Aquatic Ecology

The McLaughlin Reserve contains Davis Creek in the Cache Creek drainage, Knoxville and Hunting Creeks in the Putah Creek drainage, and the many intermittently flowing tributaries of these three streams. There are two large manmade water bodies, Davis Creek Reservoir and the tailings pond, both created in the 1980s. The aquatic ecosystems of the reserve have been the focus of a great deal of research and monitoring, because of the strict water quality regulations that federal and state agencies impose on mining operations.

Davis Creek Reservoir was built directly downstream of the abandoned Reed mine, which was causing mercury contamination in Davis Creek. On the other side of the watershed divide, the tailings pond containing the remains of the cyanide gold-extraction process was built on the headwaters of Hunting Creek. Farther downstream in the Hunting Creek drainage are the huge piles of overburden rock removed from the pit; this sulfur-rich rock produces acid mine drainage that is trapped by settling ponds at the foot of the rock piles. All of these features were cause for major concerns about water quality.

Long-term research and monitoring, sponsored by Homestake and conducted by UC Davis and UC Berkeley scientists, has borne out the company's promise to create an environmentally sound mine with minimal impacts on the aquatic ecosystems of the region. This work has led to advances in the understanding of mercury uptake in aquatic food chains, a major issue in California with its hundreds of abandoned mercury mines. These studies also created considerable baseline data for future research on aquatic ecology at the McLaughlin Reserve. Aquatic monitoring data are available in Homestake's Annual Reports, and the mercury research has been published in scientific journals (see Appendix 1: References).

We first describe the major aquatic systems of the reserve and the research that has been done on them. We then discuss the aquatic insect, crustacean, and fish faunas.

Hunting and Knoxville Creeks

Hunting Creek is the largest of the three creeks, and flows south through Morgan Valley into the Knoxville BLM lands. Its upper reaches are easily accessible from Morgan Valley Road, and the lower reaches from the BLM's Hunting Creek Campground. In Morgan Valley just south of the Core Shed, a fork coming from upper Morgan Valley is joined by a western fork coming from what was once known as Quarry Valley. This valley is now covered by the tailings pond, and the western fork is diverted around the pond by channels. This has likely caused decreased flow, increases in temperatures, and longer seasonal drying in the stream below the fork. Substrates in this creek

include large cobbles and small boulders with very little sand; there are many sections of riffles and pools.

Knoxville Creek drains the southeastern end of the reserve and ultimately flows into Lake Berryessa. Downstream of the reserve it is renamed Eticuera Creek, and meanders along the Knoxville-Berryessa Road, crossing it several times. At each crossing, large pools with sand and silt bottoms are formed upstream of the culverts. These are good places to look for plants, insects and fish toward the end of the dry season when the rest of the creek is dry. The main channel is characterized by steep, highly eroded banks, cobble, and large rocks, and long stretches of silty, sandy substrate.

Sedges (*Scirpus, Carex* and *Eleocharis* spp.), rushes (*Juncus* spp.), cattails (*Typha angustifolia*) and algae are the dominant aquatic plants in Davis, Hunting and Knoxville Creeks and their smaller tributaries. During normal to heavy rainfall years, many sections of these creeks lack well-rooted aquatic vegetation due to the scouring effects of winter runoff. However, this vegetation may rebound dramatically during drier years.

Since 1985, Dr. Peter Connors of the UC Davis Bodega Marine Laboratory, and Drs.Vincent Resh and Eric McElravy from UC Berkeley, have monitored the invertebrate and fish communities of Hunting and Knoxville Creeks. Their growing database has provided insight into the temporal variability of the aquatic fauna. The most notable trend is that insect and fish abundances increase in years following wet winters, and decline in years following dry winters, when low summer flows lead to high water temperatures and low oxygen levels. For example, California Roach populations declined in the late 1980s and early 1990s following several years of drought. This decline was reversed in 1994 when wetter conditions began to prevail.

Davis Creek

Davis Creek drains the northeastern portion of the reserve and flows through BLM land into Cache Creek. The upper reach flows southeast, and then the stream makes a dramatic horseshoe bend to the northwest at the base of Little Blue Ridge, where the Davis Creek Reservoir is now located. Davis Creek has steep banks that are moderately to highly eroded, areas of cobbles and large rock substrates, and many wide flat areas with sandy or silty bottoms. The waters are high in sulfates, presumably associated with volcanic and geothermal activity.

Like Hunting and Knoxville Creeks, Davis Creek has an aquatic flora dominated by sedges and rushes. One exception is just below the dam, where after impoundment, seepage created stagnant pools during late summer that resulted in the establishment of cattail beds. These cattails provide a favorable site for microbial methylization of mercury, resulting in higher mercury levels in fish and invertebrates.

One small stream draining into the reservoir from the west is fed by a geothermal spring that creates a noticeable hydrogen sulfate odor (similar to rotten eggs), especially following rain. This unusual stream has extremely dense populations of a rush (*Juncus* sp.*),* and an aquatic grass (*Distichlis spicata*) that stand out strikingly green in late summer and fall.

Davis Creek Reservoir

Davis Creek Reservoir was built by Homestake in 1984 to provide water to process the gold. At full capacity, its surface elevation is 435 meters above sea level, and the lowest impoundment level is 407 meters. At its full capacity of 7.4 million m^3 (6,000 acre-feet), it covers 80 hectares and has a maximum depth of 25 meters. The predicted average volume of inflow from the catchment area is 6.2 million m^3 (5050 acre-feet) per year. During the drought of the late 1980's, the mine installed recycling technology that cut water demands by over two-thirds, to 0.6 million m^3 (500 acre-feet) per year. This has resulted in a stable shoreline with well-developed vegetation.

Davis Creek Reservoir is a monomictic system, meaning it mixes once a year (late fall through early spring). The location is not quite cold enough for a winter ice cover, allowing the reservoir water column to mix aerobically throughout this period. The reservoir is also characterized as a mesotrophic system, in other words, medium-rich in nutrients. Succession in the aquatic vegetation has been occurring ever since the dam was constructed. The shoreline is dominated by narrow-leaved cattails (*Typha angustifolia*), which effectively absorb nutrients and convert green algae-rich water to clearer nutrient-poor water. Cattails also provide nesting habitat for several species of blackbirds, refuge for migratory waterfowl, food (rootstocks) for muskrats, and shelter for various other marsh dwellers. Submerged vegetation is also present in the reservoir; since 1988, pondweed (*Potamogeton pectinatus*) and water milfoil (*Myriophyllum spicatum*) have been dominant.

Phytoplankton include green algae (*Ankistrodesmus falcatus, Schroderia oocystis,* and *Elalrothrix* sp.), cryptophytes (*Choomonus* sp., and *Cryptomonas* sp.), diatoms (*Asterionella formosa*, *Melosira granula*), and dinoflagellates (*Ceratium hirundinella*). Although these forms are individually too small to view by eye, during spring and fall when algal biomass is typically greatest due to lake turnover, a slight color change is sometimes apparent due to their combined effect.

Reservoir zooplankton have historically been dominated by *Daphnia*, a type of cladoceran. Littoral zone invertebrates have included dragonflies (family Libellulidae) and damselflies (family Coenagrionidae)

Mercury Studies in Davis Creek Reservoir

The reservoir catchment includes the abandoned Reed and Harrison mercury mines. Abandoned mercury mines are a significant source of mercury contamination in water

bodies in California. Under anaerobic conditions such as lake-bottom sediments, certain bacteria convert the inorganic mercury into methyl mercury. In this form it is taken up by plankton, which are consumed by invertebrates, which are in turn eaten by fish, birds and mammals. Mercury levels in animal tissues increase at each successive level in the food chain. Fishing is banned in Davis Creek Reservoir, and throughout the Berryessa and Clear Lake region it is considered unwise for humans to consume more than a few locally caught fish per month because of the high mercury levels. It is important to understand that the water itself does not represent a hazard. Only when the mercury is concentrated many, many orders of magnitude (as in the tissues of large predatory fish) does it become a health concern.

Ever since the reservoir was created, it has been used as a natural research laboratory for the study of mercury dynamics, by a team of UC Davis researchers including Drs. Richard Axler Shaun Ayers, Charles Goldman, John Reuter, Darell Slotton, and PhD candidate Sudeep Chandra. Soon after the reservoir filled, these researchers found that the newly inundated bottom sediments contained high levels of organic matter that enhanced the microbial methylation of mercury. In turn, this produced a rapid spike in mercury concentrations in all three fish species in the reservoir: California suckers, which occurred naturally, and bluegill and bass, which were introduced to monitor the mercury situation. Since that time, mercury concentrations in these fish have declined to approximately 50% of peak values, though the concentrations remain among the highest in the western U.S.

One of the most important findings concerned the seasonality of mercury uptake (Slotton et al. 1995). In summertime the reservoir is thermally stratified, and rates of methylation are high in the bottom waters after the oxygen becomes depleted by microbial metabolism. The mixing of the waters in fall releases the built-up methyl mercury into the upper water layers, leading to a strong pulse of mercury uptake, from the zooplankton (130-270% over summer levels) to the juvenile bass (70-200% seasonal increase) and adult bass (15-25% increases). The mercury work is now focusing on identifying the bacteria involved in methylation, and understanding the role of algae in the transfer of mercury into zooplankton. Annual measurements of sediment deposition in the reservoir are being used to determine the seasonal new loading of mercury into the system.

Aquatic Fauna of the Reserve

Insects

Aquatic insects are those that live in water as eggs, larvae, or adults. They are believed to have evolved from terrestrial insects because they possess an air-filled respiratory system. The challenge of maintaining a gas-filled tracheal system in an aquatic habitat has led to the evolution of several breathing options such as atmospheric breathers (Culicidae, Dytiscidae), hair plastrons (Elmidae), and tracheal gills (Baetidae, Nemouridae).

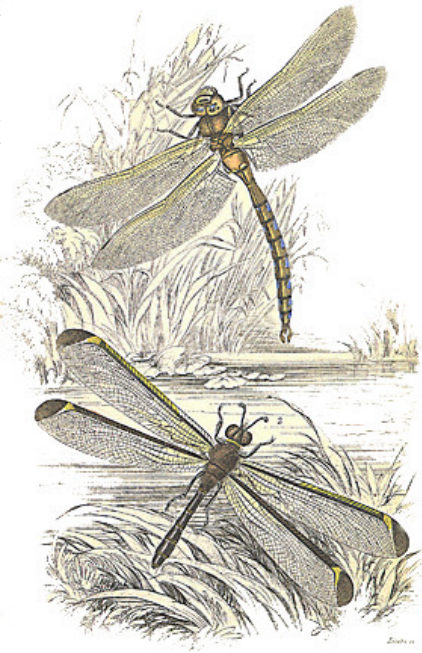
The best way to see aquatic insects is to bring a small hand net and a white enamel pan. Sweep the net through the water and empty it into a water-filled pan for viewing. Be aware that collecting aquatic insects requires a permit from the Department of Fish and Game.

Our list of aquatic insects (Appendix 9) comes from the work of UC Berkeley researcher Dr. Vincent Resh for Homestake. Most of these have been identified to family and genus, but some have been identified only to so-called "Operational Taxonomic Units" (OTUs). We also give brief descriptions of some of the major insect orders represented at McLaughlin Reserve. Consult McCafferty (1981) or Merritt and Cummins (1996) for more details.

Ephemeroptera (mayflies): Larval forms are elongate, cylindrical to flattened forms ranging from 3-20mm. Developing forewing pads are visible. Some possess tracheal gills arising from sides of abdomen. Body ends with two or three tails, but usually three. The most common mayfly in creeks at the reserve is in the family Baetidae. Adults have triangular wings that are held roof-like above the body at rest.

Plecoptera (stoneflies): Larval forms are elongate, cylindrical to flattened and range from 3-35 mm. Some species have fingerlike, branched or filamentous gills on thorax or base of legs (Perlidae). Abdomen ends in two tails. Adults have wings that are folded flat over the body and the abdomen ends in two tails.

Hemiptera (water bugs): Both adults and larval forms are oval, elongate and somewhat dorsoventrally flattened. The mouthparts are modified into a piercing tube or cone. Legs are usually well-developed, various wings or wing pads, and no gills, filaments or tails are present. The most visible member of this group, water striders (Gerridae), can be found in still-water habitats and lives on the water surface.



Dragonflies

Odonata (dragonflies and damselflies): Larval forms possess a unique raptorial beak that can be viewed from below. Wing pads are present. Larvae either have no tails (dragonfly) or three plate-like projections (damselfly). Adults are easy to spot with their large, outspread wings and long colorful bodies.

Trichoptera (caddisflies): Larvae are elongate, caterpillar-like, and measure 2-40 mm. They have small eyes and antennae, and no wing pads. The most common family in the western portion of the reserve (Sericostomatidae) builds cases from sand grains. Adults are

moth-like and hold hair-covered wings roof-like over the body while at rest. The head bears long slender antennae. In the eastern portion of the reserve, Davis Creek caddisflies are dominated by the Hydropsychid family, which do not build a case but instead create a net each day, which they use to collect drifting animal and plant food. The larvae of this group resemble "C" shaped, plump green or brown grubs, with dark head cases and short, sprig-like tails.

Diptera (true flies): Larvae are usually elongate and maggot-like, measuring 1-100 mm. Larvae may have welt-like prolegs, but never have three pairs of segmented legs, and wing pads are absent. The adults are distinguished by having a single pair of wings. Blackfly larvae can be seen in running waters clinging to rocks in masses, and you are likely to see and be bitten by adult mosquitoes.

Coleoptera (predaceous water beetles): Larvae are variable and look similar to larval flies, but usually possess segmented legs. Adults are distinctive, with forewings modified into hardened covers. They are sometimes confused with true bugs (Hemiptera), but can be distinguished by the straight midline created by the meeting of the forewings, in contrast to the overlapping wings of Hemiptera.

Megaloptera (alderflies, dobsonflies): Larvae include the hellgrammites, largest and most voracious of the local aquatic insect predators. They are characterized by a series of single strand gill filaments along both sides of the lower body, together with fierce, horizontally set jaws which can produce a pinful bite. They may be over 7 cm long. Sialid alderflies are smaller (1-2 cm), notable by the single long tail. These families are prevalent in the Davis Creek drainage.

Crustaceans

Zooplankton are an important part of the food web in the Davis Creek Reservoir, providing a link between the microscopic algae and the fish. There are two dominant orders of free-living zooplankton, Cladocera and Copepoda. The major Cladoceran species in Davis Creek Reservoir are *Daphnia pulex* and *Bosmina spp.* These filter-feeding organisms remove algae and particulates in the reservoir, thus providing water clarity and nutrient cycling. *Daphnia* can also be an important food for fish. There are two major taxa of Copepods in the reservoir, predatory Cyclopoida and omnivorous *Diaptomus*. To view the tiny but amazingly abundant *Diaptomus*, go to the water pumping station at the reservoir at night in winter and shine a light in the water; they are visible as bright red particles.

Fish

Five species of fish are common in the streams at the reserve. Natives include the California Roach, Sacramento Sucker, and Sacramento Squawfish. The most abundant is the California Roach, a small minnowlike fish that is amazingly tolerant of the high temperatures, low flow and low dissolved oxygen that prevail in late summer; roach are easily observed in the stagnant pools at this season. Non-natives include

Green Sunfish and Mosquitofish; although the Green Sunfish is thought to displace the California Roach, this has apparently not happened yet at the reserve. Golden Shiner and Rainbow Trout have been seen occasionally.

The Davis Creek Reservoir supports the native Sacramento Sucker, and the non-native Bluegill and Largemouth Bass which were introduced to assess mercury concentrations. Bluegill feed on zooplankton and invertebrate larvae, and were intended to provide food for the bass. The predatory Largemouth Bass, a Florida strain, has surprisingly been found to feed more on invertebrates and its own young than on Bluegill. During the summer, Bluegill and Largemouth Bass can be easily seen from the water pumping station in the early morning or evening.

The following are short descriptions of each species:

California Roach (Cyprinidae: *Hesperoleucus symmetricus)*: Minnow with a total length generally not not exceeding 10 cm. The mouth is terminal, with smooth lips. It is bicolored, dark on the back and silvery on the belly, usually with a dark lateral stripe. Next to the speckled dace it is the most widely distributed minnow in California.

Sacramento Sucker (Catostomidae: *Catostomus occidentalis*): A medium to large sucker with relatively large scales. The mouth is subterminal with fleshy lips and no barbells. It has a greenish back, dusky yellow belly, and faint lateral red stripe, with a total length up to about 50 cm. Adults feed on a variety of foods ranging from organic debris and algae to aquatic insect larvae. The Sacramento sucker is rather long lived and slow growing, and does not spawn until at least four years. Spawning begins in late February. The population that has moved into Davis Creek Reservoir grows at a more rapid pace, reaches larger sizes, and makes annual spawning runs up Davis Creek.

Sacramento Squawfish (Cyprinidae: *Ptychocheilus grandis*): This fish has a long pointed snout with a jaw that extends beyond the anterior margin of the eye and has no teeth. Adults have an olive-brown back and yellowish belly; during breeding season the fins are orange. Young fish are silvery, resembling a large minnow. As an adult it takes on the role of top predator, but young feed primarily on invertebrates and switch to fish at about 20 cm.

Mosquito Fish (Poeciliidae: *Gambusia affinis*): This nonnative species was brought to California for mosquito control. Its average total length is 2.5 cm; it has a small dorsal fin and a green-gray drab color. It is omnivorous and eats algae and invertebrates. These fish have tolerance to high pesticide levels and anoxic conditions and can survive in stagnant creek pools in late summer.

Green Sunfish (Centrarchidae: *Lepomis cyanellas*): This nonnative was introduced to California in 1891 and has spread throughout the state. It has a maximum length of 30 cm, rounded pectoral fins, dark opercular flap, and iridescent blue-green markings on the body and head. It is an aggressive fish with high tolerance to warm water, low

oxygen levels and high alkalinity. It often dominates small pond fish communities. The young feed on aquatic insects and adults eat fish.

Bluegill (Centrarchidae: *Lepomis macrochirus*): This nonnative has a blue-black opercular flap, vertical bars on side, and a large black spot on the posterior base of the dorsal ray. Each female can produce up to 50,000 eggs per spawning. It is highly territorial, and spawns in April- June.

Largemouth Bass (Centrarchidae: *Micropterus salomoides*): These nonnative fish can reach 70 cm. It can be identified by a black lateral stripe on the side of the body. The jaw extends beyond the posterior margin of the eye. The young feed on zooplankton and invertebrates, while adults eat fish. It is highly territorial, and spawns in April-June.