wettability, chemical composition, and soil microflora. It is not surprising, therefore, that legumes and nitrogen-fixing soil microorganisms are among the first types of organisms to re-colonize a severely burned area. Less intense fires have the advantage of breaking standing litter into smaller pieces, thereby making it more available for decomposition. Pathogenic fungi may also be killed, allowing more seedlings to emerge.

Many plant species native to areas that naturally burn at regular intervals have specialized seeds or seed structures (e.g. many cones) that will not open until there is a fire of appropriate intensity. In this manner, survival of the species can be better assured. Some plants, such as aspen trees, depend on frequent fires to prevent the establishment of competitors. Aspen forests are found adjacent to coniferous forests. Aspens are clonal, sending up new shoots from the roots. Entire aspen groves are usually made up of clones from one individual. Under normal conditions, young conifer seedlings will be killed in frequent fires. The aspens recolonize the area with offshoots from protected underground roots. Throughout the western United States, aspen forests are being lost to the encroachment of coniferous forests. This is a direct result of the long-held practice of fire suppression on public lands. When fires that would normally maintain aspen forests are put out, adult coniferous trees become established, thereby crowding out the aspens.

Fire suppression is used differently by land managers than it was prior to the huge fire in Yellowstone National Park in 1988. Before that time, forest fires were put out as soon as possible to preserve trees, habitat and ultimately, tourism. However, when the forests of Yellowstone caught fire, it became impossible to control. The forest had been allowed to grow so dense with mature trees, with so much litter, that the fires spread quickly, uncontrollably, and burned with incredible intensity. As a result, a great expanse of forest was lost. However, the area also grew back much more quickly and diversely than previously expected. The need for fire in terms of decreasing fuel for future fires, creating an age stratification among trees and allowing new seedlings to emerge and grow in clearings is vital in maintaining a healthy forest. This provides natural breaks for future fires due to the low fuel content of immature trees, adds to the diversity of habitats and therefore, increases the overall biodiversity within a forest. Hence, fire managers often now rely more on fire suppression plans focused on fire containment, rather than fire exclusion.

In many areas where fires would have naturally occurred if not for human intervention, land managers often deliberately set fires (prescribed burns) to mimic what should have occurred under normal circumstances. Prescribed burns are well planned and undertaken so as to allow the plants to go through their natural cycle while controlling the spread and scope of the fire. Unfortunately, these too can get out of control, although rarely, as evidenced in Los Alamos, New Mexico in May, 2000. There, a prescribed burn got out of control, burning 80 square miles including part of the Santa Fe National Forest, private ranch land, 405 housing units and causing $300 million worth of damage to the Los Alamos Nuclear Weapons Laboratory.

While a century of fire exclusion is likely to blame for the increased potential for large-scale, catastrophic fires in the western coniferous forests of the United States, this is probably not the case in the California chaparral regions. A USGS study in southern California found that even when prescribed burns are conducted to remove old stands of shrubs, the succeeding young shrubs fail to act as breaks against fires driven by the intense Santa Ana winds. Unfortunately, in California, human activities have dramatically increased the frequency of fires beyond the point where native shrubs can rebound. As a result, invasive species are taking over, changing native shrublands into nonnative grasslands. To make matters worse, these chaparral regions are home to many rare and endangered plants.

Antelope Island is prone to frequent fires, often started by lightning strikes. Land managers so far have mapped the major burns that have occurred there since 1994. Two of the last nine years have seen very large fires which burned between about 15 -20 % of the island each time. The key elements of the island's fire suppression/control plan include development and implementation of a prescribed burning plan, green-stripping in appropriate areas to create a vegetation buffer zone, addressing fire equipment/training needs, reviewing and addressing the effectiveness of current lightning rod structures, and identifying and prioritizing critical areas to be protected.

Antelope Island used to be much more of a shrub community than it appears today. When people settled on the island, it was used to graze domestic livestock. This lead to overgrazing, decreasing the reproductive output of the native plants. Invasive, non-native plants, such as cheatgrass (*Bromus tectorum*) were allowed to become established. Cheatgrass is now a common problem in much of the Great Basin region. This grass produces seeds and dries out fairly early in the season, therefore providing fuel for fires. Shrubs that were once separated by bare ground are now connected by continuous cover of dry cheatgrass. When fire starts, it quickly spreads from shrub to shrub, burning far greater areas than would have occurred before. Cheatgrass and other invasive species can quickly take over a burned site. Overgrazing, coupled with more frequent fires have caused the shrubland to be converted primarily to a grassland over much of the island. This has caused significant damage to the island's habitat and therefore its wildlife.

Re-vegetation efforts are underway on Antelope Island. The plan includes identifying and mapping vegetation and soil types, critical wildlife areas, and appropriate seed source areas, obtaining funding, prioritizing areas for re-seeding, and identifying actions to enhance the island tree canopy to increase both plant and animal diversity.

Antelope Island Weeds

What is a Weed? Weeds are defined as plants out of place or as "a plant that interferes with management objectives for a given area of land at a given point in times" (J. M. Torell) Weeds, plants that pose a threat to the welfare of a community, are placed into two major groups, noxious and invasive. Noxious weeds are plant species that tend to be especially injurious to public health, crops, livestock, or other properties. Invasive weeds are plant species that have the potential to spread rapidly and become noxious.

One of the most spectacular displays of spring wild flowers along the Wasatch front is provided by the weed species of plant called Dyer's Woad (*Isatis tinctoria*). This prolific, yellow flowered species was introduced into Utah in the 1800's as a dye plant and has since spread and infests millions of acres in the valleys and hillsides of Weber, Davis, Box Elder, and Cache Counties in Utah. This "beautiful" display is not as innocent as it appears in its splendor when in full bloom. The problem: When Dyer's Woad was introduced from Europe, the natural predators that helped Mother Nature maintain an ecological balance of the plant in its native habitat were left behind and upon its introduction had no natural predator to keep it in balance. In fact, it is allelopathic! The plant releases chemicals into the soil surrounding it which retard the growth and development of native plant species, giving it a competitive edge and allowing its rapid spread. Dyer's Woad is not palatable to native or domestic animals so grazing does not help control it. So, Dyer's Woad has spread throughout Utah, and surrounding states. What can we do to control it? Many communities have a day called "Bag of Woad Day" where community groups pull and bag the weed in the early spring so that it will not produce and spread by seeds. Because of environment issues and the fact that the plant occupies such an expansive area, many of which are difficult to reach, chemical herbicides are not always a desirable way to control it. Research is being done on a fungus predator that prevents the "weed" from producing flowers, hence no seeds are produced. The fungus does not infect other plant species and though it spreads rather slowly, with patience it can bring Dyer's Woad to a manageable state.

Dyer's Woad is a prime example of the problems faced by land managers who deal with introduced plant and animal species. All states in the U.S. deal with weed problems and have Weed Boards managed by the States Department of Agriculture with authority and responsibility to control weeds given to each county under the direction of the County Weed Supervisor.

Our field trip will take us to Antelope Island State Park. It is the home of one the largest publicly owned herds of buffalo in the United State that depend on the vegetation of the Island for food. It, too, has its problems with weeds as described by the Weed Management of Antelope Island 2001: "Noxious weeds are a vegetative wildfire raging out of control. However, unlike a wildfire, noxious weeds spread silently through the years and by the time we realize there exists a problem, it is often too late to eradicate the invader. We then are left to manage around these species and spend large sums of money to simply keep them at bay."

Prior to the invasion of Antelope Island in 1847 by Anglo-Saxons, the island was dominated by a blue bunch wheatgrass/sage brush community. This supply of natural vegetation was inviting to the early settlers who almost immediately brought livestock to the island. The island's vegetation has been overgrazed for nearly one hundred and fifty years leading to its conversion from the blue bunch wheatgrass/sage brush community to an open grassland system that is now dominated by the introduced, invasion species, such as cheatgrass (*Bromus tectorum*). Cheatgrass is a spring annual that grows rapidly with spring moisture and completes its life cycle before the hot, dry summer months found prevalent in Utah. As a result the cheatgrass is dry by June, hence it is also called June grass, and presents an extreme fire hazard. Frequent fires fueled by cheatgrass have aided in the loss of the native community of plant and the rapid spread of cheatgrass over the island. Farming, construction, and mans visitations are other influences that have brought changes to the islands plant communities.

Today we find eight of Utah's noxious weeds on the Island: dyer's woad, whitetop, musk thistle, diffuse knapweed, spotted knapweed, Canada thistle, bindweed, tall whitetop, and dalmatian toadflax. Other invasive weeds found on the island that present some concern include houndstongue, Russian olive, tamarisk, common burdock, moth mullein, and cheatgrass.

Just as the biocontrol fungus has been introduced on Dyer's Woad, many other measures of biocontrol have been and are being introduced into Utah's populations of noxious and invasive weeds. Presently a Weber State University student, Jolene Hatch, is working with an insect introduced to help in the control of dalmatian toadflax on Antelope Island.

The website http://utahweeds.tripod.com/index.html contains information along with picture identifications and control measure of noxious and invasive weeds found in Weber County, Utah. It is an excellent site and one you ought to visit for more information about the weeds of Weber County.

References on Antelope Island Weeds:

Weed Management on Antelope Island State Park, June 2001

Torell, J. M. 1991. Weeds of the West. Publisher - The Western Society of Weed Science in Cooperation with the Western United States Land Grant Universities Cooperative Extension Service

Review Questions for Antelope Island Field Trip

1. What is the Indian name for Antelope Island and of what significance is that name?

2. Which is older, the Weber River, or the Wasatch Mountains? Explain.

3. List the "kinds" of big game species found along the Wasatch front in pre-settlement times and discuss the changes that have taken place in those populations since 1847.

4. What has been the single most destructive force in modifying the nature of range lands in the west?

5. List six plant species that are used to define an area as a wetland.

6. Discuss the changes that have taken place in the wetlands along the Great Salt Lake as a result of the high lake levels of the last decade.

7. Discuss the studies being conducted on *Scirpus maritimus* and their possible global importance.

8. What term is used to describe organisms that tolerate high concentrations of salts such as in the GSL? List five such organisms giving both their scientific as well as common names.

9. Why is the north arm of the GSL reddish in color while the south arm is emerald green during the summer?

10. What are some notable bird species characterizing the GSL marshes and why are these marshes so valuable to them?

11. Define a "wetland" using the criteria set by the EPA.

12. Identify at least seven *values* of wetlands today and comment briefly on each.

13. What measures are taken to protect wetlands today and what can you do personally should you feel so inclined?

14. Why are grasslands, chaparrals and coniferous forests prone to fires, whereas deciduous forests rarely burn?

15. What are the three major categories of fire and how do they differ from one another?

16. How can occasional smaller fires help prevent huge, intense fires like that in Yellowstone National Park in 1988?

17. What impact has the establishment of cheatgrass had on the vegetation of Antelope Island?

18. What are noxious and invasive weeds?

19. What has caused the changes in the plant communities on Antelope Island the last 150 years? What should be done to prevent further changes and to bring back the original plant communities?

20. What can you do to prevent the introduction of aggressive nonnative species into our communities?