The Ample Charms of a Well-Fed Lake

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A Tour

The science of inland waters is called limnology, from the Greek limnaea for lake or pool. Limnologists array lakes on a continuum from oligotrophic to eutropic, Greek again meaning "poorly fed" and "well fed" respectively. At the poorly fed end of the continuum are the nearly sterile lakes like Lake Tahoe. Deep, clear, and cold, these lakes appear often on postcards and calendars. Clear Lake on the other hand, is well into the eutrophic range. Well fed lakes tend to be shallow, turbid, warm, and not quite so beautiful to look at, at least in the traditional sense. Clear Lake is seldom clear; the 19th Century journalist-historian Lyman Palmer, quoting an 1877 article in the San Francisco *Post*, ascribed the epithet "clear" to the clarity of the air not the water. (Lake County to this day enjoys extra-ordinarily clear air, partly because of zealous air quality enforcement and partly because prevailing westerly breezes bring untainted Pacific air over very lightly populated country before spilling it into the basin.) Of course, beauty is in the eye of the beholder, and to all the animals that inhabit these fat lakes, eutrophy is indeed beautiful. The Young Man agrees. "Give me a lake warm enough to swim in," he says. Eutrophic lakes produce a lot of food. "Well fed" in the limnologists' sense means lots of mineral nutrients like nitrogen, phosphorus and iron. A rich supply of nutrients means lots of aquatic plants, which feed the crustaceans, shellfish, worms, and insects that in turn feed the small fish that feed the big fish that feed the grebes, pelicans, herons, osprey, eagles, mink, raccoons, otters and humans. The abundant fish populations of Clear Lake are still one of the major reasons people visit it. Before European conquest, Indian populations around Clear Lake were large and rich, while oligotrophic lakes like Tahoe supported virtually no human life until the advent of tourism. Tahoe still has little to offer other than tourism, whereas tourism has always been second to agriculture in the economy of Lake County. The runoff from poor land makes poor lakes; the richness of Clear Lake is indicative of the richness of the surrounding lands. So, for the natural and human historian, Clear Lake holds at least as much attraction as Tahoe, its more subdued scenery notwithstanding.

To explain what makes Clear Lake eutrophic and to draw out the consequences of this and other properties of the lake ecosystem, as well as to acquaint you with some of the natural and human history of the area, we take you on a circular field trip around the lake, an eddy spun off from the circular tour that forms the skeleton of this guidebook. You do not necessarily have to visit every stop to learn about Clear Lake from the chapter, but the stops do give real experiences to back up our bookish abstractions. Reading books is only preparation for natural history. The real thrill is to read nature like an open book, not to open books about nature.

Anderson Marsh

Our tour begins at the Clear Lake stop on the master tour of this guidebook. Anderson Marsh is on the outlet of Clear Lake. Cache Creek begins about a mile and a half northwest of the Anderson ranch house. About three and a half miles downstream, the Yolo County Flood Control and Water Conservation District operates a dam, built in 1915, that regulates the outflow so as to store winter runoff in the lake. The dam is a successor to the one built in 1866 by the Clear Lake Water Company to provide power for a mill. The storage of water in Clear Lake, supplemented today by Indian Valley Reservoir on the North Fork of Cache Creek, provides about 90,000 acre feet of inexpensive irrigation water for Yolo County farms in the average year. Regulation of the outlet is absolutely necessary to make use of Cache Creek for irrigation. With no appreciable snow storage in its watershed, the headwaters streams of the creek rise rapidly

after rains and almost as quickly sink back to the very low base flows supported by limited groundwater storage. To make water available year-round for the original milling operation, or for summer irrigation, storage is required. The occurrence of a large lake with a narrow outlet provides water appropriators with an opportunity to store a considerable quantity of water without spending much on the dam.

Some say that water lawyers take home more money in California than any other specialty. Surely, some have made money fighting over Clear Lake water. The Clear Lake Water Company's dam flooded many homes and farms built around the lake in its first year of operation. Complaints to the company went unheeded and the flooding recurred in the second year. The water company thwarted attempts by flood victims at legal relief. In November 1868, frustrated Lower Lake Judge J.B. Southard could find no provision for relief under civil law, but remarked in dismissing the case *there is such a thing as a higher law.* Thus encouraged, an armed body of 300 determined but well disciplined citizens led by J.W. Mackall gathered at the mill. They restrained the miller and all the county officers resident in Lower Lake. After allowing Sheriff Manlove to do his duty by reading the Riot Act, they destroyed the mill and dam. A series of lawsuits by the water company eventually resulted in the county agreeing to pay $20,000 in compensation.

Lake County residents have never been comfortable with the appropriative water rights doctrine that gives ownership of Lake County's water to its downstream users in Yolo County. According to this doctrine, water does not belong to the landowner through whose lands it flows, but to the first user to divert the water for a useful purpose. This doctrine has its origins in the Middle East and came to Spain with the Moslems during the Middle Ages and hence to the West in Spanish colonial times. Economically, the doctrine makes sense in a water-short environment. Lake County farmers and city users have no way to use 90,000 acre feet of water from Clear Lake, whereas it can be applied to great effect on the huge expanse of flat fertile farmland in Yolo County. Nevertheless the doctrine grates on local residents. During the 20th Century, Lake County has taken the Yolo Water and Power Company and its successor public Water Conservation District to court on several occasions, resulting in a succession of legal decrees mandating how the lake will be managed. The issues are nearly the same in every case; lakeside residents would like the lake to remain at a constant level year round, if that were possible. Water storage requires capturing winter flood flows, giving rise to the threat of winter floods around the lake. Lakeside residents would like to get extreme winter flows down Cache Creek as quickly as possible to reduce lakeside flooding. Downstream resident would like to see flood flows stored in Clear Lake to reduce streamside flooding. In dry years, irrigators would like to draw the lake down far below its normal low stand, but low lake levels strand lakeside recreation facilities. Thus, legal decrees now specify in considerable detail how water is stored and withdrawn from the lake. Levels are established in terms of a gauge installed by a pioneer named Rumsey in 1872. The Gopcevic Decree (1920) dictates how the lake's rise in winter will be scheduled to leave storage for flood flows. The Bemmerly Decree (1940) prohibited the deepening of the sill at the Grigsby Riffle, near the Highway 53 Bridge, so that large flood flows have a smaller tendency to do damage in the Capay Valley and around Woodland. The Solano Decree (1978, revised 1995) regulates the allowable releases from the dam, depending upon water storage. If the water level on March 31st does not go above 3.22' on Rumsey's guage, Yolo County can take no water from the lake. In the drought years 1977 and 1990 Yolo County in fact

drew no water from Clear Lake. If it rises above 7.56', downstream irrigators get up to 150,000 acre feet of water, enough to irrigate 50,000 acres (80 square miles) of farmland. This set of regulations has done well to keep the conflict out of the realm of *higher law*. You may be sure that the staff of the Lake County Flood Control and Water Conservation District plot the lake's level day by day to check to be sure that Yolo County staff adhere to the letter of the decrees. Yolo County in turn carefully polices water usage in Lake County to prevent any encroachments on their water right. Lake County cities must purchase Clear Lake water from Yolo County, a fact that peppers local eyes. Right here within our own bioregion, we have in microcosm the water wars that are endemic in the arid West.

Dam Road is closed by a gate a mile or so upstream from the dam. Cache Creek is navigable all the way down to the dam, and if you have the time and a boat the trip is quite worthwhile. The last mile and a half before the dam is nearly wilderness.

Lower Lake to Clear Lake State Park

Lower Lake's main street is of some interest and the Schoolhouse Museum at the southern end of commercial district is worth a visit.

Our route takes the slow road around the southwestern perimeter of the Lower Arm of the lake on Point Lakeview and Soda Bay Roads. As we drive up Highway 29 out of Lower Lake, you may notice the smell of the lake, a mellow mixture of sunny rocks, oak trees and algae. In the Young Man's opinion, this pleasantly biological smell represents the lake perfectly; the gentle landforms, the lush oak woodland flora, and the simple but extraordinary aliveness of the lake environs. We climb the hill and turn right on Point Lakeview Road (following the sign to Jago Bay), almost two miles from the Highway 29-53 intersection in Lower Lake (This intersection will be our zero mileage point until we reach Lakeport). As we turn, the first vineyard of the tour is visible on the right. Grape growing is the latest agricultural fashion around the lake. Also visible down to the right, on the shore of the lake is Anderson Marsh. Before our first big views of the lake, the hills opening around us provide a good representative sample of the plant life of Clear Lake. The hills surrounding the lake are covered with a pinto mosaic of the light green bushy fuzz of short oak trees, large dark patches of nearly pure chamise, and thick scrub oak and manzanita chaparral. Scattered about are conifers, bays, toyons, redbuds, ceanothus and many other species. In the vineyard at the beginning of Point Lakeview Road note the ponderosa pines and black oaks, mountain species coming down toward the lakeshore. The vegetation cover ranges from thick to impenetrable in most places, but is broken by patches of tan grass, green in the winter and spring. On a spring day this vegetation, as in so much of lowland California, is as soft and lovely as any on Earth. The Old Man remembers an April visit to the lake a few years back straight from a clammy, gray winter in northern Germany. "Yes!" his soul sang, "*this* is a place fit to live in." Cooler north facing slopes and lower elevations tend to encourage the oak species- interior live, scrub and blue, as well as interesting crosses, while wetter areas are often populated by madrone and canyon live oaks. South facing slopes sport chaparral or open grassy glades. In the autumn, the camouflage greens of the hills are peppered with beautiful reds and yellows. Hidden below the canopy is an understory of grass, weeds, herbs and the bright poison oak that the Young English Major cannot pass up describing as rash-gold-vermillion. The valley floors, where they are not rowed into orchards and fields, are carpeted with wildflowers and Cal-ubiquitous Mediterranean weeds, studded with the few remaining

majestic valley oaks. Along Point Lakeview Road, you may see redbuds, blue and black oaks, clematis, gray pines, bays, buckeye, snowdrop bushes, and western hop trees. These last two are rarish shrubs in general, but abundant here. The lake moderates the climate, bringing highland species that resent summer heat downhill and allowing cold sensitive ones to climb a little.

Look for green or reddish surface patches on the water; their presence indicates that one of the common algal blooms is in progress. At mile 3.2 (from the intersection in Lower Lake, remember) we can see on the left the bright red rock of a volcanic cinder cone that is being mined for decorative rock. You may notice that some of the roads around the lake are paved with this red rock. Volcanics around Clear Lake have provided valuable resources to enterprising miners. Unfortunately the exploitation of these resources has often resulted in the rough scarring of the natural scenery, as at the cindercone site. Worse, it has resulted in health hazards to local people and wildlife, as at the Sulfur Bank Mercury Mine, which we will reach near the end of the tour. At mile 3.5, Thurston Lake appears on the left. This lake always has the same turbid brown-gray color. The reason for this color is a little scientific mystery that some enterprising investigator should take the trouble to solve. The ridge the road travels on is a large lava flow that has dammed Thurston Creek, creating the lake. Most likely, the lake remains small because the lava flow is porous, allowing the water to drain. The lava surfaces around the lake are all quite highly fractured and seldom have surface streams. The Clear Lake area is really a lake district in which a number of basins have been formed by volcanic damming. Clear Lake itself is merely the largest of these, where lava flows around Lower Lake plugged the Upper Cache Creek Canyon and flooded the flat valley upstream. Shortly after passing Thurston Lake we get our first good view of Clear Lake. 4.1 miles later we are treated to our first view of the volcanic centerpiece of Clear Lake, Mt. Konocti.

The mass of Konocti, a rounded hump of a mountain, stands well above the surrounding hills, its peak rising to an altitude of 4,200 feet. The lake surface is 1,318 feet at low water, zero on Rumsey's gauge. It is nearly completely covered by especially thick chaparral. Regrettably, access to its summit is restricted by private property. The view from the summit is especially fine, and a grove of huge Canyon Live Oaks stands along the way. A dormant volcano, Konocti erupted from around 600,000 years ago to around 300,000 years ago, and accounts for 13 cubic miles of lava. According to local legend, an open vent at the summit was dynamited shut in the early years of white settlement, after two boys fell in and died. In the belief of many respectable local people, including the former chief geologist at Homestake Mine, there exists a catacomb of caves and tunnels inside the mountain which open somewhere under the lake. There are Indian stories of carved sticks thrown into the crater that were later found floating in the lake. The most easily observed basis for these ideas is that the mountain breathes. As the barometric pressure changes, large amounts of air move into and out of the mountain causing perceptible drafts around certain vents. Recently, curious local explorers have attempted to discover and dig out the dynamited vent, without, as yet, finding anything more than small caves. Several narrow volcanic vents puncture the floor of the lake. Divers have failed to reach the bottom of the larger of these vents that may be hundreds of feet deep. Some of them discharge considerable quantities of gas bubbles and perhaps water. The flows are quite variable. When the large hole west of the Buckingham Peninsula is flowing strongly, locals claim that a dome of water too steep to row a boat up forms on the surface. On a high-resolution echosounder, this and similar smaller vents appear as conical pits set into the lake sediments with curtains of bubbles rising toward the

surface. Occasionally, the accumulated mud slumps into the holes and is blown up to the surface to make a conspicuous plume. The deepest parts of the lake are areas of volcanic rubble in the Lower and Oaks Arms where diffuse gas flows keep muddy sediments from accumulating.

Konocti was of special importance to local Indians. As well as figuring heavily into their religion and mythology, (Konocti means Mountain Lady in one local Pomo language) the volcano created immense deposits of high quality obsidian, which the Indians made into various tools and projectile points for daily use and trading. European settlers called Konocti "Uncle Sam Mountain," but the more sonorous Indian name has endured. Unfortunately the Indian name for the lake itself, Lypoyomi, meaning Big Water, has not stuck; it is certainly more apt than the present misnomer.

Konocti, the underwater shafts, and the various hot springs and cindercones in the area are all products of what geologist call the Clear Lake Volcanics. This volcanic field covers a large area from the lake shore between Lower Lake and Soda Bay, southward towards the Geysers Steam Field in the Mayacmas Mountains 10 miles west of Lower Lake. A line of young vents marches north from Lower Lake past the east end of the Oaks Arm and into the hills north of Highway 53-20 intersection. Eruptions began 2.1 million years ago and some of the youngest flows occurred about 10,000 years ago. The oldest eruptions were to the south and the most recent vents are along the northern fringe including those in the lake floor. The source of the volcanic eruptions at the surface is a magma chamber 14 km in diameter with its top 7 km below the surface of Mount Hanna near the western edge of the surface volcanic field. The composition of surface flows ranges from heavy basalts indicative of melted oceanic crusts to light rhyolites characteristic of melts from continental rocks. (Continents are like the foam on top of soapy dishwater; big chunks of lighter rock floating on the heavier rocks of the deeper crust and ocean floors.) Magma bodies are often quite complex, as this one is. As the hot, heavy, iron rich mantle basalt carries heat up from deep in the earth, it melts or partially melts the lighter, silicate rich continental rocks it pushes up into. The magma chamber becomes a complex system with hot basalt at its core and cooler melted continental rock tending toward the production of rhyolite on the top and sides. Some basalt may be hot enough to punch all the way to the surface, whereas other vents only tap the peripheral parts of the melted mass. Most of the characteristic red lava found around the lake is basalt; it's iron oxidizes to a characteristic rusty red color.

Localized stretching of the earth's crust in the vicinity of Clear Lake is responsible for both the opening of the Clear Lake basin and the intrusion of magma toward the surface. For the most part, the Coast Range is under compression from the pressure of the Pacific Plate offshore bearing against the North American Plate inland. Currently, this compression is insufficient to create a subduction zone, in which the heavy, iron-rich Pacific Plate would dive down under the light, silicon rich North American plate. Instead, the compressive forces are pushing the Coast Ranges toward the sky. However, such subduction did occur in the present position of the central and outer coast ranges from about 160 million years ago until just 10 million years ago when subduction ceased and the two plates began sliding sideways along the San Andreas fault system. The whole Coast Range is now being dragged northward by the friction of the northward motion of the Pacific Plate relative to the North American. Hence dozens of nearly vertical faults, large and small, parallel the main San Andreas, shearing the mountains into the northwest-southeast trending of the ridges and valleys of the Coast Range. Towards the end of Point Lakeview Road,

we cross the Konocti Bay Fault that thereafter runs along the southwestern shore of the Lower Arm. Bends in the fault system produce local stretching directly against the grain of regional compression, creating "pull-apart" basins. Instead of sliding more or less smoothly past one another, a block jams and twists sideways, forcing adjacent blocks apart. Blocks of rock topple into the pull-aparts, creating down-faulted basins such as the one occupied by the Upper Arm of the lake. Alternatively, magma can well up from below to fill the gap, resulting in the shallow magma chamber and surface volcanics of Clear Lake.

At mile 8.7, the Point Lakeview Road dead-ends into Soda Bay Road, where we make a right. In some road-cuts around this intersection, we can see where the red volcanic soil has begun to form sedimentary layers in miniature basins on the lava flow surface. On our right at mile 11.3, we see our first walnut orchard. Though it has always struggled as a moneymaker, walnuts are one of the oldest and most popular crops around the lake. On the right side of the road at this same point is Konocti Harbor Resort and Spa, built by the San Francisco Plumber's Union Pension Fund. This is the modern version of the once booming spa business on Lake County. The resort features lake tours, boat rentals, and various water sports. Its concert hall, says the Young Man, is where bands go to die. Anybody remember the Spin Doctors? Nevertheless, the bands that Konocti Harbor books are relatively big-name for such a remote place. We're told this is because a quirk of the standard promoter's contract puts Clear Lake just outside the Bay Area. Promoters insist that a given act not play another competing gig in the same area on the same tour. Konocti Harbor can book groups already visiting the Bay area more inexpensively than it could book acts playing only at Clear Lake. Konocti Harbor is currently the only large resort on the lake. Most are small-scale Mom-and-Pop operations. Paradoxically, small resort owners and planners tell us, more large scale resorts would be good for the small operators: Larger resorts can afford to advertise and draw the first-time visitors who then discover the smaller resorts and other tourism-related businesses. Since few large parcels are available around the lake, the prospects of more large anchor resorts is cloudy. Indian gaming may furnish the capital to launch larger-scale resorts.

Boating, skiing, and jetskiing are to some the glory of Clear Lake. In his (even more) formative years, the Young Man would have agreed whole-heartedly. Noisy nuisances grumbles the Old Man. Motorized water sports are extremely popular on the lake, and account for a sizable chunk of the local economy. The water is reliably warm enough for comfortable swimming and skiing from Memorial Day until Labor Day. In pursuit of such pleasures, boat ramps and lakeside vacationers' docks have replaced much of the original shoreline, 2-stroke engines pollute the lake, and in the past few years, the manic buzz of jetskis has become a nearly constant serenade to anyone strolling the more populated shores of the lake. Those averse to such shenanigans are cautioned to avoid weekends, especially big holiday weekends; a lot of people will be on hand for fun in the sun. Across the cove from our family's plot on the lakeshore is a big cabin owned by a Bay Area Scandinavian social club. They can be heard a mile across the water on a calm summer night singing old-country songs, fueled by old-country drinking habits. If a good party on the water is your thing, this is your lake. However, mass water-oriented tourism is heavily concentrated in summer weekends. The buzz-boat sensitive should plan on visiting on summer weekdays or in fall or spring or even winter. A warm, clear spring day when the redbud—the biggest star in the diverse show—blooms, finds the mountainous sections of our Bioregion tricked out in a costume that puts a rainbow in the shade.

1.3 miles past the resort, Crystal Way splits off to the right. You can follow this road on a scenic loop around the point, which protrudes out into the lake where the three arms come together. Eastlake Drive runs north on that side of the peninsula, and Westlake Drive connects back to Soda Bay Road on the other side. Cross streets run east-west across the peninsula. Ot the beginning of the detour, notice Little Borax Lake at the root of the peninsula. This is one of two places in Lake County where borax was mined in the middle of the 19th Century. We come to Borax Lake proper toward the end of our journey. Remember that the mileage of this detour is not included in our count. Beginning at the departure point of the detour, but remaining on Soda Bay Road, we now enter a dark, damp Douglas Fir forest on the north facing of Mt. Konocti. This grove stretches about half a mile along Soda Bay Road. It is a most spectacular example of a moisture-loving community being drawn down to near lake level. Among the firs are many madrones and bunch grasses. Small though it is, this dark grove creates a cool, quiet deep forest feeling not found elsewhere on the lake.

The bunch grasses mentioned above are perennial natives that have resisted the invasion of Mediterranean weedy annual grasses that so dominate California's lowland biota. Botanists don't know exactly why California's grasslands have proven so vulnerable to invasion from the Old World. One possibility is a different history of grazing. All of North America lost many genera of large grazing animals at the end of the last glacial epoch 11,000 years ago. In Eurasia, people began to domesticate livestock at nearly the same time. Herders protect their stock from predators and are able to maintain numbers of stock at considerably higher than natural numbers. California has had ten millennia of sub-normal grazing pressure and the grasses and other herbaceous plants may have lost a good deal of their grazing resistance. Plants from the Old World have had the same span of time to adapt to artificially severe grazing pressure. Perhaps the grazing-adapted grasses followed the cows as their intense grazing fell most heavily on the poorly adapted natives. The main adaptations of the exotic annuals is not so subtle. They put much of their biological energy into the elaboration of seed heads into miniature fortresses protected by long, rough, bristly awns that are unpleasant for grazers to eat. Their seeds are large and the resulting vigorous seedlings punch through any accumulated litter and rapidly outdistance competitors. The bunch grasses flower later and set fewer and smaller seeds that are less obnoxiously armed. If grazed too far into the spring, the perennial plant may set little or no seed. Although the clump can survive the dry season in a dormant state, hungry animals may kill the plant by eating the whole plant, especially when droughts make overgrazing most severe. Keep your eyes open for similar relict stands of bunchgrasses. Though no longer dominants, they are by no means rare in relatively lightly disturbed upland areas. Native grass enthusiasts have collected many local populations and propagated their seed for restoration purposes. If you are a gardener, you may feel like propagating your own finds. Most make interesting specimens and will stay green with modest amounts of summer water.

At the spot where Westlake Drive from the Buckingham Point returns to Soda Bay Road, pull across to the small parking space on the shoulder and stop. Taking care for the narrow and somewhat busy road, walk along the road until you can see down to Horseshoe Bend, the cove where point intersects the mainland. If a significant bluegreen algae bloom is on, the scums are thick enough to see quite clearly. The water within 10 to 20 yards of shore will be conspicuously greener or redder than the water further out. The prevailing northwesterly winds blow the algae

into embayments that face in that direction, resulting in significant concentrations. These algae scums can be quite abundant and can seriously detract from the appeal of aquatic recreational activities. Patches of algae a few millimeters thick float on the water surface like olive drab paint. The worst bloom on record was The Great Microcystis Bloom of October 1990. On that occasion, packed mats of algae 4 feet thick collected in places like Horseshoe Bend. The buoyancy of the algae lifted the top inch or two of the mass above water, and a dry crust formed. Beneath the crust, algae died and decayed. The Old Man remembers this bloom giving off odors redolent of a poorly run fish cannery. Where you are standing the smell rising from Horseshoe Bend was like a wall, and many residents of the Buckingham subdivision moved to motels for the duration. Substances given off included methyl mercaptin, a rotten meat odor to which humans are extraordinarily sensitive. Scientific studies of the Great Bloom were rudimentary, but we do know from monitoring data collected by the Department of Water Resources that the culprit was in the genus *Microcystis*, and that it occurred in a period when the ongoing drought of the late 1980s and early 1990s was wreaking havoc with the lake's nutrient regime. Interestingly, with the collapse of this colossal bloom, the cyanobacterial biomasses have remained rather modest compared to the recent past, and bottom-rooted waterweeds have become common for the first time since the 1920s. Algae and waterweeds seem to have an inverse relationship in Clear Lake; when bluegreens are abundant, the water becomes too turbid for waterweed seedlings to grow in the spring and early summer. Since 1930, blooms have caused problems for recreation on the lake. Usually most of the bluegreens are suspended in the water and are not particularly noxious. Scattered patches of scums cause localized problems, especially at sites where the prevailing wind causes drifting scums to accumulate. The National Resource Conservation Service estimates that in a normal algae year losses of tourism amount to some $7 million.

Once you get past the "ick" factor, bluegreen algae are fascinating organisms, the Old Man holds. Some of the oldest fossils known, dating back 3 billion years, are bluegreens. These simple creatures of the lake are some 20 times older than the oldest rocks in our bioregion! As their technically preferred name "cyanobacteria" suggests, these forms are giant photosynthetic bacteria. Their individual cells are ten to a thousand times larger than typical bacteria and are easily visible in a light microscope. The scum forming species live in colonies of hundreds to thousands of cells that reach the size of pinheads. Other algal plankton are normally a hundred or thousand times smaller, making the colonial bluegreens the redwoods of their kind. For a billion years or so these were the dominant photosynthetic organisms of the earth. The oxygen they produced during the Archean and Proterozoic Eons was consumed by the reduced sulfur and iron in the earth's oceans for perhaps two and a half billion years before photosynthesis was finally sufficient to tip the balance and create an oxidizing environment in which animal life was possible. Animals sufficiently sturdy to fossilize regularly date back only about half a billion years. Over the course of 3 billion years, bluegreens have evolved some neat tricks. The reason that they form noxious scums is that many species have gas vesicles they can use to regulate their buoyancy. When the water is turbid, they can float to the surface where plenty of light is available. Many species can also fix atmospheric nitrogen like the bacterial symbionts in the root nodules of legumes. Eutrophic lakes are generally turbid and many, like Clear Lake, are richer in phosphorus than in nitrogen. Buoyant, nitrogen-fixing bluegreens are well positioned to take advantage. Taking their nitrogen from the air and floating upward into the lighted waters while they shade their competitors beneath, they can become nearly 100% of the algal crop. More

"advanced" eukaryotic algae often dominate under other conditions but usually can't match the ancient cyanobacteria under nitrogen poor but otherwise eutrophic conditions.

The strategy does have drawbacks. Nitrogen fixation is energetically costly, and the floating trick requires those big cell aggregations. Single cells would have too much surface drag to move under the small differences in density relative to water that bluegreens can generate. By the same token, nutrients from the water only slowly diffuse into the large masses of bluegreen cells. Hence bluegreens grow slowly and much like many slow-growing terrestrial plants, they have toxins to protect themselves from too much animal grazing. The floating strategy in any case needs to be cleverly balanced lest the colony become stranded at the surface to be cooked by the sun. The trick is to float up at night to get to the surface and then become heavier than water by midmorning so as to spend the heat of the day in the top two or three feet of water. This layer is heated by the sun and doesn't mix downward until late afternoon. Surface scums that persist later as surface scum often do so because they are starved for nutrients and cannot manufacture enough heavy carbohydrates during the first hours of morning light to sink. High light towards midmorning then damages the photosynthetic apparatus and cells begin to die. Dead cells in turn release their water-soluble pigments (the most conspicuous one is blue) and become pale, bleached hulls. Ugly! Even The Old Man admits it.

Ugly, but to the curious naturalist fascination is independent of postcard standards of beauty. If you chance upon a good bloom consider yourself lucky see a wonderful complex of adaptations. Also, this is the one of the best opportunity in our otherwise very youthful bioregion to meditate on deep time. Contemplate the humble, ancient, bluegreen. Close your eyes, pinch your nose, and let you mind drift back to times near the origins of life on earth, about 3/4ths of the way back to the formation of the Earth and $1/5^{th}$ of the way back to the Big Bang. Without the eons of hard work by bluegreens, it really wouldn't matter if you held your nose or not; the gas-chamber atmosphere would kill you in moments.

Clear Lake State Park

The turnoff into the Park is at mile 17.2. Park facilities include numerous excellent campsites, a life-guarded swimming beach, and boat launching facilities. The Rangers are friendly and visitor-oriented. Inside the visitor center is a nice display of some of the wildlife in and around the lake. The 3 mile long Dorn Nature Trail gives an excellent introduction to the plants and animals of the region. The park is a good place to observe the lakeside plant community. Valley oaks dominate the deep alluvial seasonally flooded soils. The wet soils at the lake margin are dominated by willows and cottonwoods and in some places grow abundant buttonwillows. California wild grapes, blackberries, and poison oak form a thick undergrowth where they are not cleared. The hills are home to mountain lions, deer, elk, and black bears. Badgers, skunks, mountain quail, foxes and coyote move through the underbrush, while blue-bellied western fence lizards and long, slick, lanky, aggressive alligator lizards hide in the rocks. In and above the trees live great horned owls, flickers, hummingbirds, doves and woodpeckers. The visitor center sells a checklist of birds and other pertinent natural history information. The lake itself supports mink, river otters, raccoons and a considerable variety of waterfowl.

Human disturbance once eliminated or much reduced populations of fish-eating wildlife of Clear Lake. These populations have been recovering, thanks to various manifestations of our

generally increased sensitivity to environmental issues. However, some populations, such as the Bald Eagles' are still quite delicate and small, and some, such as the grizzly bear, have never returned. The most serious single insult was the repeated mass application of a chlorinated hydrocarbon pesticide related to DDT, called DDD. Historically, swarms of the Clear Lake gnat, a small insect related to mosquitoes, detracted greatly from the tourist experience around Clear Lake. Gnat larvae live in the lake, floating in the water column at night to hunt the abundant small crustacean prey that a eutrophic lake provides, and hiding in the mud during the day to avoid fish predation. They are elegant little creatures, nearly transparent and using gas bubbles to regulate their buoyancy in the water. Blind, they lurk absolutely still until they sense the wake of a passing prey, which they follow to attack their victim. Although the adults do not bite, they sometimes hatched in huge numbers in the summer. Swarms were attracted to lights, and old-timers claim they sometimes accumulated under streetlights in Lakeport to depths of 3 feet. Outdoor activities after dark were impossible, and even behind screens, the high-pitched whine of thousands of gnats swarming to get to the lights was unnerving. In the late 1930s, the Federal Government sent a team of biologists to the lake to find a way to control the Clear Lake gnat. Their work is the earliest sustained scientific investigation of Clear Lake.

After World War Two, gnat work resumed, now with the new tools of synthetic pesticides. As one member of the team, Garth Murphy, related the story to us, the scientists aimed to be cautious in their use of these powerful killers. They build a series of small ponds and stocked them with a suitably diverse selection of lake biota and tried several different pesticides. Choices at the time were limited. DDD gave good control of Gnats at levels that were non-toxic to other biota in what the investigators considered conservative long term experiments of about 3 weeks duration. Three massive, lakewide applications of DDD where then conducted in 1949, 1954, and 1957. The first application gave complete and effective control for several years. The Old Man remembers the time when faith in magic bullets like DDT and penicillin was common among the technically literate. The subsequent application was less successful and the third failed to achieve adequate control. The persistent DDD compound lingered in the sediments, and exerted tremendous natural selection for resistance to the compound. The few gnats that could survive in the presence of a little DDD in a poorly treated backwater survived, and any individual with real resistance to DDD had the most of the lake to itself. Complete resistance thus evolved in less than ten years. The Mosquito Abatement District switched to a different class of pesticide, Parathion, for control. In the meantime, western grebes, the most abundant fish-eating bird at Clear Lake, suffered a reproductive collapse. Investigations by California Department of Fish and Game biologists turned up high levels of DDD in their tissues and found that DDD accumulated in food chains. As it notoriously turned out, chlorinated hydrocarbons are stored in fat and metabolized to harmless substances at very slow rates. They also break down in the environment very slowly. Aquatic animals accumulate these compounds from the water and from their food, and pass them on to their predators. Longer-lived species higher up the food chain have progressively higher concentrations. Fish-eating birds at the top of the food chain become the inadvertent focus of the re-concentrated of DDD. The status of the larger fishing-eating wildlife such as osprey, eagles and otters at the time of the DDD application is not recorded, but if significant populations persisted in the face of human harassment up to the fifties, they would also likely have been devastated by DDD. Clear Lake was one of the first two well-documented cases of food chain accumulation of chlorinated hydrocarbon pesticides, and garnered more than a page of discussion in Rachel Carson's famous *Silent Spring.* Thus, the

long-term tests of the Clear Lake Gnat researchers turned out to be woefully inadequate. In defense of Murphy and his colleagues, chlorinated hydrocarbons are very devious compounds. Very few synthetic chemicals are as stable and very few accumulate in food chains. The lesson we draw from Clear Lake's hard lesson with DDD is that, scientific uncertainty being what it always is (great), being prepared to quickly discover and correct mistakes is as important as trying not to make mistakes in the first place. The grebes of Clear Lake suffered, but alert actions by Fish and Game investigators saved the population and made an important contribution to our knowledge of the dangers of chlorinated hydrocarbons to boot.

Interestingly, the Clear Lake gnat has not been a serious pest for decades. While the Parathion treatments continued, a Mosquito Abatement District worker accidentally—some say deliberately and certainly illegally—introduced an experimental control organism, the Mississippi silversides, into the lake. When the parathion treatments were stopped in the mid 1970s, populations of silversides were abundant. Although work by UC Davis scientists at the time could not verify that the silversides were having any impact on the gnats, in fact gnats have remained at low numbers. The Mosquito Abatement (now Vector Control) District staff continues to closely monitor gnat populations for fear that ongoing changes in the lake might one day again unleash them. Our Vector Control Districts are, incidentally, the all too seldom recognized front line defense against much more serious pests than gnats. For example, malaria was a vicious problem in the Valley and around Clear Lake beginning with the movement of European settlers into the marshy habitats in the 1830s. The diligent mosquito control that we take too much for granted is responsible for our current near-freedom from this menace.

The current status of most fish-eating wildlife is excellent. When UC Davis investigators began intensive Environmental Protection Agency funded studies at the lake in the early 1990s, about 10 pair of osprey nested at the lake. Successful nests averaged about one and a half fledglings, a number experts consider sufficient for a growing population. Sure enough, by 1999, 20 pairs successfully nested. In 1999 a bald eagle pair nested at the lake and unconfirmed reports suggested a second nest. Osprey, unlike eagles, are not shy of humans, and have nested right at the Park swimming beach in years past. Since nests are often in unsound cottonwood snags, pairs move from year to year. Ask rangers if any nests are active in accessible areas. Osprey can catch quite large fish, and seeing one successfully plucking from the water a fish weighing nearly as much as itself is quite a sight. UC Davis investigators' work on western grebes show that they today carry hardly more than the regional background levels of chlorinated hydrocarbons. Grebes are typically present at Clear Lake in considerable numbers; Audubon Society members have found as many as 10,000 in the Christmas bird count. Grebe reproduction on the lake has been sporadic in recent years, most likely because of too much human activity around their tule marsh nesting habitat. Most of the remaining tule marsh on Clear Lake is the narrow fringe strip that is exposed to close approach by boaters. Boaters should take care to stay well away from tule stands where grebes show any signs of nesting. Other fish-eating birds that are now common on the lake include other species of grebes, double crested cormorants, white pelicans, belted kingfishers, and great blue herons. A considerable variety of ducks winter at Clear Lake. The abundance of all these spectacular birds is one of the chief payoffs of a eutrophic lake. Enjoy them!

If you are lucky or patient you may get a chance to observe the mating display of the western grebe, one of the most dramatic of any species. The pair begins with a vigorous display of synchronized head bobbing, then take off half flying, half running side–by-side across the water with heads held high for 50 yards or more before, still in perfect synchrony, abruptly diving beneath the water. Bird behavior doesn't get much more breathtaking.

State Park to Lakeport

Return to Soda Bay Road and turn right towards Lakeport. Just after leaving the park we can see a row of giant valley oaks to the right of the road. Half a mile after this we are off of the volcanic landforms and onto the flat agricultural land of Big Valley. This area was the cradle of white settlement and is still the leading agricultural area around the lake. At mile 18.1 we see Bartlett pears, Lake County's most famous export, growing on the left. Just afterward, we bear right, remaining on Soda Bay Road, the left fork leading to Kelseyville. At mile 18.5 we cross Kelsey creek. In the late spring, it is worth stopping to see if the hitch are running upstream to spawn. Hitch are one of the big native minnows that historically dominated the fish fauna of lowland California. As described in Chapter __, introductions of sunfishes, catfishes, carp and others have greatly impacted the native populations. In Clear Lake, hitch and Sacramento blackfish (a lake spawner) still thrive, but two other important stream-spawners, squawfish and splittail, declined sharply in the 1940s. Most likely, the widespread use of electric irrigation pumps lowered water tables and dried up the lower reaches of stream-spawning habitat too early in the year for these species to successfully reproduce.

Kelsey Creek and other major streams were also extensively mined for gravel from the late 1920s until the early 1980s, when county regulation began to move extraction to off-stream sites. Notice how deeply Kelsey Creek is incised into the Big Valley alluvium. The downcutting here is ironically due to the opening of the tule marsh and delta at the mouth of the creek to develop the boat harbor at the State Park about 25 years ago. The lower reach of the stream began to flow faster when in flood eroding itself deep into its bed. Even seemingly small and innocent environmental modifications can have serious consequences.

The mystery of the misnomer "Clear Lake" may lie in this fact. While never as clear as an oligotrophic lake like Tahoe, the few reliable reports from the early years all suggest a relatively clearer lake than scientists came to know beginning in 1938. In the mid 1960s, when he was 60, John Jago, brought up on the lake as a boy and later operating his family's resort on Jago Bay, gave a long reminiscence to the Lake County Historian. When he was a youngster, waterweed growth was abundant in the lake, as it has been in the recent clear-water years. Jago thought that increasing sedimentation gradually caused the lake to become cloudier due to these sediments in winter. Scientific research has generally endorsed Jago's hypothesis. We know that sediment is rich in phosphorus, and is likely to encourage nitrogen-fixing bluegreen algae. Disturbance of stream channels and land surfaces began on a large scale with the development of heavy powered earthmoving equipment in the 1920s. Around 1925 the modern types of heavy earthmoving equipment, led by Caterpillar Tractor's innovative bulldozers and motor graders, began to see widespread use. Road-building, mining, wetland filling, diking, aggregate extraction and similar types of projects were revolutionized as the cost of moving a cubic yard of loose material fell by a factor of ten or more. Coincidently or not, the lake still supported abundant rooted bottom vegetation in 1925 when a Department of Fish and Game biologist made a

reconnaissance visit, but by 1938 federal gnat investigators found a turbid lake largely free from this vegetation. Heedless use of heavy equipment is one of the likeliest culprits in the deterioration of the lake's water quality. Still, Clear Lake was always eutrophic and will always remain so. Livingston Stone, a government fish culturist who attempted to establish Great Lakes whitefish in the lake in 1872-3, complained about the turbidity and "swamp-water" taste of the lake. He ripped the namers of the lake: "it is a singular fact, illustrating the inaptness with which names are often given to natural objects, that the water of Clear Lake is never clear." Nevertheless, he noted that rooted vegetation was abundant. Abundant bluegreens have shaded out such vegetation in most years since the 30s. The fact that Clear Lake is naturally eutrophic does not imply that the heavy scum growth of the 20th Century was a natural or necessary condition at Clear Lake.

At mile 19.2 we come to a county park with lake access. The park is about a mile down Park Drive from Soda Bay Road. If you walk out to the end of the jetty to the left of the boat ramp and look a few hundred feet to the left, you will see a large tule marsh along the shore. If you have a boat or canoe, this park is a good place to strike out to explore the tule habitat. Boating is really the only way to get a good close look at these habitats; you cannot get more than a glimpse of this one from the shore. These tules, backed landward by cottonwoods and willows, are the type of natural shoreline that has been replaced along much of the shore of the lake. Along the toe of Big Valley, the gently sloping and soft ground leaves a wide marshy shore that is difficult to farm or develop. Hence the best-preserved marsh is along this stretch of shoreline. The tules are a favorite environment to many species of fish, as well as home to crawdads and clams. Something of the importance of tule marsh to the lake is illustrated by a Department of Fish and Game study showing that fish abundance along tule beds is about double that of shoreline where tules have been removed. Western pond turtles can often be found sunning themselves on the tops of boulders sticking out above the water among the tules, and otters and mink make their homes among the reeds while blue herons, mallards and grebes cruise through the air or over the water. Cormorant colonies use the lakeside trees for roosting and hunt on the tule fringes. Recognizing the importance of these habitats, Lake County has instituted tule preservation and mitigation requirements for developments that disturb the remaining marshes. You will see newer floating boat docks with their access ramps raised over the tules rather than driven through them. Areas cleared of tules in new projects are minimal, whereas the old style was to tear them out entirely to produce a clean beach or wall. You may spot informal tule replantings beginning to reclaim some of these stripped beachfronts. Lakeside residents generally want to do right by the lake, and the era of creating lots of barren shore is past.

The turnoff to the quaint agricultural town of Finley is on the left at mile 20.9. It sports an excellent Mexican restaurant, the only currently active retail business. Although American fur trappers traveled to Lake County as early as 1833, and Salvador Vallejo ran cattle in the area from about 1840 onwards, it was crop agriculture that first drew settlers to Clear Lake in any numbers. After the Gold Rush brought waves of people to California and then disappointed most of them, they needed a place to make their living, which meant farming for the majority in those days. Beginning in the 1840s, families began moving into Big Valley, clearing land, grazing cattle and experimenting with crops that might yield well in the hot, dry climate. Settlement was inhibited by Vallejo's vast land claim, which was declared invalid in 1866, fully opening Big Valley and the other rich valleys around the lake to homesteading by Anglo settlers. By the

1870s, Anglos had firm control of the area. At this time farms began to change from subsistence to commercial operations. Grapes, walnuts and pears were among the cash crops that farmers experimented with, but pears proved to have the most lasting value. Also in the last half of the 19th century, mineral spring resorts began to pop up in the hills around the lake. It was this industry for which Clear Lake was most famous for during this period. Thousands of vacationers every year were brought to the remote spas by trains and overland coaches for month-long health retreats.

By 1900, most farms were commercial, using Indian and Chinese labor (later to be replaced by Mexican workers). Sawmills, mines and canneries began to open and settlement constantly if slowly increased. Lake County grew approximately in parallel with the rest of California, albiet on a smaller scale. Its remote location, exacerbated by difficult transportation, has always held back the prosperity of the area. From 1850 to 1925 there were many efforts to have a rail line put into Lake County, but one was never built. The steep topography and weak rock of the surrounding area make construction and maintenance of transportation links expensive, and travel over them slow. For example, Highway 20 from the east is subject to rockslides. You may have noticed the extensive work CalTrans has done to the worst sections. The Hopland Road, State Highway 175 from Lakeport to Highway 101, may be the crookedest 15 miles in the entire statewide system, and the Saint Helena Grade on Highway 29, the main route into the County from the Bay Area, is not a whole lot better. The easiest route into the basin is Highway 20 from Highway 101 at Redwood Valley, but it just connects Lake County to more lightly populated rural country. Even quality two-lane public roads were late in coming, and today there are no freeways leading to the lake. As a result of its geographical barriers, Lake County retains a sense of rural and small-town identity common in the mountain West but rare in urbanized California. Yolo County, with its historic proximity to the main transportation corridor linking San Francisco to points east and north, has neither the sense of isolation nor the sense of identity and self-sufficiency of our bioregion partner.

Half a mile down the road from the Finley turnoff is the Big Valley Indian Rancheria, one of five Indian settlements in Lake County. The Big Valley Rancheria was originally the Catholic Saint Turibius Mission, established in 1870. As more and more whites began to settle around the lake, they pushed the Indians ruthlessly to give up their rights to the land. Federal agents negotiated treaties setting aside reservations for the California tribes in 1851 and 1852, but vigorous lobbying by Anglo Californians prevented their ratification by the US Senate. The State Legislature passed statutes depriving Indians of basic civil rights, including the right to testify against Europeans in court. Lacking even the most elementary protections of the law, Indians were driven from their lands whenever it was convenient for settlers to do so by whatever means settlers chose to use. They became refugees in place, surviving as best they could in a thoroughly hostile world. Saint Turibius gave shelter to about 100 local Pomo, but at the expense of giving up their traditional ways, particularly their sacred ceremonies. Some Indians were able to purchase their own lands, but not until around 1910 was the Rancheria system of micro-reservations established for the surviving people by the Federal Indian Agency.

The Big Valley Indian Rancheria is home to one of many poor Native American groups with major improvements on the horizon thanks to the casino business. The Big Valley Rancheria includes one of the largest remaining tule wetlands on the lake, and one of the planned

improvements in the works is the protection and restoration of this area. Plans also include new housing, a cultural park, a community center, a marina and a new hotel and casino. The Old Man hopes that some care is taken to document or even preserve some of the historic shacks and trailers that served Indian people during the long period of their perilous existence. This may sound strange, but the past century has been a pivotal time in the history of their culture, and future generations may be as interested in this era, sorrowful passage of their history though it may be, as we today are interested in pre-Anglo times.

Lakeport

A couple of miles past the rancheria, we enter Lakeport via its modest industrial district. Lakeport is a historic and dignified town, with a lush city park on the water. Behind the park lays the quaint downtown including cafes, a used book store, a museum with a small but informative display on European and Indian history, and, of course, plenty of waterski shops. Residential streets to the west of Main Street have many interesting older residences. The waterfront Library Park at Lakeport is built on fill that consumed a tule marsh. If you have a boat, visit the excellent tule marsh that begins on the southern outskirts of Lakeport.

Lakeport is the County Seat of Lake County. The present County Courthouse is just behind the museum that occupies the historic courthouse. The Lakebed Management Department, Flood Control and Water Conservation District, Vector Control District, County Planning Department, Air Pollution Control District, and the U.S. Natural Resource Conservation Service all have offices in Lakeport. The California Department of Fish and Game serves the Clear Lake area from its office in Yountville in the Napa Valley. UC Davis is represented by a County Cooperative Extension Office and by the Clear Lake Environmental Research Center. The Center, housed in the historic Carnegie Library building in Library Park, has information and programs on the lake available for the public. Ask there for current information. The Forest Service office is in Upper Lake and the Bureau of Land Management has its office in Ukiah. These local, state, and federal agencies have the main environmental management and protection responsibilities for the lake and its watershed. Although such a plethora of agencies might seem an invitation to bureaucratic infighting and inertia, the Clear Lake Integrated Resource Management Committee effectively coordinates the efforts of these disparate agencies. Chaired by a member of the Board of Supervisors, the committee includes members representing the relevant government agencies as well as citizen groups ranging from the local Audubon Society chapter to the Farm Bureau. A number of subcommittees report to it. Citizen involvement is high and has resulted in such initiatives as a “zero tolerance” policy regarding pollution of the lake. The Old Man reckons that competent people in a strong community like this make short work of the red tape that a less motivated community might find quite daunting.

Lakeport to Rodman Slough

Remaining on Main Street (which becomes Lakeshore Boulevard) through town, reset your odometer for the second half of the trip at the county library close to the north end of town. 5.1 miles past the library we take a right at the Nice/Lucerne Cutoff Road and take it until we reach the bridge over Rodman Slough, about a mile down the Cutoff Road.

Stop on the generous shoulder on the west side of Rodman Slough, just before the bridge. Notice the utility pole crosstree with the osprey nest on it. Utility poles are very attractive to osprey for nest platforms, but building nests there is of course very hazardous to the osprey and to reliable electrical service. PG&E's solution is to put up a slightly taller pole next to the one the osprey have selected. The birds want to place their nest on the highest place available, and obligingly move their nest to the new pole. If only all human-wildlife conflicts had such an elegant solution!

You are likely to meet fishermen along Rodman. The main targets of the current sport fishery are the introduced channel catfish and largemouth bass. In former years bluegill and crappie were abundant and the objective of many anglers. According to data collected by Vector Control, these species have slowly declined over the last few decades as largemouth bass have become more abundant. The causes of these population shifts are difficult to explain. This ecosystem, as is unfortunately typical, hides its complex secrets from the ecologists' all-too-skimpy observations and all-too-occasional experiments. The most important fishery is the competitive tournament fishery for largemouth bass. On any weekend you are likely to see the expensive, specialized boats that participate in these tournaments probing Rodman Slough (and virtually every other likely spot around the lake). Loaded with powerful motors, sophisticated sonar fish-finders, a dozen or more rods, and big tackle boxes crammed with a colorful and sometimes improbable looking array of artificial lures, two man (almost always men) teams compete for large prizes given for the largest fish and the heaviest ten fish. This is a catch-and-release fishery; all fish are returned to the lake after weigh-in. Clear Lake hosts perhaps 20 tourneys a year. In good years, bass are taken at Clear Lake at twice the rate of other locations in the region. A modest commercial fishery on the lake takes carp and Sacramento blackfish for sale live in ethnic markets in the Bay Area.

About half of the total stream inflow into Clear Lake comes through Rodman Slough. Middle and Clover Creeks drain the high country to the north of the lake. Scotts Creek, with headwaters west of Lakeport, drains a large area to the west and northwest. Historically these streams fed two large wetlands, Tule Lake (600 acres) and Robinson Lake (2,000 acres) at the northwest end of the lake. If you cross the bridge and look north, you will see the southern part of the former Robinson Lake. These systems were drained and diked between the turn of the century and the late 1920s. Such wetlands retain much of the nutrient-rich sediment that flows through them, and the muddier, more bluegreen dominated lake that existed from the early 1930s until 1990 likely owes much to the removal of these wetlands from the inflow system. Tule Lake still floods in winter and then is pumped dry for farming. UC Davis researchers estimate that as much as two thirds of the phosphorus carried by Scotts Creek is deposited in Tule Lake. Robinson Lake no doubt captured considerable sediment flowing in from Middle and Clover Creeks. Middle Creek carries a higher sediment load than any other creek.

As of this writing, Lake County and the U.S. Army Corps of Engineers were in the design phase of a wetland restoration project that, if implemented, will restore all or part of Robinson Lake. In addition to holding back nutrients, the restored wetlands will be a haven for wildlife populations. Many landowners in the reclamation area will be so- called "willing sellers" because of their homes are threatened with flooding. The levees of the reclamation area are substandard; in places they have sunk as much as 3 or 4 feet since their construction in the

1920s. Even the levees built in the 1950s to protect Upper Lake from flooding never met the Army Corps' standards. Much like the islands in the Sacramento-San Joaquin Delta, reclamation contractors built levees by dredging organic-matter-rich muds from Rodman Slough and similar channels putting them on top of the deep soft sediments that underlie the whole area. With no stable foundation or internal cohesion, the materials of the levees are gradually seeking their natural state—flat. Every high-water year brings the threat of a disastrous breach of the levee system. Overtopping of the cross levee in the middle of the Robinson Lake reclamation was prevented only by heroic effort by Flood Control personnel in the high-water winter of 1997-1998. Reclamation districts are supposed to be self-supporting, but currently the maintenance bill for the system runs several times the tax payments by landowners. If the levees are breached in a flood, no agency is likely to step forward with funds for repairs. As in the case of the Delta, reclamation of tule marshland has not proven to be a sustainable project. On the other hand, the principle crop in both Robinson and Tule lakes in recent years has been a very profitable wild rice planting. For many years vegetable crops produced in the reclaimed lands supported commercial canneries employing hundreds of residents. Though this conflict between the interests of the environment and the current interests of humans is more complex than just a taller pole, "dereclamation" seems to be both beneficial to the local ecosystem and a way out of a financially perilous situation for a number of local residents.

Bloody Island to Blue Lakes

From Rodman Slough we drive about 1 mile further on the Nice Lucerne Cutoff to Highway 20, which we take left toward the Blue Lakes. We pass the Robinson Rancheria of the Eastern Pomo and its casino on the right.

On the left at mile 9.1 are Reclamation Road and the Bloody Island Massacre Monument. The monument commemorates the massacre of an unknown number of Indians by the US Army in retaliation for the killing of the settlers Stone and Kelsey. The story follows a familiar Western theme. Stone and Kelsey bought Salvador Vallejo's cattle operation headquartered in Big Valley in the fall of 1847. Vallejo had impressed and trained local Pomo as vaqueros, under the leadership of Chief Augustine. This "recruitment" of Indian labor by Vallejo followed Hispanic practice at ranchos, plantations and missions all over the New World. After statehood, the California Legislature actually legalized the practice of impressing Indian labor. Stone and Kelsey's treatment of the Indian community in Big Valley was more high-handed and brutal than Vallejo's. Indian outrage peaked in the fall of 1849 when, in the grip of gold fever, Kelsey forced 50 Indian men to accompany him to the gold fields as laborers. There Kelsey opportunistically sold to miners the supplies meant to feed the Indians. Due to his neglect only one or two returned home alive to report Kelsey's actions to their fellows. Indian outrage grew, but Stone and Kelsey remained as carelessly brutal as ever. Men were beaten, some say even shot, on drunken whims. Women were forced into concubinage, including, fatally, Augustine's wife. A plot was hatched under Augustine's leadership. His wife poured water onto the powder charges of all the White men's firearms. Picked men burst into the house at dawn, killing Kelsey immediately with an arrow. Stone leaped through a window but was shortly found hiding by an old man who brained him with a rock.

In the spring of 1850 a US Army company commanded by a Lieutenant Stoneman came to the lake to punish the Indians. Using forced guides from the Elem Pomo living at the southeast

end of the lake, the column moved through Big Valley without catching any of Augustine's no doubt wary band, but came upon an unknown group of Indians fishing on the island in Robinson Lake. Figuring one "savage" to be as good as another for the purposes of a punitive expedition, they used boats and a cannon to assault the group, and killed a number people with indiscriminant fire. Augustine, who was not present but presumably heard first hand reports, put the number killed at 16. The army also murdered their two Elem guides. The troops then left the Clear Lake area but shot up another village far to the northwest before returning to Sonoma. This atrocious punitive raid did have the desired effect; local Indian leaders were quite willing to negotiate with treaty agents and further violent conflict with settlers was minimal, despite the fact that the treaties were never approved. Interestingly, even Lyman Palmer's 1881 history of the settlement of Lake County, sold by subscription to the settler community, treated the Indian cause as just and made no attempt to defend Kelsey's, Stone's or Stoneman's behavior.

Before European conquest, about 3,000 Indians lived in the drainage basin of Clear Lake, most of whom spoke one of three mutually unintelligible Pomo languages. Small numbers of Wappo and Miwok also lived near the lake. The Miwok villages near Lower Lake were settled later, under pressure from European Ranchos in the Capay Valley, according to Elem historians. Each language group was composed of a number of tribelets centered on a major village site. For example, the Southeastern Pomo were divided into three tribelets- the Koi around Anderson Marsh, the Komdot of Buckingham point, and the Elem on peninsula at the eastern end of the Oaks Arm. The peninsula is now called Rattlesnake Island, for the rattlesnakes that Elem people sold to Chinese miners living there for food around the turn of the century. Eating mainly fish, game, wild herbs, tule shoots, grass and wildflower seeds, and especially mashed acorns, the Indians followed a seasonal lifestyle whose essentials date back some 4,000 years. They believed that a "circular path" best preserves balance in and of life, and that responsibility for the environment is an important part of this balance. This belief finds manifestation in current plans for nature preserves built with casino money. The breakup and scattering of a tribe was, Southeastern Pomo believe, not simply due to European malevolence, but is indicative of a deeper upset of human balance with nature. This belief is prophetic; the settlement of Europeans profoundly altered California's ecological systems as well as the lives of its native peoples. Charitably, our Pomo informant feels that the Pomo share responsibility for the fracturing of the circle.

Fear of bears kept the Indians from travelling much into the hills to the east of the lake, but every year treks were made to the coast to trade with coastal tribes for shell-money. The Clear Lake Indians had many goods to offer in trade. Having a ready and inexhaustible supply of obsidian, they were able to make many beautiful and useful tools, including arrowheads, knives, ax-heads, scraping tools and ornaments. They also made beads of locally mined magnesite, another form of money. The crowning achievement of local handicraft, however, were the Pomo baskets. Intricately designed and finely woven, these watertight baskets have been called the best in the world. Good examples of both obsidian tools and baskets can be seen at the Lakeport museum, and arrowheads can still be found on some beaches around the lake.

Among the Southeastern Pomo, family groups controlled individual coves, and had rights to fishing, acorn gathering and hunting there. The family system was matrilineal. Newlyweds went to live with the wife's tribe, and even men's political offices were inherited from their

mother's families. There was relatively little conflict between tribes and families, and life was rich and easy around the lake. The wealth of the Pomo supported an elaborate ceremonial life. For example, the Lake Pomo shared with many North-Central California groups the Kuksu religion that focused on healing ceremonies aimed at repairing damage to the group as a whole by whatever problems arose. The chief ceremonies were annual multi-community dances held in the host village's semi-subterranean roundhouse. Kuksu was a "secret" society. Elders inducted only upstanding citizens into official membership in the cult. The punishment of severe deviants was banishment. The banished, unless they had sympathetic friends or relatives in another community faced a most penurious and lonely existence. The multi-tribal nature of Kuksu went far towards mitigating violent conflict between tribelets and tribes. Indeed, California seems to have been a more peaceable place than ethnographically similar areas like New Guinea because of sophisticated conflict management institutions. Pomo and other Californians did feud and war—Southeast Pomo villages were all on easily defended islands and peninsulas—but peaceful relations were the rule not the exception.

The Old Man begs you reflect on the fragile relativism of wealth. The Pomo were prosperous, even wealthy, people by their traditional standards. Subsistence was ample, practically every household had items of luxury, and communal institutions were strong. Europeans, however, had material riches beyond compare, and their presence in any numbers automatically made Pomo poverty stricken "Digger Indians" by comparison. Some economists argue that modern consumerism lives by constantly threatening to impoverish us. Because consumption of luxuries satisfies mainly comparative pleasures and pains of relative status, rising prosperity of all on average makes us feel no wealthier. The Pomo were perfectly happy with shell money, magnesite beads, intricate baskets, and ceremonial obsidian blades until invidious comparison made these things seem puny next to a crude frame house with wavy glass windows and a one-horse buggy. Nowadays, someone living at a 19th Century settler's level would fall far below the poverty line. We consume vastly more goods than our settler forbearers, yet most of us don't feel especially rich, no richer than Lake Pomo felt before they saw guns, cloth, wagons, sawmills, and the rest of the goods of 19th Century settlers. Students of happiness across cultures find it mainly correlated with measures of the strength of communal institutions, not with measures of material wealth. For example The Swiss and the Dutch are happier than the Germans (the argument goes) not because they are richer but because their communities are stronger. The Pomo had strong communal institutions and were likely as happy if not happier than the settlers who impoverished them. Some modern European inventions no doubt increase our happiness irrespective of invidious comparisons. We are all happy that modern medicine reduces child mortality below historic levels. But when it comes to the ways in which we seek happiness, perhaps we have something to learn from Pomo institutions. The Young Man agrees absolutely, but snidely wonders what the Old Man would do without his altimeter-watch and electronic weather station. The Old Man replies that almost everyone is susceptible to competitive consumption; that is the problem. The Pomo weren't immune, witness the work put into fancy baskets and beadwork and the pain they must have felt when European coins made their shell money valueless. The Young Man's taste for expensive, jet-fuel-burning foreign travel is as good an example of conspicuous consumption as the Old Man's watch. The solution isn't Puritan asceticism but some way of restraining the race to consume when it produces harm, say steep taxes on luxuries in proportion to their environmental damage. Would the tax be higher on my electronic gadgets or your airplane tickets?

In the aftermath of disease and ill-treatment, the Pomo population of Lake County dropped to perhaps 450 people by the turn of the Century. Recovery was slow, partly because intermarriage and loss of Indian identity was common. Active abuse turned to indifference to the Pomo, except on the part of ethnographers, especially Alfred Kroeber. He and his students did their best to salvage knowledge from elderly Indians all over the West about their pre-conquest lives. However, the present lives of Indians held less interest for ethnographers, which led them to some "documentation" practices that still rankle the Pomo. For example, the roundhouse that used to serve the Elem community was collected in full by Kroeber and now presumably lies somewhere in the museum vaults in Berkeley. Indian activism aided by European philanthropy made some modest gains in the 1920s in the area of respect for the Indians, but lost ground in the Depression. In the 1940s and 50s the Bureau of Indian Affairs, perhaps to hasten what they considered inevitable in the long run, operated a program to terminate the Rancheria system and with it any official recognition of the Rancheria groups by the Federal Government. Indians were relocated to training centers in cities (many Pomo went to Oakland). Rancheria lands were assigned fee-simple to individuals. By 1955 only about 250 Indians still lived in Lake County. Only one community, Elem, avoided termination of its Rancheria and maintained significant observance of traditional culture. Elem has the only functional ceremonial round house among the Lake Pomo today. The passage of the Indian Self-determination Act in 1975 set the stage for a real recovery of Indian culture in California by setting up a mechanism for tribes to reverse termination.

The use of Indian tribal sovereignty as a basis for establishing casinos is today drawing many families back to the rancherias. The lure of gambling profits puts real teeth in the 1975 Self-determination Act, but gambling does not automatically mean real re-establishment of tribes in a social sense. Many newcomers are interested only in the money. This situation caused a miniature shooting war within the Elem community in the mid 1990s, which fortunately ended without a casualty. The conflict was substantially between traditionalists and urbanized people interested in gambling revenue. Still, Indian communities have experienced a strengthening, at least in numbers; the Elem colony alone now enrolls 275 people. The Indian communities around Clear Lake now have a shot at prosperity, and hopefully they will have the luxury to rebuild their cultural heritage if they choose. Giving Indian tribes a partial monopoly on gambling is a strange way to compensate Indian people for the holocaust of European conquest, but how can we say no? Better something than nothing, and better late than never.

As of this writing, you can drive down Reclamation Road to see how the bed of the former Robinson is being used for residences and farmland. If the wetland restoration project is successful, the scene will be very different in a few years. Notice how Bloody Island would once again become an island if the marsh were reflooded.

Continuing north on Highway 20, we pass through the small town of Upper Lake. Its main street (a right turn off Highway 20) has some interesting old storefronts and a Carnegie Library. Elk Mountain Road north leads to Elk Mountain Summit, the northernmost edge of our bioregion. Still further north are Snow Mountain and Lake Pillsbury, the small northern section of Lake County in the Eel River Drainage. We pass the roads leading to Witter and Saratoga Springs, sites of major resorts in the 19th Century. We reach Lower Blue Lake at mile 16.2.

Though they are not far from Clear Lake, the Blue Lakes are of a different breed altogether. The two small, deep lakes sit narrowly in the bottom of the steep and densely wooded Cold Creek Canyon. Considerably less eutrophic than Clear Lake, the Blue Lakes live up to their name much better than does Clear Lake. With only a few small resorts and no high-horsepower motorboats, the Blue Lakes are much more tranquil and serene than the bustling green lake to the south.

At one time Clear Lake drained north out through this valley to the Russian River. A few thousand years ago, a giant landslide from the west blocked off the valley, raising Clear Lake and forcing it to drain out of the Lower Arm into Cache Creek on the southern end, and forming the Blue Lakes in the old canyon. We turn around at Blue Lakes Road at mile 18.8. Here the pass that you see Highway 20 climbing toward just in front of us is the crest of the old landslide, and looking up to the left you can see the scar from whence it slid. You can return on Blue Lakes Road if you want to get a closer look at these lakes.

The Blue Lakes slide is part of the story of the Clear Lake and Russian River fish faunas. Many of Clear Lake's native fishes, such as the Splittail, Hitch and Tule Perch, are derived from the Sacramento River system, although in a time when the Coast Range was lower and Cache Creek a meandering lowland stream. These slow-water species could not ascend the steep torrent that the river has become today. Cache Creek is not exceptional in this regard. River systems are often more ancient that the mountains through which they flow, because down-cutting can often keep pace with the rising mountains. The Clear Lake Volcanics at some point in the last 100,000 years produced lava flows that dammed Cache Creek, causing Clear Lake to rise and flow through Cold Creek Canyon into the Russian River, whence its Sacramento derived fishes colonized. The landslide later restored the outlet to Cache Creek by raising the lake level until it found its way across the lava flows. Clear Lake has thus left and rejoined our bioregion, rather recently on the geological time scale, a small testimony to the dynamism off the earth's surface. *(Perhaps Peter M will cover this story?)*

Driving back down Highway 20 past the cutoff road, we come to the town of Nice at mile 31.4 or so. All along Highway 20 are occasional road cuts exposing Franciscan Formation rocks. Note the jumbled texture of these rocks and the considerable difference in color and texture from roadcut to roadcut. Most of the rocks in the central and western Coast Ranges are part of the Franciscan, a complex mélange composed of miscellaneous bits of ocean crust, sedimentary rocks deposited on the ocean floor, and remnants of islands. Franciscan rocks dominate the Clear Lake region, apart from the southwestern volcanic field. Franciscan rocks were deposited in a subduction zone along the West Coast over a period of 150 million years. Lighter rocks on the surface of the diving Farallon plate jammed against the margin of the North American plate. The Farallon Plate was almost entirely subducted away under North America, before being pushed off to the north by the Pacific Plate sliding along the San Andreas. Too light to be subducted, Franciscan rocks choked the subduction zone and pushed it seaward. The continued compressional stress of the Pacific against the North American Plate threw up the Coast Ranges, with the Great Valley Formations' orderly, if steeply tilted, continental shelf sandstones and mudstones forming the inner ranges. You will pass back onto the Great Valley Formation near the junction of Highways 16and 20. Just west of the Great Valley Formation are the oldest subduction zone chokers of the Franciscan, which become progressively younger until they reach San Andreas itself.

A mile or two past Nice we meet up with the lake again and continue along the shore, passing Bartlett Springs Road. The Bartlett Springs Road leads to Bear Valley through some of the most remote country in our bioregion; a good trip for those that like a slow and possibly adventurous backroad drive. We are now in resort country. Thanks to vulcanism, Clear Lake early on earned a reputation as a premier resort destination. Starting in 1852, Victorian resorts in the European style quickly sprang up around various mineral springs in the hills around the lake—Bartlett Springs, Witter springs, Saratoga Springs and others. Guests traveled first by train and then on a long, bumpy carriage ride to reach the springs. Steamers plied the lake, taking stage riders, workers, and supplies from Lakeport to the landing of the various resorts. Once there, guests stayed for weeks or months in the huge gabled hotels and spent their days playing genteel lawn games and "taking the waters," which were reputed to cure diseases and ailments of all descriptions. We shouldn't think of the mineral spring spas as resort tourism in the modern sense. They were an important part of 19th Century medicine. The curative properties of mineral waters were much touted in Europe. Charles Darwin took cures (in vain) at such establishments for his chronic disability, thought by some historians to have been due to panic attacks and by others to have been a tropical disease picked up on the voyage of the Beagle. The Clear Lake establishments compared themselves favorably to famous European springs, advertising the chemical composition and temperature of their water in great detail. Witter Springs somehow acquired a reputation for being an excellent syphilis cure, leading to jokes about the clientele, perhaps the downfall of the resort. Modern scientific medicine—American style—caused the death of the mineral springs by disparaging their efficacy. Germans still frequent spas (paid for by their health insurance system) just as herbal remedies are still part of mainstream medicine there. A revival of the mineral spring spa is not likely perhaps, but it is not impossible to imagine.

We arrive in Lucerne (the name, as with Nice, was chosen for its Old World resort connotations) at mile 34.8. Just up 13th Avenue in Lucerne is the huge, gothic Christian Conference Center, an old resort hotel, replete with squared towers, faux columns and a spacious lawn. This is the only spa hotel still standing. Beginning in the middle of this century, the weekend resort and water sport business began to rival agriculture in local economic importance, supplanting the dying traffic to the hot springs spas. The lake itself became the focus of recreation to a much greater degree than in the spa days. Weekend resorts became possible in mid 1920s when the state highway system began to take shape. Depression and war slowed the growth of the industry, but resorts began popping up in numbers after WWII, especially along the northeastern shore of the lake. At first, Clear Lake was one of the most accessible large lakes to the Bay Area. However, by the late 1950s newly built Interstate 80 began siphoning off much of the tourist business to the suddenly more accessible Lake Tahoe, the newly created Lake Berryessa and other reservoirs. Competition for the tourist dollar became and remains stiff. The result today is the funky, faded look of the quaint east-shore motels and vacation spots. The Young Man is especially struck by washed-out signs in 50s diner style advertising COLOR TV! They are not uncommon in Nice and Lucerne, nor are rusting 35-year-old Dr. Pepper machines and early mass-designed architecture. The Old Man is not amused by the thought that items of his early adulthood are becoming antiques. The Young Man *is* amused, "Becoming?" The uncommon modern condos and hotels stick out quite obviously from the frozen-in-time décor of the area. Since they cannot offer slick modern conveniences, you can be sure that such resorts

survive by providing friendly service at reasonable prices. Clear Lake is ripe for a retro revival of its tourist industry. Lakeport has spruced up its main street in recent years, and antique stores have sprouted up in Lower Lake and Upper Lake. The lake's water quality has improved. County efforts backed by UC Davis research and help from the Army Corps, may keep it that way. You may want to consider an investment in Lake County real estate now. When you see the first profile of Clear Lake in *Sunset* you will know it is too late!

In the 1960s, the scenic setting and relatively low land prices began to attract retirees, many of whom could now afford land on the lake thanks to the new social security system. Today there are many retirees living on and around the lake.

Past Lucerne, beginning around mile 37 are a series of roadcuts showing quite good examples of Franciscan rock. Note that the shoreline here plunges steeply into the lake, quite unlike the gentle gradient of the opposite Big Valley shore. The Upper Arm of the lake comprises a land block that is dropping along this section of the shore relative to the mountains to the northeast, and rising in Big Valley. As the pull-apart motion in the vicinity opens a gap in the earth's crust, a large, deep block toppling sideways as it sinks relative to the rising mountains is creating a lake basin that is deep on the northeast and shallow on the southwest. In the absence of withering rates of erosion, Clear Lake would be much deeper and the surrounding mountains significantly higher. As it is, Clear Lake averages only about 25 feet deep, but the geological basin is about 600 feet deep. The US Geological Survey cored the bottom of Clear Lake in 1973 and 1980 and their deepest core was 177 meters (590 feet) long. The age of sediments at the bottom is about 480 thousand years, making Clear Lake the oldest securely dated lake in North America. Lakes are normally quite temporary features on the earth's surface because they are relatively small and quickly fill with sediment. Large, exceedingly deep lakes like Baikal and Tanganyika survive for millions of years, but they are rare. Clear Lake would completely fill at current rates of erosion in about 5,000 years. It has lasted 10 times that long because its floor has been sinking about as fast as erosion has been filling the lake. USGS scientists compiled a wonderful pollen record of Pleistocene climate fluctuations from their cores. During warm periods like the present, oak pollen dominates, but gives way to pine pollen in cooler, ice-age climates. The Clear Lake pollen record is almost perfectly synchronous with records of climate fluctuation recorded in Greenland and Antarctic ice and in marine cores around the world. It thus comprises an important part of the evidence that Pleistocene climates varied in concert all over the world.

At mile 39.7 begins the most up-scale area on the lake, Paradise Cove. The perfectly manicured lawns and three-car garages are strangely juxtaposed with the rustic and organic look of the rest of the shore. The canyon running north from Paradise Cove contained the first bald eagle nest in Lake County in recent times. Maybe the eagles are as fond of modern tract opulence as the people of the country they represent, The Young Man cracks cynically. The Old Man prefers to think that current conservation efforts are rebuilding a little of the Pomos' sacred circle. A little over a mile later we can see Anderson Island and Buckingham Point to the right. At about 2 o'clock at mile 43.3 we can see the bare yellow waste dumps of the defunct Sulfur Bank Mercury Mine on the shore at the far end of the lake. This is our next stop, after passing through the resort communities of Glenhaven and Clearlake Oaks. In Clearlake Oaks we pass by one of about 20 canals that make up the Clear Lake Keys subdivision, carved into Schindler

Creek's lakeside wetland in the 1960s. Shallow, warm, nutrient rich, and downwind, these canals sometimes have phenomenal growths of bluegreens. In the Great Microcystis Bloom of 1990, The Young Man, then a small boy, threw pebbles into the canal while The Old Man took pictures. About half of the pebbles sank through the muck, and about half stuck on the dry crust.

Sulphur Bank Mine

To reach the mine we turn right on Sulfur Bank Road at mile 46.9, about one half-mile past the canal. As you turn, notice the cinder cone on your left down Highway 20 that is in the process of being removed entirely for decorative aggregate. This is one of the youngest features of the Clear Lake Volcanics. 1.4 miles past this we will come to a triple fork in the road. The right two forks are dirt roads, and we will take the left of these, the middle fork. Stop on the high point of the road overlooking the Herman Pit with its pH 3 pond as the centerpiece. The right fork leads to the Elem Rancheria. Currently there are no facilities open to the public at Elem, but a casino may reopen there in the future. The roundhouse dances that occur at Elem every year or so are real religious rituals and are not put on for the public. However, visitors are welcome. They are expected to make a small offering at the center-pole and then to observe quietly from the periphery.

The sulfur and mercury mined at the site were deposited near the surface by still-active hot springs (Hydrothermal systems are common sources of metal ores). Surface water percolating into the fractured rock of an active volcanic region is heated to quite high temperatures at rather high pressures. Hot, high pressure water is very corrosive and dissolves many otherwise insoluble minerals. Even at the surface, the hot water is still sufficiently corrosive to leach most minerals out of the host rock, giving rise to the bleached and discolored rocks you see high on the wall of the pit. The hot water is buoyant and finds its way to the surface through cracks and fissures. As it leaves the deep heat source, the water cools, and the dissolved minerals begin to precipitate. The column of hot water thus creates a layer cake of minerals of differing solubilities. Gold, for example, leaves solution at rather high temperatures, and mercury at around the boiling point of water. Sulfur is the last major constituent to precipitate. Hence, Sulfur Bank originally had a thick layer of native sulfur at the surface covering a deposit of cinnabar, mercuric sulfide, the ore of mercury. The McLaughlin gold mine south of Lower Lake had a profitable gold deposit underneath the cinnabar. The sulfur deposit at Sulphur Bank was first mined in 1865 using simple surface excavation techniques. John Veatch, the pioneer exploiter of borax in Lake County (see next stop) developed the mine at Sulphur Bank. 2 million pounds of pure sulfur were produced before increasing contamination with cinnabar made the production of sulfur uneconomical. In 1873, exploitation of the mercury ore began, using simple surface cuts. Later, shafts were driven into the deposit to find the seams of mercury deposited in fissures in the fractured andesite flow (medium density volcanic rock) and adjacent Franciscan Formation rocks that are the main formations at the site. The fault that bounds the southern side of the Oaks Arm runs right through the mine site, creating the fractures through which the hot geothermal fluids penetrate to the surface.

Work in the mine was brutal. The active geothermal system made the temperature in the tunnels so hot that the Chinese and Indian workers could only work in 15 minute shifts before their body temperatures started to climb toward lethal levels. Sweat-bathed miners were hoisted up the shafts on an elevator, cooled by a blast from a firehose, and lowered back down for

another stint. A hundred yards or so from the high point on the road you can see the remains of the headworks for one of the shafts. When these tunnels caved in, very little effort was made to dig out trapped miners. Even today, you can often smell hydrogen sulfide (odor of rotten eggs) on the road above the mine and with binoculars you can see the vigorous gas springs that vent into the Herman Pit in the middle of the site (20 acres, 90 feet deep, 700 acre feet of water). The traditional image of Christian Hell must be based on mines like Sulphur Bank, driven 400 feet down right into the throat of the geothermal system. When you read this, the US Environmental Protection Agency may have completed plans to remediate and rehabilitate the site. Too bad in some ways. Unremediated, Sulphur Bank is an informal Hell's Half-Acre Theme Park, reminding the sinners among us to repent, or at least take up atheism.

Notice the ruins of the retort up on the hill to the left, where cinnabar, the principal ore of mercury, was roasted to recover the pure liquid metal. Total production of mercury from the mine amounted to 4,500 tons or more of liquid mercury. About 60% of the total was extracted in the 19th Century using shallow surface excavation and underground mining techniques. In 1927, the Bradley Mining Company brought in heavy excavating equipment and created an open pit mine. This episode of mining continued until 1944, when wartime parts shortages caused the mine to close. Some mining was conducted during the mid 1950s and 1957 was the final year of operation. The mine site now consists of about 120 acres of heavily disturbed waste rock, tailings piles, and denuded earth surrounding the Herman Pit. Much of the waste material was bulldozed right into the lake, creating a new shoreline as much as 400 feet lakeward of the original. In the 1970s, California Department of Fish and Game surveys found Clear Lake fish to be contaminated with levels of mercury slightly above official health warning levels. Subsequent surveys have found widespread mercury contamination in California waterways. Mercury was mined at many sites in the Coast Range, and in the 19th Century, most mercury produced was used in the Sierra gold fields to amalgamate flour gold and silver. Mercury is a dangerous contaminant in many parts of the world; international conferences on the problem draw thousands of participants. As with the DDD contamination, Clear Lake was a sentinel ecosystem for this important ecotoxicology problem. In the mid 1980s the California Department of Health Services issued warning regarding the consumption of fish from Northern California Coast Range lakes. Levels of mercury in Clear Lake fish are below levels that would cause frank mercury poisoning in humans. As we've seen, osprey are tolerating their not inconsiderable dose of mercury from Clear Lake fish without detectable effects. Still, mercury is a suspected carcinogen and may cause neurological damage in fetuses and children at low doses, so to be conservative, DHS recommends that adults limit their intake of fish from contaminated systems and that children and pregnant women refrain from eating them entirely. The only local reports that we've had of possible mercury poisoning in humans are from the Elem Pomo, who live very near to the mine and traditionally consumed a lot of fish. In the past some Elem people suffered illnesses consistent with mercury poisoning. Regrettably, studies were not conducted until many years after people had reduced their fish consumption in accord with DHS warnings. The Central Valley Regional Water Quality Control Board commissioned the first ecotoxicology study by Humboldt State University investigators in the late 1980s.

Sulphur Bank was made an EPA Superfund site in 1990. In 1992, the EPA did an emergency project here to stop erosion from the waste rock piles along some 1200 feet of lake frontage. The graded and rip-rapped piles of dirt and rock you can see from the lake today are the

results of that effort. Numerous contractors working for EPA have labored to understand the source and extent of mercury contamination in the lake since that time. About 100 tons of mercury have escaped from the mine and are buried in the sediments of Clear Lake. Most of this mass is now buried too deeply to be a problem.

However, in addition to whatever mercury flowed into the lake before 1992 from erosion, considerable rain-water and geothermal inflows seep into and through the mine waste, become quite acid, dissolve mercury, and discharge into the lake. Because the toe of the waste rock pile is underwater the main discharges are below the lake surface and hard to see and measure. They went undetected by the Humboldt State study, conducted during the long drought from 1986 to 1992. UC Davis field workers sampling lake bottom mud discovered masses of a suspicious white flocculant material near the mine face after the rainy 1994-5 winter, which turned out to be comprised mainly of a clay mineral precipitated from acid mine drainage. Sometimes, white billows of this material can be seen at the lake surface right along the base of the waste rock piles. As it turns out, practically all sulfide ore mines are sources of acid mine drainage. During open pit operations especially, large volumes of sulfide rich minerals, mainly iron sulfide, are disturbed and exposed to leaching by rainwater and any surface or ground waters that penetrate the waste rock heaps. When sulfide is exposed to air or dissolved oxygen in water, bacteria oxidize the sulfide to sulfate, creating large amounts of acidy in the process. The result is the not-so-dilute solution of sulfuric acid you see in Herman Pit. In the winter and spring the waste rock piles west of Herman Pit show a dappled pattern of green and brown (straw and brown in summer). The brown patches are surface lenses of sulfide rich waste that form soils too acid for any plants to grow.

Interestingly, Herman Pit waters contain very little mercury because they are still rich in un-oxidized sulfide generated by the hot spring and related gas flows. This reduced form of sulfur produces the very insoluble mercuric sulfide mineral, cinnabar. Small amounts of cinnabar are thus still being deposited, tending slowly to build a new ore body in Herman Pit (this poses no problem for the lake). However, under acid *oxidizing* conditions, mercury is about as soluble as table salt. The floc found in the lake does contain significant amounts of mercury, so somewhere beneath the waste rock piles, air is dissolving into the acid water in sufficient quantity to extract mercury. The EPA's task is to understand how this underground system is plumbed and to try to find a way to stop the production of acid mine drainage, or at least acid mine drainage containing oxygen and mercury. The trouble is that the miners ripped the relatively compact natural sulfide deposit to pieces, jumbled uneconomic minerals together with miscellaneous overburden rock, and piled the resulting poisonous mélange 30 or 40 feet deep over the tunnel-laced rock of the former underground mine. Finding out how water and air flow through the resulting mess is a devilish task. Remediating acid mine drainage is also not easy. The Roman-era tin mines of Cornwall are said to still be sources of acid discharge.

The trouble with the mercury in the sediments is not the inorganic mercury compounds themselves, which are harmless in the concentrations in which they are found in the lake. Rather, bacteria living in the sediments convert a small portion of the mercury to methyl mercury. We don't know why bacteria form this compound, but in the anaerobic sediments a half an inch or so below the surface, they do produce it. The concentrations of methyl mercury in the water (levels of about a part per trillion) and sediments (levels of a few parts per billion) are not obviously

alarming. As sanitary engineers say, “the answer to pollution is dilution.” Usually this is so, and these levels are dilute indeed. However, quite unusually for a heavy metal, methyl mercury bioaccumulates in food chains just like chlorinated hydrocarbon pesticides. The compound has a high affinity for the sulfur-bearing amino acids in protein and is excreted very inefficiently from the body.

The UC Davis team studying the mercury problem in Clear Lake for EPA has documented another classic case of food chain accumulation of mercury. Small invertebrates near the base of the food chain have methyl mercury levels around a few hundredths of a part per million. Small fish run around a tenth of a part per million. Big, long-lived predatory fish—the bass and catfish that appeal to most consumers—run about 1 part per million. Carp that eat lower on the food chain are considerably lower and are quite safe to eat. Osprey run around 2 parts per million. The levels of methyl mercury in shellfish eaten by the Japanese people who were poisoned in the 1950s at Minimyata Bay had mercury concentrations around 10 parts per million, so it is probably impossible for an adult to contract frank mercury poisoning from eating Clear Lake fish. The DHS warning reflects, as it should, a safety factor. As we should expect, the small, statistical effects of low doses of methyl mercury are not well understood. Thus, the objective of the EPA cleanup is to reduce influx of inorganic mercury into the lake so that natural burial of the contaminated sediments eventually reduces the supply of mercury for the methylation process and brings fish methyl mercury concentrations back into the safe range. UC Davis investigators estimate that five to ten years should be sufficient to dramatically reduce the inorganic mercury available at the sediment surface, once the ongoing supply is stopped.

The mine is still owned by the Bradley family. They have argued that the mercury contamination of the lake is as likely due to natural discharges from diffuse hot springs sources as to their mine. Two lines of evidence speak against this hypothesis. First, the contamination is far higher right in the vicinity of the mine than elsewhere. The finger of the mercury gradient in the sediments points right at the mine. Second, a series of cores taken by UC Davis investigators show a dramatic chemical signature of mining activity. In the Upper Arm, far from the mine site, background inorganic mercury levels in the deep sediments are quite low. Three to four feet deep in the sediments, the concentration doubles, to about two-tenths of a part per million. Sediments of this depth were deposited about 1873, when the mining of mercury started. In sediments a foot to two feet below the surface in different cores, sediment concentrations jump by a factor of ten, to two to three parts per million. Sediments from this depth date to 1927 when the mine began to be operated using open pit methods. Quite clearly the mine is the source of the contamination and open pit methods were much dirtier than underground mining. Small declines in mercury occur near the surface of the cores, suggesting that EPA’s remediation of mine waste slopes may be having an effect on supply rates of mercury to the lake. However, recovery of the lake without intervention to control acid drainage is likely to take centuries.

Interestingly, the cores fail to document the increase in sedimentation rate that earlier investigators thought mainly responsible for the post-1925 increase in sediment and phosphorus supply that supposedly made the lake more susceptible to large bluegreen blooms. Sediments after 1927 are drier and contain less nitrogen than pre-1927 layers, as if the organic-rich sediments were being diluted by inorganic erosion products transported by winter storm flows. However, the post 1927 deposits are not reliably thicker than earlier layers. Further coring work

may yet demonstrate greater sedimentation rates after the advent of heavy earthmoving equipment, but other hypotheses as to what causes the bluegreen blooms are on the table. The first is that the acid mine drainage carries enough sulfate into the lake to at least double the sulfate entering the lake, perhaps much more. Sulfate is used by sediment bacteria to oxidize organic matter and could account for the less organic sediments after 1927 and more efficient recycling of nitrogen, depleting that element in the sediments. Exactly how increased sulfate reduction might lead to more efficient recycling of iron, the nutrient most limiting to bluegreens, is not (yet) clear. Second, the acidity from the mine may have triggered changes in lake chemistry, ironically by making the lake more *basic*. Basic minerals in the lake mud neutralize the acidity, while sulfate reduction regenerates the basic hydroxyl ions consumed in producing the original acid. This idea is an unproven hypothesis at the moment. Lakes are favored for study by ecologists because they are relatively simple as ecosystems go. They are not simple enough for practical purposes, regrettably. When we get our lakes into trouble we are like an inadvertently naughty toddler. We have difficulty figuring out what we did wrong, much less how to fix the problem.

Sulfur Bank Mine to City of Clearlake

Turning back out onto Sulfur Bank Road, we take the pavement to the right and head up and over the ridge to our last stop, Borax Lake, or Medicine Lake as it was known to the Elem. This lake was the source of the first borax found in the New World. Borax was quite valuable as a flux in metallurgical operations. Until Veatch's discovery of the Lake County sources here and at Little Borax Lake, the world's supply of borax came at considerable cost from remote mines in Tibet. Veatch's miners at first simply picked up large borax crystals from the surface of the mud at Borax Lake, but later used more sophisticated techniques. However, the discovery of the famous and much larger deposits of borax in the deserts of Southern California ended the Clear Lake industry. As you can see, the lake has no surface outlet. Water rich in borate, ultimately derived from geothermal sources, flows into the little lake and concentrates the borate by evaporation until borax crystals precipitate. The buoys you may see in the lake support insect control experiments conducted by the county's Vector Control District.

Past the lake, the road enters the city of Clearlake, and you have to filter through some residential streets. Keep bearing to the right until you reach Lakeshore Boulevard, then turn left. You can continue on Lakeshore Boulevard until it runs into Highway 53 just across Cache Creek from Anderson Marsh, or you can take one of the major intersecting boulevards uphill to Highway 53 further north. The city of Clearlake is the county's largest town, although it was not incorporated until 1980(?). It grew up as a collection of unincorporated resort communities and retirement subdivisions in the 20th Century and lacks the historic core of Lower Lake, Lakeport and Upper Lake. Clearlake must look to the future.

What Clear Lake Means To Us

Our tour is finished but our account only hints at why we and so many residents and visitors feel so deeply about this lake. Perhaps its personal meaning to us is representative.

For The Young Man, roots grew with childhood familiarity. *From the time I was born to the age of 13 or so, I visited the lake quite often with my family. Our cabin under Konocti was among my favorite places in the world. As a kid I was fascinated by the endless treasures I could*

find hidden on the ground or scooting under rocks; imagine the paradise that Clear Lake was for me—arrowheads on the beach, shining chunks of obsidian everywhere, and critters galore. Next to our plot of land was, and is, about 10 acres of undeveloped shoreline, a dense shoreline jungle of tules, great gnarled willows and cottonwoods, ancient snags, volcanic boulders, stately oaks and every manner of creepy crawling thing known to a legion of dirty-handed Tom Sawyers. My first million (ha) has been earmarked as long as I can remember for buying this bit of land. The place has been for sale for years and I can imagine few things that would dismay me more than seeing it cleared and developed.

Aside from the more naturalistic delights of the lake, waterskiing offered me more than enough of a thrill to keep me out of trouble when I got home. Watching my skis slice through the glassy green water as the docks and tules sped by is one of my most clear and glorious memories of childhood. Of course, as a kid I was never bothered by any but the worst algae blooms. I do remember though, when the water turned thick and green lately red, beneath my skis, and imagining what it might feel like to be neck deep in such "water," I prayed that I wouldn't fall until we'd crossed back into the clear.

However, it was the mysterious remnants of the Indians that fascinated me most. Along with the obsidian arrowheads, scraping tools, knives and axeheads that washed out of the sand on our beach, we found mortars and pestles, fishing weights and, ominously, a hunk of raw lead for molding bullets. I remember being ankle-deep in the water, picking up an especially fine arrowhead. As I stood up and looked around I was suddenly overwhelmed by the realization that not more than a couple hundred years before, the man who had made this object must have been standing in this same spot. A vision of an Indian village in the place of our cabin condensed in my mind, tule boats plying the water, teepees along the shore. I'm sure this vision was hideously stereotyped, but nevertheless it was the first time that I conceived of Native Americans as an actual people, real women and men who lived right here, rather than the characters I had read about and seen on TV. In these and other ways that I cannot describe, and some I probably can't even remember, Clear Lake was a paradise to me.

As our family got busier and lost interest in the lake, we began to make the trip less and less often. By the time I came here with the Old Man to research this chapter, I hadn't seen the lake in five or six years. My old love of the lake was immediately rekindled, though it was a shock to find out how small everything actually was. I couldn't believe that the towering bulk of Konokti that hid our beach from the sun by 5:30 even in summer was hardly more than a very big hill. However, this was far from my greatest disappointment.

As I learned more and more about the lake, and especially about its recent history, I was again and again disillusioned about my paradise. As I now see it, Clear Lake is typical of the wildernesses of our bioregion, and of the world at large, California especially. As lush, beautiful, bountiful and seemingly pristine as Clear Lake is, we can never experience it in its true natural state. In the literal meaning of the word, the area has been decimated by humans, especially by the Anglo settlers of the last century and a half. Not only has pavement covered so many acres of land, but the even the "wild" land has been altered. Native grasses and groundcover have been drastically reduced and few of the once-plentiful Valley Oaks are left in the valleys. Most of the natural fish have been run out of the lake and replaced by foreign

species, and many species of birds and animals have been pushed off the land. The impact of these salient changes on the minutia and workings of local ecology is impossible to measure. To me, so many California vistas are bleared by the knowledge that that stickery tan grass isn't even supposed to be there, and has pushed the lush and varied native groundcover far back into the hills. This is not a case of "save the dolphins, screw the tuna;" I am not romanticizing the native species as abstractly "better." I simply think it is a tragedy that while we may enjoy what is left of the area, and it is still beautiful and largely natural, we will never know the real Clear Lake. And of course, though we now struggle to mitigate our impact on nature, success in this struggle is measured in either minor victories or the slowing of the destruction. No matter how much we slow new construction, the fact is that once we pave an acre, we're not going to unpave it in the foreseeable future. It seems quite likely that Clear Lake is closer to pristine now than it will be for a long time hence; until we either begin to make major sacrifices to preserve our wilderness, or disappear completely. I don't pretend to have any specific solutions, I just know that unless we make major changes in the way we live, we will give our grandkids plenty of reason to resent us.

Clear Lake means very different things to the Old Man, who knew it as a child only from one memorable trip with his father. *My most vivid experiences of Clear Lake come from being an applied scientist trying to help solve its problems. Most of my career has been spent on basic research, but I'd always wanted to try my hand at more practical matters. Opportunities arose to study the algal scum and mercury contamination problems and I took the opportunity.*

I discovered that applied science is a more complex business than basic science. One part is the same, trying to understand how a piece of nature works. You can't very well help people solve a technical management problem unless you have some real understanding of the system at issue; applied science is science applied. Clear Lake is full of great scientific puzzles. Some, like working out the phosphorus budget of the lake, were quite straightforward applications of some well tried limnology, though it was still quite a thrill when we could balance the flows of phosphorus in and out of the sediments surprisingly precisely. Four of us put perhaps a collective year of work into that really lovely set of data. I don't know if the concept of "lovely data" is or can be made intuitive to non-scientists, but it is very real thing to us. Other data are ugly. Some of our mercury data turned out to be affected by a laboratory artifact and dissolved a significant fraction of our understanding of that problem into an awful mess. Some data just tantalize. The iron cycle in Clear Lake is all-important because it limits the ability of bluegreens to use atmospheric nitrogen. Since the productivity of the lake is nitrogen limited, the whole metabolism of the system is regulated by iron availability. However, iron chemistry in natural waters is complex and plagued with methodological complexities. It does show some simple patterns and we have hypotheses to test, just not the resources to do them justice right at the moment.

For a basic scientist, ugly data are perhaps a nuisance or even an embarrassment, but they are also grist for the next grant proposal. Tantalizing data are generally the basis of your best new ideas. We love tantalizing data and Clear Lake has yielded it up in abundance. Nothing is more fun than getting a lab or seminar room crackling with excitement as a crude, fresh idea gets its first rough polishing at the hands of constructively critical, knowledgeable colleagues. But applied scientists, alas, haven't the luxury of taking such an insouciant attitude toward

current ignorance, at least not taking it outside the laboratory. People are depending upon them to solve pressing problems. People's lives and the environments they live in will be affected by your recommendations. Many lay citizens around the lake knew that studies of the bluegreen scum problem had gone on for years without any practical solutions being offered. They rightly fear that scientists left completely to their own devices will keep pursuing intriguing problems till the last piece of the puzzle falls into place. In the case of something as complex as a lake, the last piece will never be fit; science is the "endless frontier." So the refrain "you've studied it to death, now it is time to do something." This prodding comes in unsophisticated form from unsophisticated people, but even the most sophisticated practical person will not let you off the hook. You must screw up your courage and make the best recommendations you can in the face of the considerable uncertainty you at least glimpse from your ugly and tantalizing data. You have in mind the history of Clear Lake's slipshod fish introductions and DDD applications when good applied scientists made large blunders. Is something as cross-grained as the biomagnification properties of DDD and methylmercury lurking out there to ruin my *recommended action? The applied scientist can make a mess that cannot be cleaned up in the next grant proposal.*

The applied scientist, at least this applied scientist, can't help but feel moral responsibility for his recommendations. As a corollary, I find it enormously stimulating to work with real people on real problems. Most people in Lake County have welcomed researchers warmly into their community and supported our work. I made new friends. The people of Lake County renewed my faith, badly shaken by administrative work in a big, conservative bureaucracy, that people of good will working together make good things happen.

Once I took to the people living in the place, I found it hard to use wilderness as the master measure of environmental quality around Clear Lake. The people live in and love Lake County even as they have removed most of it from the category of wilderness. While retaining as much area as possible in near-natural state and restoring really scarce communities like tule marsh and valley oak woodland should certainly be major objectives of management, I'm at least as concerned with the inhabited landscape that dominates the lake. The osprey nest in PG&E's utility pole at Rodman Slough is symbolic to me. Osprey and many other magnificent animals tolerate humans fine as long as we take care to give them their necessary niches. So too we can make room for the microfauna that so delighted the Young Man on this unsupervised explorations of his childhood microwilderness (a narrow lakeside tangle on the edge of a neglected walnut orchard, truth be told). Making room for wild things in the nooks and crannies of the humanized environment is no sacrifice! Our spirits soar every time we see an eagle in flight or a child eyes aglow over a beetle. In Europe, in the Andes of Peru and Ecuador, and no doubt in many places I don't know personally, we tour pastoral landscapes, villages, and even cities of surpassing beauty. The humanized environment need not be a disaster. It cannot be wilderness but it can be shared with wild and beautiful things. If we hew too strictly to the wilderness standard we must always fail, for even that which we preserve or restore can never again be perfectly *wild. If we imagine, following the Pomo, that humans are part of the environment and that we have a special responsibility to balance the circle as a condition for living well in it, we set for ourselves an ambitious but achievable standard.*

So I say to The Young Man, keep the whole in mind but consider the problems and projects one at a time. Your seeking to preserve a scrap of lakeshore where kids can hunt crawdads and chrysalises is a perfect example. Having half acres of semi-wilderness and osprey nest power poles richly mixed into the settled landscape is as important, but not more important, than remote million acre preserves and thousand acre restorations. Currently we do the latter tolerably well, but not the former. In my daydreams about the future I've heard a German tourist (German in my imagination because they are the most relentless tourists of all) tell one of my grandkids that Lake County has not only some of the most interesting wilderness in America, but also that its pastoral landscapes and small towns are more beautiful than Tuscany's. Let us make it so!

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