

Powers of Ten: A Photo Essay Analyzing the Ecology of Horsetooth Reservoir

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Acknowledgments

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Introduction

This illustrated research document, in the form of an extended photo essay, is the culmination of four years studying journalism and biology at Colorado State University. When anyone asked what I was studying, the answer was followed by a quizzical look, then a smile. The liberal arts specialists seemed astounded at my interest in science while the science majors seemed it odd that I enjoyed writing.

I decided to pursue biology and journalism my senior year of high school as I recognized a dire need for people who could communicate complicated ideas simply. Advancements in research and technology demonstrate that there is an endless amount of relevant information about any given topic. Deciding what's important becomes even more crucial.

This photo essay contains images of Horsetooth Reservoir from different levels: first, as a tiny dot on a world map, zooming in through 16 photos concluding with an image of chloroplasts. Each photo is paired with a brief discussion about the human, ecological, and biological context of the photo.

The goal is to show a holistic view of a very complicated system. As you will see, Horsetooth Reservoir is not merely a fresh water container for eastern Colorado, but it hosts organisms of many sizes. The reservoir itself brings up complicated issues about water worldwide, regional and local water rights, a "natural" manmade system, native species protection, and many other topics. The essay also mentions natural and human historical events that surround the reservoir.

The essay contains many minutia and interesting tidbits, as well as general research. Ideally, experts and laymen alike can glean an understanding, or at least a holistic perspective on a complicated system through this piece.

Enjoy. As my dad likes to remind me daily, "You might slip and learn something."



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat

Google earth

1) The World's Water

According to the Global Water Partnership, the world contains 1 million cubic kilometers of water.¹ The world's water could fill 400 billion Olympic-sized swimming pools. Since only about 2.5 percent of this is fresh water, the world's fresh water supply could be contained in 10 billion Olympic-sized swimming pools.

Only about 0.3 percent of the fresh water, or 3 hundred million Olympic-sized pools' worth, is contained in rivers and lakes. Most of the earth's population relies on lakes and rivers as their fresh water source. Based on the recommended consumption (eight U.S. glasses) and a human population of 7.3 billion, the human population should consume about 2,725 Olympic-sized swimming pools daily. That said, ignoring the water cycle, we have enough fresh water in lakes and streams to last the human population about 110 days. Although this is a false premise, and the water cycle continually provides fresh water, there has been an ongoing debate about how renewable water really is as a resource.²

To combat this issue, conservationists, scientists, politicians and engineers have built reservoirs worldwide. Reservoirs are commonly created by extending lakes or damming a canyon or valley where rivers naturally flow. The largest fresh water reservoir is Lake Kariba in Zambia and Zimbabwe that can hold a maximum of 180.6 cubic kilometers, enough to fill over 7.2 million Olympic-sized pools.³

¹ "Water Statistics," Global Water Partnership, May 25, 2010, accessed February 1, 2016, <http://www.gwp.org/Press-Room/Water-Statistics/>.

² N F. Gray, *Facing up to Global Warming: What Is Going On and How You Can Make a Difference?* (Cham: Springer, 2015), 1, accessed February 5, 2016, <http://dx.doi.org/10.1007/978-3-319-20146-7>.

³ A. B. Avakyan and S. P. Ovchinnikova, "Data On World Reservoirs," *Hydrotechnical Construction* 5, no. 8 (August 1971): 773-77.



Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth

2) US Reservoirs

The United States struggles with fresh water, especially in the West where frequent droughts occur. The largest manmade reservoir in the United States is Lake Mead in Nevada. It holds just under 14 million Olympic sized swimming pools' worth of water, or more than one tenth of a percent of the world's freshwater.⁴ Lake Mead, along with many reservoirs in the Western United States, is managed by the Bureau of Reclamation, the largest water wholesaler in the nation.⁵ The agency is responsible for many dams, power plants, and canals, including the Hoover Dam. The agency's properties alone irrigate 60 percent of the United States' vegetable crops.

The United States Army Corps of Engineers manages other reservoirs, including Lake Oahe in South Dakota and Sakakawea in North Dakota.⁶ The Corps of Engineers is responsible for dam regulations and construction, as well as wetland protection.⁷ Its water-oriented goals aim to ensure that Americans have access to safe, fresh water. It works closely with other agencies such as the U.S. Department of Wildlife and the Environmental Protection Agency. The most recent collaboration of the Corps of Engineers and the EPA manifests in the Clean Water Rule, a 2015 Act meant to protect wetlands and water sources from pollution.

EPA Administrator Gena McCarthy said in the EPA's press release about the legislation: "For the water in the rivers and lakes in our communities that flow to our drinking water to be clean, the streams and wetlands that feed them need to be clean too...Protecting our water sources is a critical component of adapting to climate change impacts like drought, sea level rise, stronger storms, and warmer temperatures."⁸

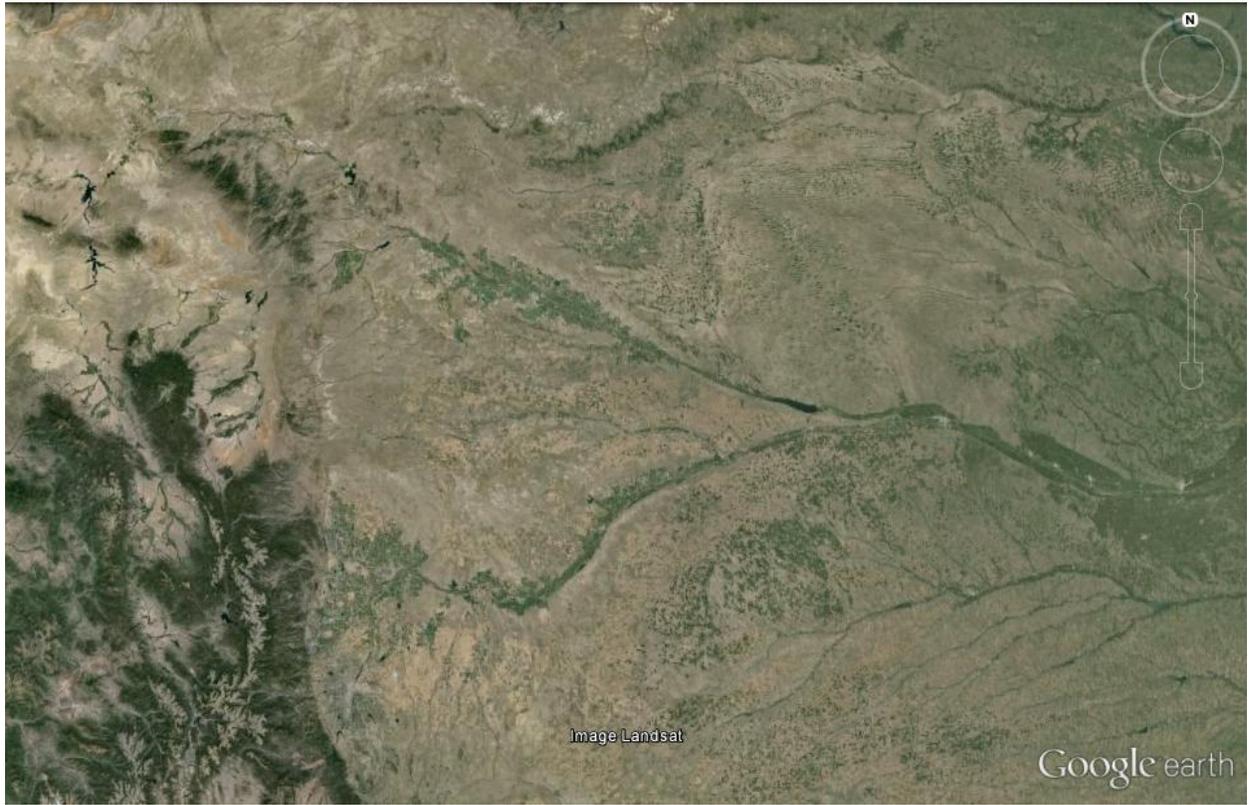
⁴ "Dam, Hydropower and Reservoir Statistics," United States Society of Dams, accessed February 1, 2016, http://www.ussdams.org/uscold_s.html.

⁵ "Mission/vision," United States Bureau of Reclamation, accessed February 1, 2016, <http://www.usbr.gov/main/about/mission.html>.

⁶ *Ibid.*

⁷ "About Us," United States Army Corps of Engineers, accessed February 1, 2016, <http://www.usace.army.mil/About.aspx>.

⁸ "Newsroom: Clean Water Rule Protects Streams and Wetlands Critical to Public Health, Communities, and Economy," United States Environmental Protection Agency, May 27, 2015, accessed January 25, 2016, <https://yosemite.epa.gov/opa/admpress.nsf/0/62295CDDD6C6B45685257E52004FAC97>.



3) The Colorado-Big Thompson Project and East Slope Distribution

The veins in the land visible from satellites reflect the drainage system of Colorado. The large Y-shaped veins are the North Platte and the South Platte. Runoff from the Rocky Mountains in the West flows into these rivers onto the Eastern Slope.

The Front Range and Colorado plains rely on the Big-Thompson Project for access to water from the Colorado River headwaters on the Western Slope. The B-TP is managed by the Bureau of Reclamation. The plan diverts about 130 thousand Olympic-sized swimming pools of water to the Big Thompson River for recreational, irrigational, electrical and community use along the East Slope every year.⁹ The water is distributed to 120 miles of tunnels and canals and 12 reservoirs and is used by six hydroelectric power plants.¹⁰

The Alva B. Adams Tunnel funnels the water under the Continental Divide in the Rocky Mountains. The artificial river runs 13 miles from the Granby pumping station on the West side of the divide to power plants and reservoirs on the East side of the mountains.¹¹ Steel braces and a concrete lining made out of the rocks they removed while building the tunnel support the infrastructure that was built in the 1940s.¹²

Water had become a problem along the Front Range as early as the 1890s with a growing population. Farmers asked for regulation because upstream residents claimed too much water, leaving downstream agriculture with merely a trickle. The area fell under the jurisdiction of the Reclamation Act of 1902.¹³ About 80 percent of Colorado's population lives between Fort Collins and Pueblo, most of whom rely in some capacity on the B-TP.¹⁴

⁹ "Colorado-Big Thompson Project," United States Bureau of Reclamation, July 18, 2013, accessed January 25, 2016, http://www.usbr.gov/projects/Project.jsp?proj_Name=Colorado-Big+Thompson+Project.

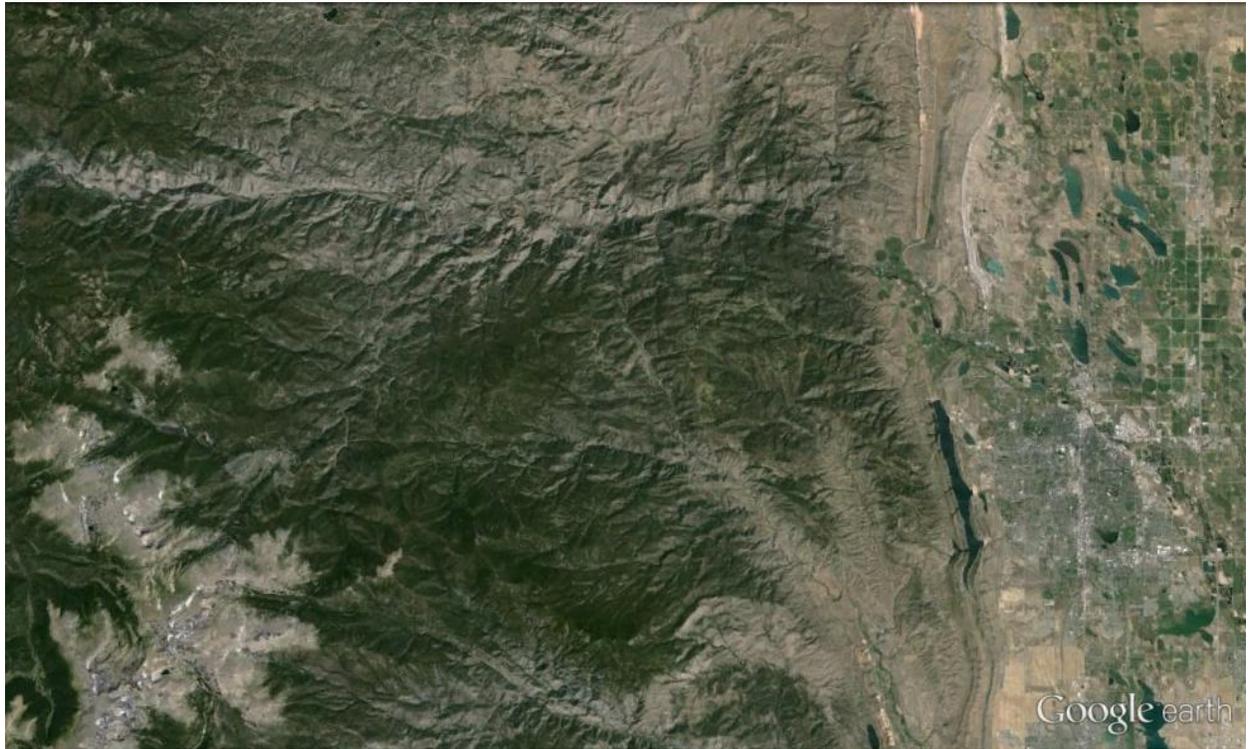
¹⁰ "Colorado-Big Thompson Project," Northern Water, accessed January 25, 2016, <http://www.northernwater.org/WaterProjects/C-BTPProject.aspx>.

¹¹ *Popular Science*, Man-Made River Pierces the Great Divide, September 1947, 119-21, accessed January 25, 2016, https://books.google.com/books?id=miQDAAAAMBAJ&pg=PA119&dq=popular+science+1947+%22piped+through+the+rockies%22&hl=en&ei=1QHRTlueLcSHnQfwjMWxDA&sa=X&oi=book_result&ct=result#v=onepage&q&f=true.

¹² Robert Autabee, "Colorado-Big Thompson Project," United States Bureau of Reclamation, 1996, accessed January 25, 2016, http://www.usbr.gov/projects//ImageServer?imgName=Doc_1303159857902.pdf.

¹³ Reclamation Act/Newlands Act of 1902, H. Act. 1093, 57th Cong., 1st sess. (June 17, 1902): H1.

¹⁴ Campbell Gibson and Kay Jung, "Historical Census Statistics On Population Totals by Race, 1790 to 1990, and by Hispanic Origin, 1970 to 1990, for Large Cities and Other Urban Places in the United States," United States Census Bureau, February, 2005, accessed March 17, 2016, <https://www.census.gov/population/www/documentation/twps0076/twps0076.html>.



4) Horsetooth Reservoir

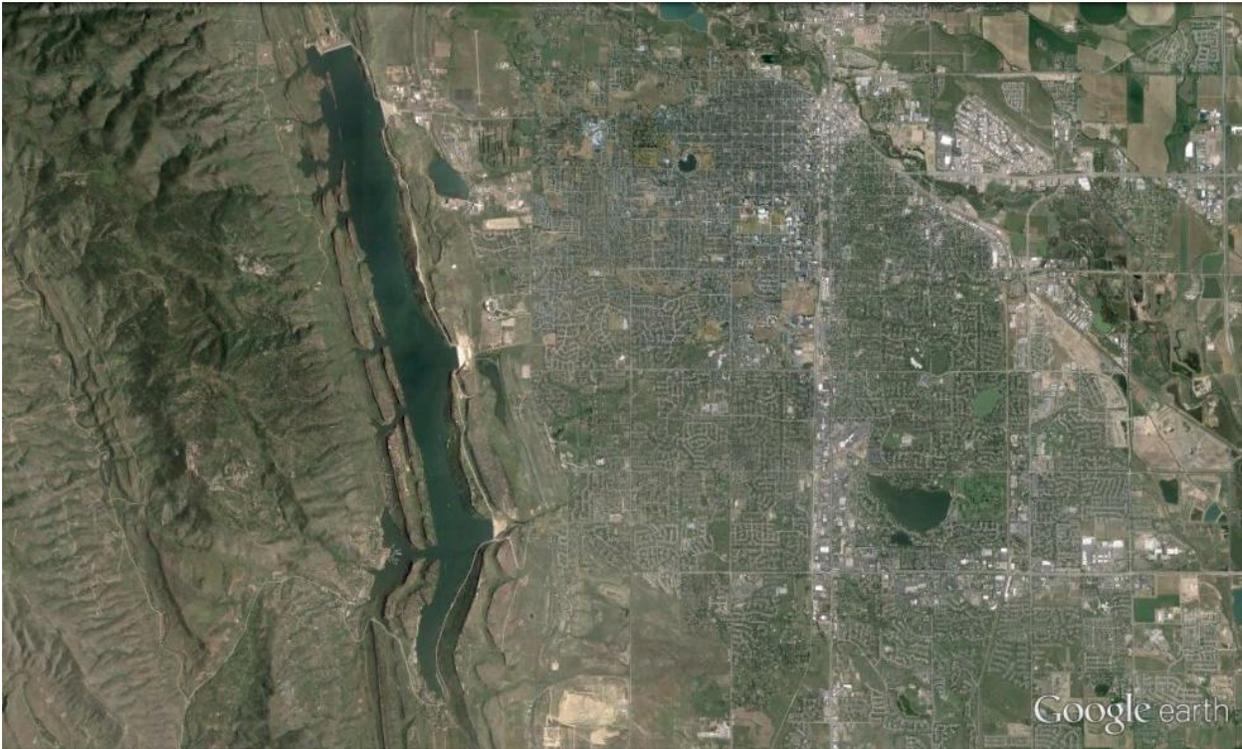
Water from the Adams Tunnel flows into East Portal Reservoir on the Wind River. It travels through Mary's Lake Powerplant to Lake Estes. Lake Estes is a regulatory point that can release water into the Big Thompson River or through the southern "power arm" where it goes through three power plants.¹⁵

After going through another series of canals, the water arrives at Flatiron Reservoir where it can be pumped southward to Carter Lake or northward to the Big Thompson River and Horsetooth Reservoir through the Charles Hansen Feeder Canal that runs through Masonville.

In 2000, the Bureau of Reclamation, part of the Department of the Interior, released the rights for the part of the C-BT downstream from Horsetooth to the Northern Colorado Water Conservancy District. The NCWCD helps manage the downstream effects of having upstream water rights. According to the agreement, the Bureau of Reclamation provides flow to the NCWCD's property downstream from Horsetooth Reservoir.¹⁶

¹⁵ United States Bureau of Reclamation. "Colorado-Big Thompson Project."

¹⁶ Ibid.



Google earth

5) The Reservoir Itself

Horsetooth Reservoir is jointly operated by the Bureau of Reclamation and the NCWCD. Its 75 thousand Olympic-sized swimming pools' worth of water is contained within a 6.5 mile stretch.¹⁷ It holds water for irrigation, drinking, and recreation for the Poudre Valley, accounting for 50 percent of the water used by the C-BT.

The reservoir has four earthfill dams ranging from 155 to 240 feet high. The north side is contained by the Horsetooth Dam. The Soldier Canyon Dam, Dixon Canyon Dam, and Spring Canyon Dam hold the water along the eastern hogback ridge.¹⁸ The canyons formed over thousands or even millions of years as erosion from run-off dug grooves into the mountain as it flowed to the Eastern Slope. The dams were first constructed between 1946 and 1949. They are made of bedrock and limestone, and were reinforced and modernized in 2000-2004 for seismic stability.¹⁹

The City of Fort Collins bought rights to access to the C-BT in the 1950s, and has increased its rights and usage by trading developed lands.²⁰ The first year it was open, 1951, farmers used 98.6 percent of the available water leaving hardly any for municipal purposes. In the 1990s, agricultural use dropped to about 60 percent.

The reservoir was named for the nearby tooth-shaped boulder, Horsetooth Rock, which serves as a landmark and popular hiking destination.

¹⁷ Ibid.

¹⁸ Ibid.

¹⁹ "Horsetooth Reservoir and the C-Bt," Colorado State University Public Lands History Center, accessed January 25, 2016, http://publiclands.colostate.edu/digital_projects/dp/poudre-river/moving-storing/horsetooth-reservoir-and-the-c-bt/.

²⁰ Ibid



6) Stout, Colorado

Fort Collins area residents are familiar with an odd sign at the south of the reservoir, “Stout, population 47-1/2.” The sign references a town that was wedged in the south of the canyon base now occupied by the reservoir. Before the valley offered water to the Poudre Valley, it supplied builders nationwide with building materials.

Stout was a mining town in the late 1800s that produced sandstone, including that used in Chicago’s World’s Fair buildings.²¹ Quarry workers boarded at Stout’s Hotel, the owner of which also owned Stout Stone Quarries.²² Stout originally hoped legislature would allow him convicts to work for free, but the legislature did approve the plan. The Colorado and Southern Railroad had its northern terminal in the town, running through Spring Canyon, and Stout’s quarries could fill as many as 25 car loads a day.²³

By the end of the nineteenth century, Mr. Stout gave management of his tiny empire to his sons and moved on to invest his time and money in the Union Pacific. The buildings in Stout were sold or moved. Some, like Stout’s Highland School house, remain buried under the reservoir today.²⁴

Today, the South Bay, as it is called by locals, hosts a small tackle shop and the primary recreational entrance to the Reservoir and the park near it, Horsetooth Mountain Open Space. The recreational sites belong to Larimer County.

²¹ “Stout: The Town Site under Horsetooth Reservoir,” Fort Collins History Connection, accessed January 25, 2016, <http://history.fcgov.com/archive/newsflashback/stout.php>.

²² “Larimar County Water Ways: Stout Hotel with 60 Rooms,” Larimer County Digitization Initiative, 2001, accessed January 27, 2016, http://history.fcgov.com/waterways/item_viewer.php?CISOROOT=/ph&CISOPTR=5950&CISOBOX=1&REC=1.

²³ “Larimar County Water Ways: Stout, Colorado panorama,” Larimer County Digitization Initiative, 2001, accessed January 27, 2016, http://history.fcgov.com/waterways/item_viewer.php?CISOROOT=/ph&CISOPTR=5951&CISOBOX=1&REC=4.

²⁴ “Larimar County Water Ways: Stout Schoolhouse,” Larimer County Digitization Initiative, 2001, accessed January 27, 2016, http://history.fcgov.com/waterways/item_viewer.php?CISOROOT=/ph&CISOPTR=6037&CISOBOX=1&REC=7.



7) Intersections

This intersection sits at the southern end of the Spring Canyon Dam. To the east lays Fort Collins and the Front Range, and to the southwest, the reservoir and the Rocky Mountains. The fauna visible represent the most robust survivors and pioneer species amid a highly disturbed area, where nature and recreation overlap.

Although not in the top 10 most dangerous intersections in Fort Collins, this intersection of County Road 38 E and Centennial Drive has a blind corner coming from the east or northwest. There is a row of sand bins lining the rocks at the south side of the intersection. These slow run away vehicles down as they come down the hill on the North side of the dam. The drive over the dam allows a lookout over Fort Collins.

Runners and bikers traverse the hills that surround the reservoir to train for marathons, bike races, and triathlons. A common bike path goes over the three dams on the east side of the reservoir with either end of the loop on County Road 38 E in southern Fort Collins and Laporte Colorado just northwest of Fort Collins. Several partners in the Fort Collins area offer triathlon training events including Horsetooth open water swims, non-competitive runs, and bike climbing clinics.²⁵

Locals and tourists alike travel west into the mountains to hike the Horsetooth Open Space trails to Horsetooth Falls or the reservoir's namesake rock. The prairie and red sandstone of the mountains offer a close-to-civilization scenic escape. Others use the road to see Masonville, a small town in the mountains that hosts a historical leather shop, mercantile, post office, and Presbyterian Church.²⁶ County Road 38 E also connects with N County Road 27, which leads towards Loveland and Estes Park.

²⁵ "Open Water Swim and Tri Training Series," Horsetooth Tri Training, accessed March 29, 2016, <http://horsetoothtritraining.com/>.

²⁶ "The Little Stone Church On the Hill," Buckhorn Presbyterian Church, accessed March 29, 2016, <http://www.buckhornpres.org/home.htm>.



8) Fish of Horsetooth

The number and types of fish in the reservoir change with fishing patterns and other biological factors. Kurt Davies is an aquatic biologist in Fort Collins who has studied fish and fishing patterns in Horsetooth Reservoir as well as in other rivers and lakes in the C-BT. Colorado Parks and Wildlife manages the Horsetooth Fishery. The underwater ecosystem is dominated by cold water and cool water varieties, since Horsetooth stays cool for most of the year.²⁷ The Reservoir has been monitored and stocked for many species since the 1950s.

Horsetooth generally has rainbow trout, cutthroat trout, brown trout, mackinaw and splake. Walleye, smallmouth bass, white bass, and yellow perch were stocked, but now maintain their own populations.²⁸ The fishery has had difficulty maintaining the larger sport varieties because most of them feed on smaller species. This means that the fishery aims for ecosystem balance in order to create a steady food chain.

For instance, walleye consumed the plentiful yellow perch until the late 1960s, but when the yellow perch population declined, the fishery management introduced rainbow smelt for walleye consumption. However, the smelt depleted forage in the reservoir leading to an ecosystem crash and then the demise of their own population.²⁹

The ecosystem and fishing of Horsetooth affects the palatability of the fish to vertebrates, including humans. Mercury is an element that is toxic to humans at relatively small quantities, but it bioaccumulates in lower vertebrates, especially fish. Bioaccumulation occurs when organisms low on the food chain accumulate small quantities of a toxic chemical. The next order of the food chain derives its energy by consuming large numbers of the bottom order organisms, acquiring an exponential increase in the concentration of the toxic substance. There is evidence that predator-prey balance that prevents over-consumption may also reduce bioaccumulation of mercury in the short-term.³⁰

The ethics of stocking a manmade lake are coupled with maintaining a “natural” system within a manmade system. The populations within the reservoir may be indigenous to the Front Range, but no fish population is truly indigenous to Horsetooth Reservoir. Perhaps the difficulties in balancing populations is reflected in the difficulty of establishing a synthetic system that imitates a natural system.

²⁷ “Horsetooth Reservoir,” Colorado Parks and Wildlife, accessed January 27, 2016, <http://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/HorsetoothReservoir.pdf>

²⁸ Ibid.

²⁹ Ibid.

³⁰ Brett Johnson et al., “Reducing Mercury Bioaccumulation Via Fishery Management,” Northern Water, accessed March 17, 2016, http://www.northernwater.org/docs/WaterQuality/2015_Stakeholders/Reducing_Mercury_Bio.pdf.



9) Water

As a human water source, Horsetooth Reservoir has high levels of manganese, geosmin, and total organic carbon (TOC).³¹ These affect plumbing and laundry, taste and odor, and carcinogenic compound production, respectively. Hard to remove items might not be affected by the water cleaning or bleaching process, or, in the case of TOC, may become carcinogenic when in contact with bleach. The North Weld County Water District, the East Larimer County Water District, and the Fort Collins-Loveland Water District share the Soldier Canyon Dam filter plant.³² This plant filters the water and adds ions to soften (or, scientifically, to adjust the pH of) the water that comes from the East Slope through the reservoir and channel system.³³

Within the aquatic system itself, oxygen levels largely control what organisms can flourish. Dissolved oxygen in the reservoir is affected by the decay of organic material that flows in from Hansen feeder canal and sediment oxygen demand.³⁴ Essentially, the organisms responsible for eating or absorbing detritus require oxygen. Sediment and sediment-dwelling microorganisms also absorb or use oxygen.³⁵

Another measure we use to describe water involves the specific conductance, or the amount of electricity conducting matter dissolved. The reservoir's powdery sodium bicarbonate sediment makes its specific conductance much higher than that of the feeder canal.³⁶

While conservationists hope the manmade waterways will provide refuge for native species that prefer the higher altitude, they have to watch for invasive species, like the Zebra mussel. The Zebra mussel is an invasive species that has infiltrated much of the inner US waterways. It has not been spotted in the C-BT a problem thus far, and, if conditions persist, it may be protected by its relatively low calcium levels.³⁷

³¹ "Horsetooth Water Quality Study," Northern Water, accessed March 17, 2016,

<https://www.northernwater.org/WaterQuality/HorsetoothWaterQualityStudy.aspx>.

³² "Soldier Canyon Filter Plant," Northern Weld County Water District, accessed February 1, 2016,

<http://www.nwcwd.org/scfp.html>.

³³ "Introduction," Fort Collins Utilities, accessed March 25, 2016, http://www.fcgov.com/utilities/img/site_specific/uploads/intro.pdf.

³⁴ Ibid.

³⁵ Thomas Butts and Ralph Evans, "Sediment Oxygen Demand Studies of Selected Northeastern Illinois Streams," University of Illinois Urbana-Champaign, accessed February 1, 2016, <http://www.isws.uiuc.edu/pubdoc/C/ISWSC-129.pdf>, 4.

³⁶ Ibid.

³⁷ Ibid, 127.



10) Along the Coast of a Manmade System

The shore of the reservoir is a recreational hotspot: fishing, camping, hiking, rock climbing, and swimming. The reservoir is surrounded by 1,900 acres of public lands.³⁸ The public lands represent an ecotome between the “wild” mountains and human-dominated foothills. An ecotome is a border or an overlap where two different ecological systems overlap. Usually, ecologists characterize the area by a large amount of species and diversity. The border of the reservoir, for instance, represents an ecotome between pioneer species on land, inflow of organisms from the upstream C-BT, and other species from the surrounding prairie.

Despite the overlap between ecological systems, however, the landscape is unmistakably dominated by human impact. To consider the Horsetooth a natural example is to ignore its unnatural beginning and influences. Pioneer species dominate the shores which were disturbed in order to create the reservoir. Although Colorado’s dry climate and difficult soil require pioneer species at some level, the ecological turbulence results in an influx of species like rabbitbrush and cottonwood. With humans constantly occupying the surrounding area, it is impossible to say whether secondary species will develop in the near future. Since the reservoir is only relatively recently established and only pseudo-natural, the diversity may be reduced.

The rocks that border the reservoir are sedimentary rocks that were mined by men such as Stout before the reservoir was conceived or filled. The rocks and shrubs protect the shores from soil erosion, but the boulders endanger the humans who enjoy recreation in the reservoir’s valley.

³⁸ “Horsetooth Reservoir,” Larimer County Colorado, accessed January 25, 2016, <http://www.co.larimer.co.us/parks/horsetooth.cfm>.



11) Cottonwood Trees

The repair of the dams and lower water level in 2000-2004 allowed scientists to analyze the ecology of plants below and at the water line in comparison to the natural vegetation surrounding the reservoir.³⁹ This helps study the biological process of succession, how organisms colonize newly exposed or disturbed areas. In this case, the terrestrial plant ecosystem from the valley was disturbed when submerged by the water, allowing the establishment of species that did not usually occupy the area.

Cottonwood trees, specifically the narrowleaf cottonwood, are endemic to the Great Basin, including Colorado. However, they are not endemic to the foothills and valleys the reservoir itself occupies.⁴⁰ The tree's range has probably been expanded by planting along ditches and rivers to prevent erosion.⁴¹ Cottonwoods grow quickly, usually in arid areas next to a body of water.⁴² Because of its water and nutrient requirements, it is a notable pioneer species. It is one of the first species to grow and flourish in newly disturbed areas, not relying heavily on other organisms.⁴³

Seedlings along the Horsetooth Reservoir grew higher than scientists might predict, which suggests a strong hold in the area. With establishment of a major pioneer species, the ecology is established as being geologically different than the surrounding landscape. Ecologists predict that, even if the reservoir was drained and the dams were removed, the composition of organisms that might thrive in the area would be different. The surrounding area has soil that is nutrient poor and dry, which makes the rich soil of the reservoir area conducive to other species.

³⁹ G. Auble et al., "Early Vegetation Development On an Exposed Reservoir: Implications for Dam Removal," *Environmental Management* 39, no. 6 (19 April 2007): 1, accessed February 1, 2016, <http://link.springer.com/article/10.1007%2Fs00267-006-0018-z>.

⁴⁰ Ibid

⁴¹ "Narrowleaf Cottonwood," Virginia Tech Department of Forest Resources and Environmental Conservation, 2015, accessed February 1, 2016, <http://dendro.cnre.vt.edu/dendrology/syllabus/factsheet.cfm?ID=898>.

⁴² "Cottonwood," The Living Wild Project, accessed February 1, 2016, <http://www.livingwild.org/winter/cottonwood/>.

⁴³ Auble, et al, 2007.



12) Rabbitbrush

Rabbitbrush is a relative of the Sunflower, is native to Colorado, and can be found above the waterline near Horsetooth Reservoir. It tolerates dry, alkaline soil and thrives where its roots drain well.⁴⁴ Because of this tolerance, yellow rabbitbrush (*Chrysothamnus viscidiflorus*) is commonly found in disturbed areas as a pioneer species.⁴⁵

Similarly, reduced competition, lack of surrounding plant life, induces an increase in seed production.⁴⁶ This life history alteration also occurs when other plants around it have been overgrazed. Additionally, it blooms until late in the fall, allowing it to spread the excess seeds after the spring and summer grazing, taking full advantage of overgrazed drylands. Consequently, rabbit brush probably thrives in disturbed areas, like the area immediately around Horsetooth Reservoir, due to a lack of plant diversity.

Because of its adaptability, it thrives in many different ecosystems, often near sagebrush, another native Colorado shrub. Rabbitbrush can be used to stabilize cliffs and soils, protecting them from erosion.

Rabbitbrush also provides shelter for native birds and small mammals including sage sparrows and jackrabbits. Its golden foliage in the late fall also provides sustenance for ungulates like deer and elk.⁴⁷ Palatability among mule deer and elk in Colorado has been measured “good” and “fair,” respectably. It does not have high nutritional value, but becomes one of the most available food sources in the late fall.⁴⁸

Native Americans across the western United States used various parts of the shrub as a medicine, dye, chewing gum, and skincare products.⁴⁹ Today, people have adopted it in xeriscaping because it requires little maintenance in the dry climate.

⁴⁴ “Rabbitbrush,” Plaintalk Colorado, February 22, 2016, accessed March 1, 2016, <http://www.ext.colostate.edu/ptlk/1741.html>.

⁴⁵ “Plant Guide,” United States Department of Agriculture, accessed March 1, 2016, http://plants.usda.gov/plantguide/pdf/pg_chvi8.pdf.

⁴⁶ James Young and Raymond Evans, “Population Dynamics of Green Rabbitbrush in Disturbed Big Sagebrush Communities,” *Journal of Range Management* 27, no. 2 (1974): 127-32.

⁴⁷ “Species: *Chrysothamnus Viscidiflorus*,” United States Forest Service, 1999, accessed February 17, 2016, <http://www.fs.fed.us/database/feis/plants/shrub/chrvs/all.html#FEDERAL%20LEGAL%20STATUS>.

⁴⁸ Ibid.

⁴⁹ “Plant Guide,” United States Department of Agriculture.



13) Lichens

Lichens, like this colorful structure, are a combination of two or more different organisms.⁵⁰ Biologists refer to this relationship as a mutualistic symbiosis, a relationship that benefits both organisms. This lichen shows the relationship between a fungus and an autotroph. The fungus probably makes up most of the biomass.⁵¹ However, the exact number of individual organisms that comprise the symbiosis is impossible to tell, since many lichens consist of more than one genetic fungus.

Autotrophs, including the algae or cyanobacteria that make up some of the lichen, provide their own energy by fixing carbon from non-organic sources like rocks or air. Algae and cyanobacteria have the same mechanism as plants and photosynthesize to fix carbon. Cyanobacteria also fix nitrogen, a nutrient required for proteins and other molecules, from soil or organic matter. The fungus part of this lichen decomposes its environment and absorbs the nutrients. Fungi take in nitrogen and carbon fixed by the autotroph, and the autotroph uses material the fungi decompose.

Because of its appearance, this lichen is described as one of the leafy foliose lichens.⁵² Lichens are a diverse group of more than 13,000 symbiotic relationships. The diversity and interdependence of these organisms allows them to grow in dry, harsh climates as well as wet, temperate ones. The lichen pictured was found near the shore of Horsetooth Reservoir on a low level of branches within sage brush in the late fall. It thrives on the lower branches where it is rarely disturbed, safe from most of the elements. Part of the year, it is covered in snow; part of the year, it is dry and hot.

They are, along with rabbit brush and cotton wood, a pioneer species. Lichens have an incredible ability to adapt to changing environments by slowing down their metabolism. Slow growing metabolism has been used, in some areas, to determine the approximate age of disturbances.⁵³ By breaking down organic material, lichens help to establish and recycle wildlife communities.

⁵⁰ "Lichen," Fungal Biology, accessed March 26, 2016, http://bugs.bio.usyd.edu.au/learning/resources/Mycoology/Plant_Interactions/Lichen/lichenBiology.shtml.

⁵¹ Ibid.

⁵² Ibid.

⁵³ PR Nelson et al., "Non-Parametric Methods Reveal Non-Linear Functional Trait Variation of Lichens Along Environmental and Fire Age Gradients," *Journal of Vegetation Science* 26, no. 5 (September 2015): 848-65.



14) Insects

Grasshoppers are an abundant insect group in the Colorado area. They blend in against the greens, browns and yellows of shrubs and grasses, making the shrubbed foothills of Horsetooth Reservoir advantageous to many species. A brief analysis of grasshopper color, speed, and height can show which grasshoppers are likely to survive around the Reservoir. Birds and small mammals are their primary predators.

Some tend to perch higher in grasses, relying on strict color patterning for camouflage, while some, like the grasshopper pictured, tend to be found lower in the grass for cover.

This young grasshopper, also called a nymph, is possibly a *Hippiscus ocelote* or “wrinkled grasshopper,” based on a dark black band found around its femur.⁵⁴ However, nymphs are difficult to identify given the complexity of their development stages, species markings, and individual distinctions. When fully grown, *H. ocelote* is one of the larger species of grasshoppers and “whirs” through the air.

Most grasshoppers are polyphagous, eating several varieties of small grasses and plants. *H. ocelote* is a non-pest grasshopper that feeds on short grasses, only occasionally causing problems in pastures or rangelands.⁵⁵ It can be found in areas where there is more moisture than in the immediate area. Perhaps Horsetooth Reservoir is an *H. ocelote* oasis in the middle of a dry plain.

Some grasshoppers are omnivorous, also eating animal or feces. Many grasshoppers can digest structures and chemicals that mammals cannot, breaking it down chemically and absorbing the nutrients.

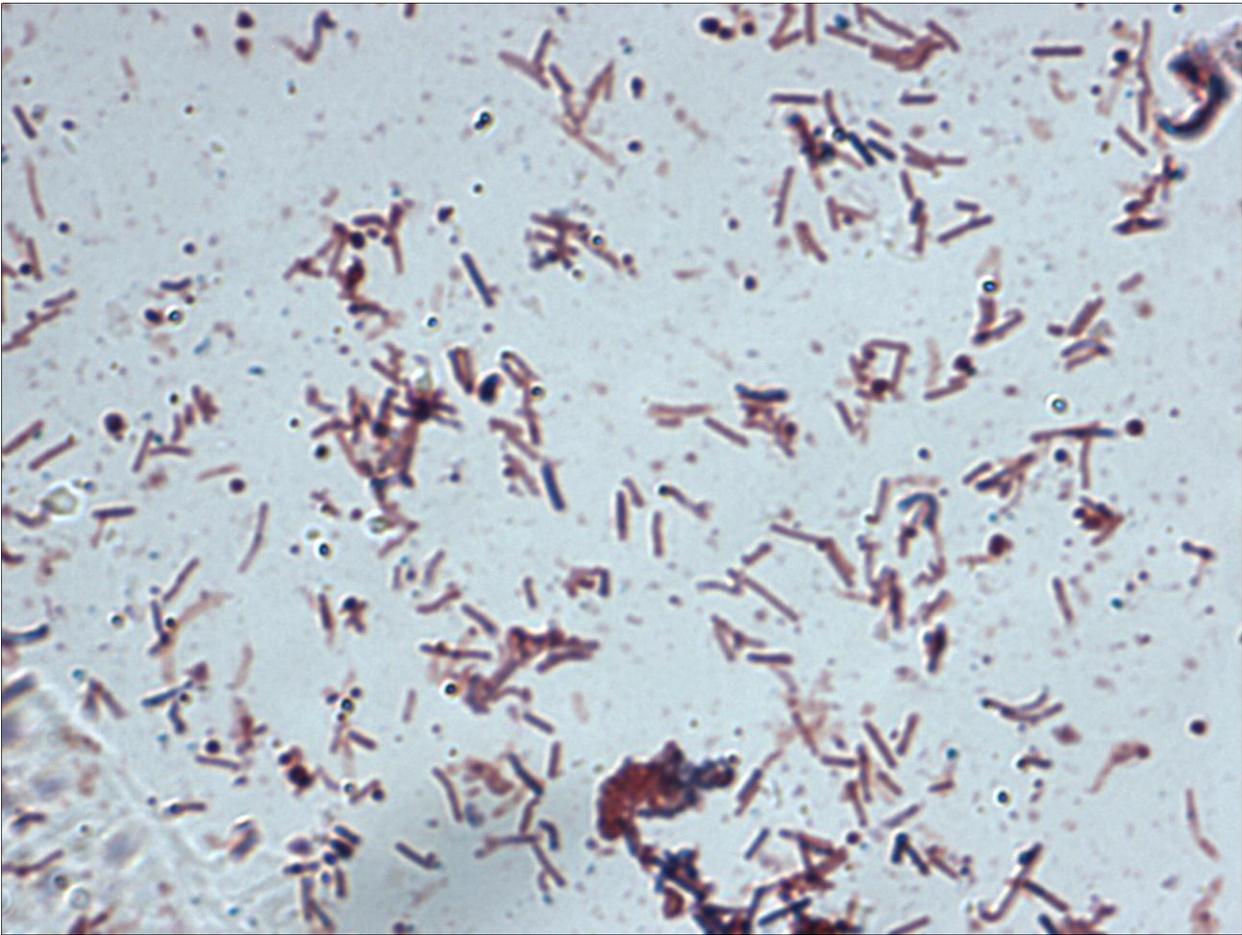
In other parts of the Front Range, farmers battle grasshoppers that damage crops, especially in the drought-plagued summer.⁵⁶ Fishermen in the area use grasshoppers for live bait. Some believe we should value them more than pests and consider feeding them to other species. Sustainability advocates advise that humans should eat locusts and grasshoppers for their high protein content.⁵⁷

⁵⁴ “Grasshoppers of the Western U.S. : *Hippiscus ocelote*,” USDA ITP, November, 2014, accessed March 1, 2016, <http://idtools.org/id/grasshoppers/factsheet.php?name=13180>.

⁵⁵ “Species *Hippiscus Ocelote* - Wrinkled Grasshopper,” Bug Guide, last modified September 26, 2013, accessed March 1, 2016, <http://bugguide.net/node/view/33141>.

⁵⁶ Joey Bunch, “Grasshoppers Skip Colorado’s Hay, Wheat and Fish This Year,” *Denver Post*, July 11, 2013, accessed March 1, 2016, http://www.denverpost.com/ci_23637854/grasshoppers-skip-colorados-hay-wheat-and-fish-this.

⁵⁷ Institute of Food Technologists, “Insects as the food of the future: Locusts, grasshoppers, crickets, silk moth pupae, and beetle and moth larvae.” ScienceDaily. ScienceDaily, 25 June 2014 accessed March 1, 2016, www.sciencedaily.com/releases/2014/06/140625101215.htm.



15) Microbes

This collection of microbes was taken from the surface of Horsetooth Reservoir along the bank near the Spring Canyon dam. The cells were visualized using a technique called a Gram stain in which bacteria are grouped by the characteristics of their cell wall. The plethora of purple shows that most of these are Gram positive, having several layers of a compound called peptidoglycan. The pink stains apply to other microbes, categorized as Gram negative.

Gram positive cyanobacteria produce some of the geosmin that makes the water taste and smell earthy.⁵⁸ Other geosmin producing species are filamentous. The purple cells are rod-shaped Gram positive bacteria that form in long lines. These bacteria could be a cyanobacteria, a geosmin-producing bacteria, or another group since a Gram stain is still only a general marker.

Bacteria in water develops when conditions favor the bacteria. For instance, since these samples were taken near the surface of the water, it can be assumed that the bacteria prefer oxygen. Additionally, the surface temperature was chilly, as the samples were taken in early spring. Therefore, the bacteria that grew in that region preferred (or at least could survive at) high levels of oxygen in chilly water.

Bacteria in fresh water sources comes from many sources, especially as coliform bacteria, bacteria from fecal matter. Filtration systems must be able to remove not only the organisms but also their cysts.⁵⁹ Lack of well-filtered fresh water leads to higher occurrences of giardia, *E. coli* poisoning and cholera.⁶⁰

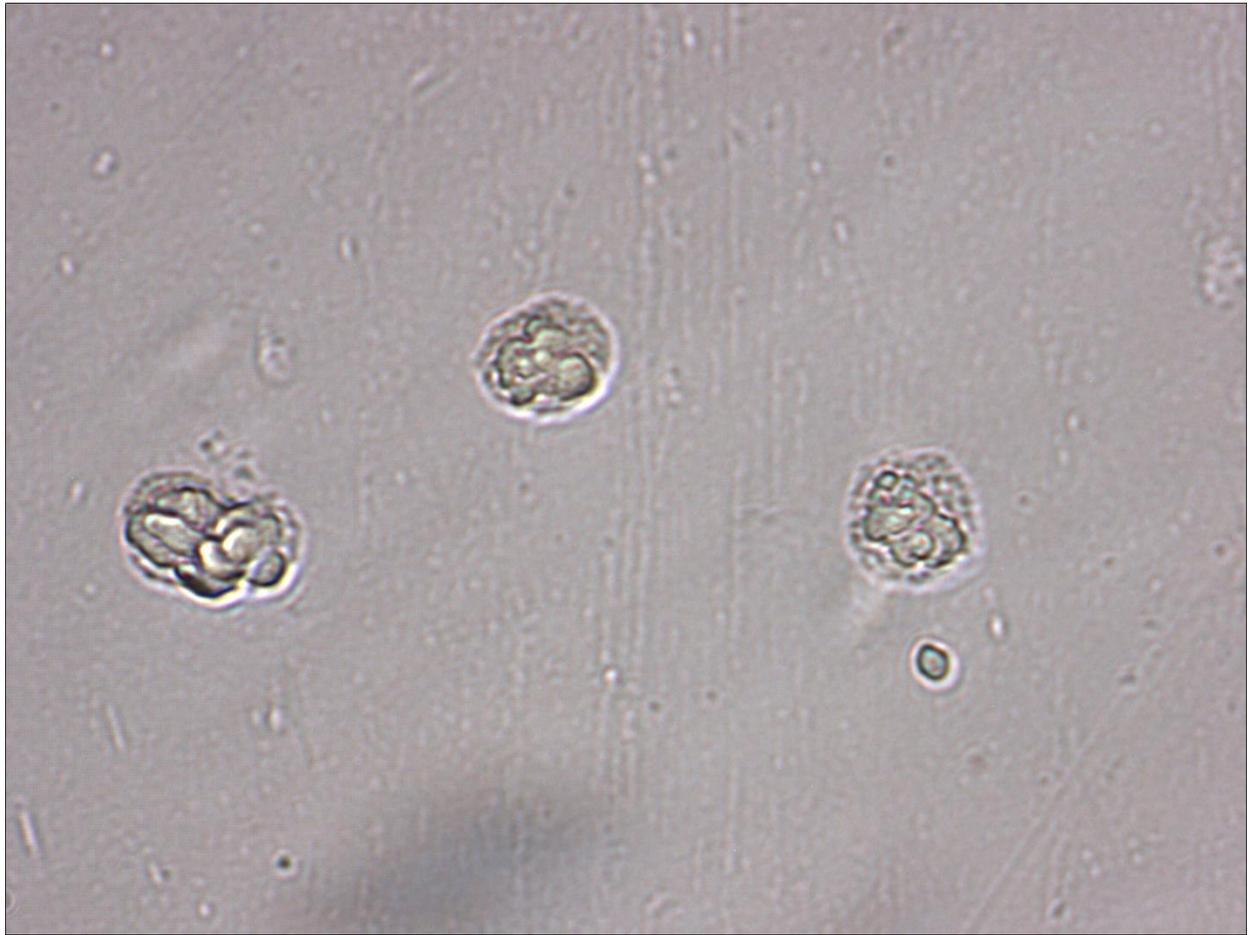
Because of their potential harm and benefit, scientists have attempted to map out not only relatedness among species, but also among the environments they live in.⁶¹ The microbiology of water is still poorly understood, which means the impact of manmade waterways on microbe ecosystems is even less understood.

⁵⁸ Jared Heath and Jill Oropeza, "2013 Horsetooth Reservoir Water Quality Monitoring Program Report," Fort Collins Utilities, June 27, 2014, accessed March 1, 2016, http://www.fcgov.com/utilities/img/site_specific/uploads/2013HT_report_final.pdf.

⁵⁹ Gary S. Logsdon, *Water Filtration Practices: Including Slow Sand Filters and Precoat Filtration* (Denver, Colo.: American Water Works Association, ©2008), 243, accessed March 18, 2016, <http://site.ebrary.com/id/10522381>.

⁶⁰ Neil Clark and Richard Robinson, "Microbes in Lakes and Streams," *Water Encyclopedia: Science and Issues*, accessed March 1, 2016, <http://www.waterencyclopedia.com/La-Mi/Microbes-in-Lakes-and-Streams.html>.

⁶¹ Ryan Newton et al., "A Guide to the Natural History of Freshwater Lake Bacteria," *A Guide to the Natural History of Freshwater Lake Bacteria* 75, no. 1 (March 2011): 14-45, accessed March 1, 2016, <http://doi.org/10.1128/MMBR.00028-10>.



16) Chloroplasts

Chloroplasts are the organelles that provide the machinery that permits all life to exist, providing plants and algae with their own food. Using a complex series of inner and outer membranes, a chloroplast is able to harvest energy from the sun into organic sugars for use in respiration. Since all organisms do respiration, the plant provides life for itself and other organisms.

Chloroplasts in photosynthetic organisms also have their own characteristic set of 120 to 200 genes.⁶² These genes seem to derive from a bacterial-bacterial symbiosis, a theory called the Endosymbiont Theory founded by Lynn Margulis.

Chloroplasts are responsible for the “primary productivity” of an ecological system. In other words, a measure of a community’s success supporting organisms is the photosynthesis and carbon fixing that occurs. To the casual observer, color is a decent measure of a community’s success: green means more chlorophyll/light capturing and thus more productivity. The Front Range’s productivity is highly seasonal and depends heavily on the water available to it.⁶³

Generally, the area surrounding the reservoir is not vivaciously green, but woody – yellow and brown, mostly. The green grasses, however, provide oxygen in exchange for sugars.

This image was created by doing a protoplast extraction of *Arabidopsis thaliana* in the Pilon-Smiths Lab at Colorado State University.⁶⁴ A protoplast extraction degrades the cell wall so only the membrane and interior structures remain. A differential gradient and centrifuging allows further purification of the thylakoids, the internal chloroplast membranes where photosynthesis occurs. Although this is not a Horsetooth Reservoir native plant, its thylakoids are still representative of the terrestrial plant community.

⁶² “Chloroplast Genome Database,” last modified June 21, 2007, accessed March 1, 2016, <http://chloroplast.cbio.psu.edu/>.

⁶³ William Moir, “Steppe Communities in the Foothills of the Colorado Front Range and Their Relative Productivities,” *The American Midland Naturalist* 81, no. 2 (April 1969): 331-40, accessed March 1, 2016, <http://doi.org/10.2307/2423974>.

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