RESOURCE INVENTORY

AQUATIC LIFE

Big Basin Redwoods State Park

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by

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INTRODUCTION

The aquatic resources of Big Basin Redwoods State Park are foremostly associated with Waddell Creek, a major Central California coastal stream which supports a well-documented fishery, and its tributaries. The unit contains over 45 miles of streams: Waddell Creek and tributaries (and most of their watersheds), major portions of two streams which enter the Pacific Ocean north of Waddell Creek (Elliot and Finney Creeks), small segments and watershed of three other major coastal creeks (Scott, Boulder, and Año Nuevo Creeks), and segments of two other minor Pacific Ocean tributaries. The Park also includes portions of the watersheds of six other regionally-important streams (Figure 1), including short segments of channel of Cascade, Gazos, and Green Oaks Creeks. The unit also contains lacustrine, palustrine, and estuarine aquatic resources: Sempervirens Reservoir, a man-made water supply impoundment on Sempervirens Creek (a tributary in the Waddell Creek watershed), and the Hoover Marsh and seasonal Waddell Lagoon complex.

Waddell Creek is comprised of two major forks. The East Branch originates from tributaries draining the slopes surrounding the heart of Big Basin. The West Branch drains the area between Chalk Mountain and Mt. McAbee, north to the Santa Cruz/San Mateo county line. Each fork receives several major tributaries which flow year-around and provide habitat for resident and anadromous fish and other aquatic animals. After the forks merge, the main stem meanders south for about 3 miles (as the crow flies) to Hoover Marsh and a seasonal lagoon and the Pacific Ocean. A more complete description of the watershed can be found in the Hydrology chapter of the BBRSP Resource Inventory (Rischbieter and Waldron 1998).

Small (typically seasonal/intermittent) tributaries to the waters noted above are relatively numerous. Most have names, such as Timms Creek and Rogers Creek, but some names are only locally-recognized (e.g., Buck Creek, Huckleberry Creek, Mill Creek). These and other small channels provide aquatic habitat for many months of the year, some with small amounts of surface water permanent for short reaches. The canyon slopes within the Park have a few widely-scattered small springs and seeps, which are also probably important resources for wildlife.

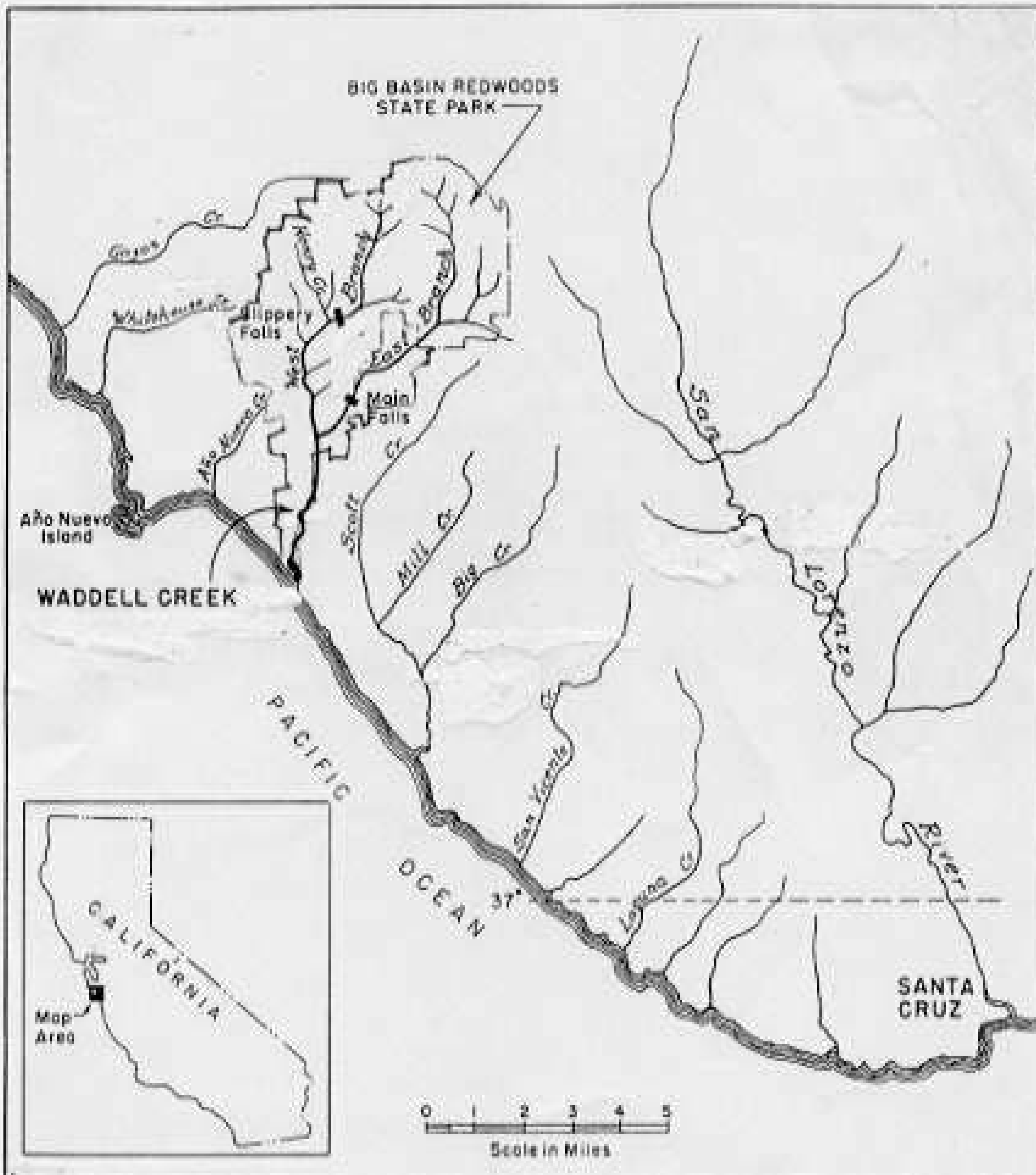
Big Basin Redwoods State Park includes about half of Finney Creek and Elliot Creek, two relatively small streams immediately northwest of the Waddell's mouth, and their respective watersheds. Both of these streams provide a small amount of permanent aquatic habitat for native amphibians, aquatic invertebrates, and other wildlife, and Elliot Creek sustains a small population of resident rainbow trout (Oncorhynchus mykiss) downstream from the Park. Finney Creek and Elliot Creek are also sources of appropriated water for downstream properties.

The Park contains relatively short segments of Boulder Creek (tributary to the San Lorenzo River), Año Nuevo Creek, and Scott Creek, three local streams which support notable native fisheries. The Park also includes lands, and in some cases seasonally-dry headwater channels, within the Butano, Cascade, Gazos, Green Oaks, Pescadero, and Whitehouse Creek watersheds, all San Mateo County streams which also support native fisheries and other sensitive aquatic resources in their lower reaches.

Few other State Park units contain as many distinct and diverse aquatic habitats as BBRSP. The many miles of streams support rich, diverse, and sensitive aquatic communities. Sempervirens Reservoir provides habitat for the State Endangered (federally Threatened) California red-legged frog (Rana aurora draytonii). The Waddell Lagoon provides habitat for several other listed or otherwise sensitive aquatic animal species including coho salmon (Oncorhynchus kisutch), steelhead, tidewater goby (Eucyclogobius newberryi), red-legged frog, southern Pacific pond turtle (Clemmys marmorata pallida), and San Francisco garter snake (Thamnophis sirtalis tetrataenia). The aquatic resources of Big Basin Redwoods are truly unique in the State Park System.

The information presented in this section of the Resource Inventory was compiled primarily from reports and documents in files of three agencies: the California Department of Fish and Game (DFG), the State Water Quality Control Board Division of Water Rights, and DPR. Aquatic resource field investigations of Big Basin State Park waters by DPR staff took place in March and May 1996, June and December 1997, April 1999, and March 2000.

Figure 1. Location of Big Basin Redwoods State Park amongst major Central California Coastal streams (adapted from Shapovalov and Taft 1954).



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The area drained by Waddell Creek and tributaries (and neighboring coastal streams) constitutes part of one of several discrete sub-drainage areas within the Sacramento-San Joaquin ichthyofaunal region (Moyle 1976), based on the native aquatic species associations typical of the area. The Pajaro-Salinas subsystem, comprised most notably of the major streams which flow into Monterey Bay but also the smaller coastal drainages north of Monterey Bay, is unique because varying numbers of fish species of the Sacramento-San Joaquin Region are present in different watersheds in close proximity. It is also the southern limit of the distribution of several species of Pacific salmon.

California's coastal streams usually exhibit a wide range of seasonal flows. Flooding torrents can be typical of spring, but by late summer many streams have dried to trickles. Most smaller streams are steep and flow rapidly to the sea, although some larger streams also meander across floodplains in their lower reaches. The 0.8 mile-long floodplain of Waddell Creek is relatively narrow and is occupied by marsh and lagoon under most conditions.

Moyle (1976) describes streams of the Sacramento-San Joaquin region as containing five intergrading zones: a rainbow trout zone, a California roach zone, a squawfish/sucker/hardhead zone, a deep-bodied fishes zone, and an estuarine fishes zone. The rainbow trout zone is found in clear headwater areas where the stream gradient is high, water is cool, and substrates are coarse. There are more riffles than pools and aquatic plants are few or absent. The dominant native fish is the rainbow trout but sculpin and speckled dace are also likely to be found in the lower portions of this zone.

The California roach and squawfish/sucker/hardhead zones are intermediate in altitude and can exhibit a wide range of flow and temperature conditions. However, pools are usually deeper and riparian vegetation more developed than in the rainbow trout zone. California roach as a species is well-suited to intermittent stream reaches, and Sacramento sucker is usually the dominant species in the squawfish/sucker/hardhead zone. Anadromous fishes, predominantly steelhead but also salmon (especially in the latter zone), use these reaches for spawning and rearing. Young anadromous fish typically move out into larger water before low water or high temperature conditions occur.

The deep-bodied fishes zone is typified by a variety of stagnant backwaters and deep pools and can support a mixture of fish fauna including true freshwater fishes, anadromous fishes, and fishes of marine origin. This zone then intergrades with the estuarine zone which is the region influenced daily by tides; the estuarine zone typically ends at a seasonal lagoon which forms during low flow periods behind sand bars formed by wind and waves. Substrates in the estuarine zone are usually dominated by varying mixtures of sand and silt. Fish in the estuarine zone can include additional marine species, though species segregation is apparently dependent on salinity preferences, feeding habits, and seasonal movements (Moyle 1976).

Because prehistorical (middle to late Pleistocene) connections of the Pajaro-Salinas subsystem to the main Sacramento-San Joaquin system were probably through Pajaro River tributaries, the Pajaro until recently contained eight of the eleven true freshwater fishes from the Sacramento-San Joaquin (Sacramento perch and tule perch are now locally extinct). This is the likely avenue of freshwater fish colonization into the subsystem. Native freshwater species present in the Salinas and San Lorenzo Rivers were originally fewer than the Pajaro (Snyder 1913), with only Sacramento sucker, California roach, and speckled dace present in the San Lorenzo. No prehistoric headwater connection of Salinas or San Lorenzo tributaries to the Pajaro is known; native species presumably were able to spread out of the Pajaro through lowland connections when sea level was lower, or through estuarine connections such as those which occur when flooding makes surface waters almost fresh (Moyle 1976). Waddell Creek contains fewer species than the Pajaro, Salinas, or San Lorenzo Rivers probably due to its smaller size and area, and thus because of the lesser likelihood of prehistoric connections.

Eleven other anadromous or estuarine fish species are native to the Pajaro-Salinas subsystem: Pacific lamprey, Pacific brook lamprey, coho salmon, rainbow trout/steelhead, threespine stickleback, tidewater goby, staghorn sculpin, coastrange sculpin, prickly sculpin, riffle sculpin, and starry flounder (Moyle 1976). Several other anadromous or estuarine/marine species are occasional visitors.

AQUATIC HABITATS

The aquatic habitat classification system proposed by Cowardin et al. (1979) provides for several levels of habitat description including system, subsystem, and class. Most of Waddell Creek is a riverine system, further subclassified as a rock bottom class of upper perennial subsystem. The lower reaches of several tributaries also fall into the above classification category. Areas of intermittent riverine habitat are present in the upstream-most reaches of all Waddell Creek tributaries and in headwater areas of other regional streams.

In its lowest 0.8 miles, Waddell Creek is estuarine habitat. Low areas outside the main stream, such as oxbows and other small ponds, are classified as palustrine. Classes of these habitats are typically aquatic beds and emergent wetlands, with some areas of unconsolidated bottom. Small examples of a forested class of palustrine wetland occurs within the redwood forest, as small areas of seasonal standing water, in some natural and man-made depressions surrounding the reservoir.

Sempervirens Reservoir is mostly lacustrine habitat, though because of its relatively small size and the persistence of emergent vegetation, its margins resemble palustrine habitat. At least four classes of lacustrine habitat are present, each in small quantity, including aquatic bed, unconsolidated bottom, unconsolidated shore, and emergent wetland.

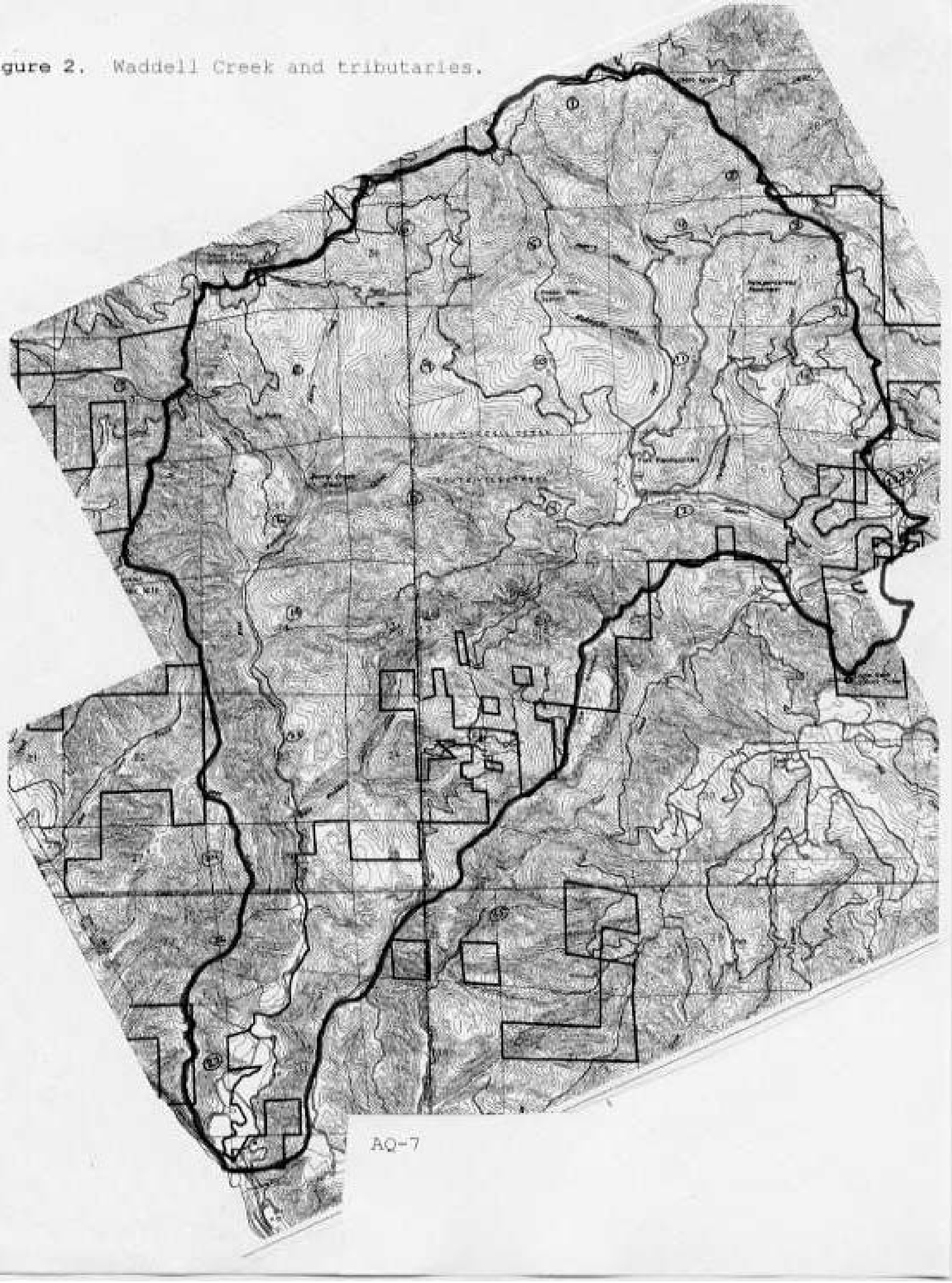
Waddell Creek

Waddell Creek and its many tributaries (Figure 2) arise from springs and surface runoff in the mountainous, northernmost portion of Santa Cruz County. The main stem and the two major forks of the creek flow generally to the south-southwest for most of their length and then empty into the Pacific Ocean about 17 miles north of Monterey Bay. The watershed encompasses an area of about 26 square miles with the streams beginning about 2,000' elevation; permanent flow persists below about 1,000' elevation in both forks and the larger tributaries (streams above this elevation are typically seasonal).

Extremely detailed information about the aquatic habitat in Waddell Creek is available because AmeriCorps crews, directed by DFG biologists, conducted an extensive "Stream Inventory" in June

and July, 1997. The standardized surveys followed standard methods (DFG 1994) and recorded flow, channel type,

Figure 2. Waddell Creek and tributaries.



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temperatures, habitat type, shelter/complexity, substrate type and embeddedness, bank composition, and vegetation for all of lower Waddell Creek and much of the East and West forks. Summary narratives and figures reporting the results were prepared by DFG staff (J. Nelson, pers. comm.; J. Nelson, unpublished file reports); the following descriptions of Waddell Creek are primarily derived from excerpts of those reports.

This inventory did not include a nutrient analysis, but Waddell Creek water quality data is regularly collected by staff of the water treatment plants at BBRSP. These measurements are made both upstream and downstream of the discharge of the BBRSP wastewater treatment plant (effluent is also tested) on the East Fork of Waddell Creek, and at Sempervirens Reservoir, source of potable water for most of the Park's developed facilities and residences. Discussion and reports of various water quality parameters are summarized in the Hydrology chapter of the BBRSP Resource Inventory (Rischbieter and Waldron 1998).

Main Stem Waddell Creek

The first 4,500' of Waddell Creek upstream from the ocean is estuarine in nature: meandering flatwater habitat subject to tidal influences. The habitat of the lagoon and marsh is discussed separately below. Flow in lower Waddell Creek can vary from about 1 cfs during droughts to several thousand cfs during flood peaks; water temperature varies diurnally and, while typically cool, can exceed 70 degrees F on warm summer days.

Upstream of the estuary the main stem contains another 20,000 feet of stream though it appears to be only half that length on maps; this sinuous channel is classified as an "F4" type, characterized as entrenched, meandering, dominated by riffles and pools with low gradient, high width/depth ratio, and gravel-dominated substrate. The habitat in this reach, between the estuary and the confluence of the East and West Forks, is 22% riffle, 37% runs and glides, and 42% pool by length. Eighty five pools, mostly (57%) mid-channel pools and typically deeper than 3' (58%), were identified in this reach during 1997. For about four percent of its length, the main flow of lower Waddell Creek is split between two channels.

Dominant substrate in the main stem varies by location and habitat type but is typically gravel and small cobble. Boulders dominate in some riffles and both boulders and sand dominate some pools and pool-tails. Streambanks are covered almost exclusively by deciduous riparian forest with small areas of coniferous forest or brushy/grassy areas, but as one proceeds upstream, more and more sites of active bank erosion exist. Several eroding banks exists which are over 100' long and 10' to 25' high.

<u>Waddell Lagoon and Hoover Marsh</u>

The area near the mouth of Waddell Creek is a complex of emergent marsh, wetland meadow, open water, and various swales and small ponds which occupy remnants of former Waddell Creek channels. This complex covers about 200 acres, most of it within BBRSP. A few hundred feet of Waddell Creek is usually to the west of Highway 1; this is a beach area and the site of periodic sandbar formation. The creek either flows over the sand to the ocean or ends here as shallow, sandy-bottomed lagoon.

Streambanks along the main creek channel support a variety of riparian shrubs, rushes, sedges, and other aquatic plants; deciduous riparian forest borders the stream at the head of the floodplain. The water quality in the lagoon varies by season and between years depending on rainfall and runoff, from fresh in periods of high runoff to brackish during late summer and fall. Periods and zones of high salinity often occur within a few hundred yards upstream of the ocean, and also as thin "lenses" on the bottoms of deeper pools during periods of low inflow. When the sandbar, if formed, is naturally breached after the first heavy rain of the season, freshwater conditions are restored. Though the sandbar often remains open through the winter, if inflow tapers off, then high tides can reintroduce saline or brackish conditions east of the highway.

The importance of lagoon and estuarine systems to aquatic communities cannot be overemphasized. This dynamic interface between freshwater and marine environments is rich in nutrients; estuarine habitat is more productive than any other ecosystem known except the coral reef (Owen 1976). Remaining coastal wetland areas in California are especially valuable to wildlife; up to three-fourths of our State's historic coastal wetland is gone and much of the remaining area is degraded (Clark 1980).

The lagoon of Waddell Creek provides valuable habitat utilized by all the fish species native to the creek. It is also typical of habitat preferred by most native amphibians and the southern Pacific pond turtle. Food organisms are relatively abundant in the lagoon. This productivity, combined with deep water, debris, and streambank cover, make the lagoon ideal for rearing juvenile aquatic organisms during important periods of their respective life cycles.

West Waddell Creek

The West Waddell contains about 6 miles of permanent stream upstream from its confluence with the East fork and another mile of seasonal stream in the headwaters. The lowest 4 miles are similar in description to the main stem (above) except that boulders dominate the substrate (F2 channel type) and the streambanks are forested predominantly by coniferous trees (74%). The upstreammost mile of permanent stream is also classified as F2, but in between is a short reach of C2 (low gradient, meandering, cobble-dominated alluvial channel with well-defined floodplain) and a little over a mile of F4 channel. Fallen trees contribute to pool formation, sediment detention, and habitat complexity throughout the West Waddell, though much of the wood is concentrated in debris accumulations and not dispersed where it might otherwise add to habitat complexity.

Bedrock features are exposed at several locations in and along the West Waddell, most notably in the vicinity of Henry Creek and within a mile of that confluence. Bedrock sheets create shallow runs and occasional bedrock walls create cascades or small falls. A wide, sloping (15' long at 40 degrees) bedrock formation creates a cascade about 100' upstream of the confluence of Henry Creek. Over its length, habitat in the West Waddell is 45% runs and glides, 41% pools, and 14% riffles. A total of 342 pools were identified in 1997 (three-fourths were main-channel pools, formed by mid-channel scour and not associated with banks or plunging water). About a third of the pools are greater than 3' deep.

Major West Waddell Creek Tributaries. Henry Creek, Berry Creek, and Kelly Creek are major, year-around tributaries of the West Waddell. Timms Creek and five unnamed streams, each averaging about a mile in length, also contribute cool water to Waddell Creek but are seasonal in their upper reaches. Only Henry Creek has a substantial reach of low gradient stream; Berry Creek has a popular 40' waterfall about 100 yards from its mouth and the other streams are also steep, with exposed bedrock and plunge pools which limit access and spawning habitat for anadromous fish to areas near the mouths.

Henry Creek was the subject of part of the 1997 DFG Stream Inventory Survey. About three-fourths of a mile of this stream is accessible to anadromous fish, above this point gradient steepens rapidly and there is a 75' cascade. An unnamed tributary about half a mile from the mouth was also surveyed. Henry Creek is a B4 channel type--entrenched with a moderate gradient and stable banks and gravel substrate.

At its confluence with West Waddell Creek, Henry Creek is underlain by bedrock and extremely entrenched between vertical banks (10' to 50' high!) of redwood forest. The mouth of Henry Creek is formed by a bedrock sill which extends out into West Waddell Creek. There is a shrub understory along lower Henry Creek which makes streamside travel difficult--it is easier to walk on the bedrock-bottomed stream even though it is only a few feet wide. Entrenchment moderates proceeding upstream and the stream is 63% riffles, 19% pools, and 15% runs/glides by length. Summer flow is typically only about 0.1 cfs, but the stream is well-shaded and springs and seeps maintain cool water temperature. Of 51 pools in the surveyed reach, only three were deeper than two feet. Woody debris was lacking, but undercut banks provide fairly good cover. Riffles and pool-tails have good deposits of unembedded gravel.

Short reaches of Kelly Creek and two unnamed tributaries to West Waddell Creek were also surveyed by DFG. Kelly Creek is steep and is characterized by bedrock cascades and boulder pools. The other tributaries reportedly had deposits of silt and sand, many feet deep, retained behind accumulations of woody debris. They were also steep and narrow and dominated by bedrock and boulders.

East Waddell Creek

The East Waddell begins when Blooms Creek and Opal Creek converge in the heart of Big Basin, and ends where it joins the West Waddell, a distance of about four miles. The only major tributary to this length of stream is Last Chance Creek, which is about one mile in length and enters the East Waddell about 0.5 miles from the mouth. (Last Chance Creek also has one unnamed intermittent tributary.) The lowest mile of East Waddell, and most of Last Chance Creek, is within BBRSP. Park ownership is also contiguous for about 1.5 miles below the Blooms/Opal Creek confluence. Two reaches in the central portion, a total distance of less than 0.5 miles, are privately owned.

The 1997 DFG Stream Inventory Survey included only the lowest 1.3 miles, upstream to a 30' waterfall located on one of the aforementioned private properties. This lower portion of the East Waddell, accessible to anadromous fish, is classified as an F2 channel type up to just below the Last Chance Creek confluence, and B2 (moderately entrenched, moderate gradient, boulder-dominated channels with infrequently-spaced pools and stable banks) the rest of the way up to the waterfall. The surveyed reach consisted of 61% runs/glides, 34% pools, and 5% riffles. Boulders, cobbles, and bedrock were all abundant--substrates are markedly coarser in this stream than in the West Waddell, but woody debris is conspicuously absent along the East branch. Streamside vegetation included both deciduous riparian forest and coniferous forest.

Last Chance Creek was not surveyed or visited during this inventory. It is steep with numerous small waterfalls (R. Briggs, pers. comm.); streams of this gradient are typically dominated by bedrock and coarse substrates.

The upper reach of the East Waddell quickly transitions from the relatively low gradient riffles and runs of the Big Basin area to a series of step-runs and plunge pools downstream. In between, near the outfall of the Big Basin sewage treatment plant, exists what is probably the largest pool in the system. Formed by exposed bedrock at the tail, this pool about 100' long and is usually scoured over 25' deep (sometimes storm runoff and erosion can result in deposition in this pool). The small turn in the creek's course caused by the bedrock's strike creates a counterclockwise circulation which is eroding the high right bank. Below this pool, the stream flows through a series of bedrock pools, cascades, and bouldery areas for a little over a mile as it descends steeply (about 400' per mile) to the aforementioned waterfall.

The effluent from the sewage plant is tertiarily treated, but downstream areas still are posted, warning of unpotable water. Water quality is monitored and dilution rates are typically high, but residual chlorine in the effluent may occasionally be detectable.

Opal Creek. Opal Creek drains the northernmost portion of BBRSP and flows south through the Park Headquarters area. Headwater channels are similar to other local streams (steep, intermittent, forested) but in its lowest two miles the stream flows year-around, meandering from pool to pool among the bottomlands and fallen redwood logs of central Big Basin. Opal Creek receives its name from a bluish-green "opalescent" color; it does not appear that there is a geologic reason for this, instead it is probably due to organic turbidity most obvious in pools. In fact, low summer flows of less than 1 cfs result in extensive flatwater areas appearing stagnant in summer and fall, but riffles in the "Barnes Kiosk" area flow clear and cool even though reddish iron-reducing bacteria are common in this stream. Opal Creek remains low gradient, flat water habitat for most of the rest of its length. It receives inflow from Rogers Creek and Maddocks Creek, which both have only a short length of permanent stream at their mouths. It ends with a 3' fall over a bedrock sill where it joins with Blooms Creek to form East Waddell Creek.

Blooms Creek and Union Creek. Union Creek and then Blooms Creek contain about two miles of permanent stream, from the Union Creek culvert crossing near the intersection of Lodge and Rogers Roads, to Blooms Creek's end where it merges with Opal Creek (to begin East Waddell Creek) below the Blooms Creek Campground. Habitat in the upper reaches is formed by woody debris, outcrops of bedrock, and deposits of alluvium which combine to form narrow pools with depths between 1 and 3 feet and having sandy, gravelly substrate and undercut banks amidst coniferous forest. The gradient moderates from step-pools to low-gradient riffles and shallower pools in the vicinity Sempervirens Campground; this downstream area is characterized by riparian shrubs in addition to coniferous forest along the banks.

Water quality in Union and Blooms Creeks occasionally suffers from leaching sewage. Relative high coliform counts have been measured in Union Creek though pollutants get diluted downstream, however coliform counts have been shown to rise again as the stream flows through the campground (Rischbieter and Waldron 1998). Sign are posted along Union Creek to caution against human contact.

Sempervirens Creek. Sempervirens Creek is both the main tributary and the outlet stream of Sempervirens Reservoir, BBRSP's main water supply. Most of the half-mile of stream above the reservoir is seasonal, though permanent flow exists for the lowest few-hundred feet where it is fed by a number of small springs. A small unnamed tributary joins the main stream at the head of the reservoir. Both these streams are entrenched in deep forest soils with a large amount of woody debris strewn in and over the narrow channels. Substrate is gravel and sand; pools are typically small and shallow.

Below the reservoir, Sempervirens Creek flow is a combination of the outflow from the reservoir, which can be surface water (spill) or deepwater (controlled, valve) outflow, and permanent flow from seeps and springs. The stream flows for about 2 miles between Sempervirens Dam and its confluence with Blooms Creek. A mile downstream from the reservoir, Sempervirens Creek receives year-around inflow from Union Creek. In the occasional absence of reservoir discharge, the creek channel will be dry for a few hundred feet below the dam in summer, before accretion from springs restores surface flow. Bedrock substrate dominates the channel below the dam though deposits of boulders, cobble, gravel, and sand occur in and between pools. The gradient is fairly steep until the last half-mile, with high-gradient riffles, step pools, and cascades and an eight-foot waterfall as significant features, but pools are. Typical established pools in this area are bedrock-formed and relatively deep. Large woody debris (from fallen trees) is also common in the channel.

Stream habitat above the reservoir is limited but relatively constant, with cool water temperature and good water quality. High flow in response to heavy rainfall does transport substantial sediment however, as evidenced by the accumulation of fines at a young delta at the head of the reservoir. This sediment discharge may be related to the development of Highway 236 through the upper portion of the reservoir watershed.

Stream habitat below the dam can be subject to a variety of relatively harsh changes. Stream temperature varies depending on the volume of surface water passing over the spillway. Typically the warmest water in the lake, especially in spring and summer, this spilled water will only cool when there is proportionately enough flow contributed from springs (and Union Creek) downstream. Conversely, periodic deepwater discharge from the reservoir is invariably cool, but water quality can be poor when anaerobic conditions occur in the hypolimnion (common in summer). The anoxic water can be high in sulfides, low in pH, and high enough in volume that the harsh aquatic environment it creates cannot be quickly diluted by accreting springflow.

Sempervirens Dam stops sediment transport from the upper watershed, so the creek below the reservoir is prone to scour. Some sediment recruitment occurs because of the steep canyon walls, so this condition does not significantly degrade habitat. Bedrock exposure is a natural condition in the lower watershed as evidenced by the presence of Sempervirens Falls and the slickrock area to the west of the falls.

Elliot Creek

The upper 1.5 miles of Elliot Creek is within BBRSP, fed by springs and precipitation. Almost all of the watershed for this reach is also within the Park. This creek has one unnamed seasonal tributary of significant size, about 1 mile in length, which is entirely within the Park. At the Park boundary and upstream, most of Elliot Creek (and tributary) is dry in summer, but downstream flow is permanent. It is difficult to determine where permanent flow ends because the channel is overgrown with a mixture of riparian shrubs and coniferous vegetation and difficult to access; in some places surface flow percolates into alluvial deposits and reemerges in areas of bedrock or entrenched channel. A five-foot flashboard dam exists near the Park boundary, diverting water under an appropriative right to the Coastways Ranch; the owner reports that the stream is dry at the dam only in drought years (T. Hudson, pers. comm.).

In BBRSP, the stream flows through areas of old- and second-growth redwood forest. In some places the stream has cut below roots and is deeply entrenched, in other places it flows over fallen logs. Substrate is typically sand and gravel behind such logs and the dam, but bedrock is exposed in some places upstream from the dam. In most places this stream is only one to three feet wide and pools rarely exceed one foot in depth.

Finney Creek

Approximately 1 mile of upper Finney Creek is within BBRSP. Finney Creek originates from springs and surface runoff in a narrow canyon immediately northwest of the Elliot Creek watershed. Like Elliot Creek, it flows southwest directly to the ocean and is difficult to access in many places because of a dense streamside shrub understory (though the area is predominantly coniferous forest) and areas of steep bedrock.

Much of Finney Creek is steep and entrenched in deep forest soils. These entrenched areas often contain logs and other forest debris, sometimes with a few feet of sediment detained behind them. Just inside the Park boundary is a moderately steep (sloping) area of exposed bedrock about 30 or 40 feet long. From this bedrock area is a gravity-flow diversion (1" pipe) for domestic water to the Coastways Ranch. At the point of diversion flow is permanent, though in drought years volume is insufficient to maintain the diversion (T. Hudson, pers. comm.). Even in most summers, Finney Creek at this point is a shallow trickle of water that disappears into any area of porous substrate. There are only small pools (few over 1' deep) and the stream in rarely more than 2 or 3 feet wide. The low-volume diversion of water from this bedrock area does not appear to significantly affect quantity or quality of aquatic habitat.

Above the diversion, only about 0.1 miles of stream normally flows all year. Groundwater emerges in the channel at and below smaller areas of bedrock and the stream normally gains flow from the input of additional springs as it courses through a series of small bedrock pools, riffles, and step-pools. Forest debris fills much of the channel in several places, and hydrophytic vegetation is established in a few low streamside areas which are not otherwise too steep or rocky. A detailed description of streamside vegetation can be found in the Plant Life section.

Boulder Creek and San Lorenzo River

About a square mile of northeastern BBRSP is in the San Lorenzo River watershed, mostly through a major tributary, Boulder Creek. The San Lorenzo is Santa Cruz County’s largest river and is discussed in more detail in the Castle Rock State Park Aquatic Resource Inventory (Rischbieter 1996). Most of the San Lorenzo River watershed is under private ownership. Vast undeveloped areas are managed for timber resources, but numerous developed areas are characterized by semi-urban and rural development. The two disjunct Boulder Creek segments under BBRSP ownership, totaling about 1 mile of stream, are along and near China Grade Road about two to three miles upstream from the Boulder Creek Golf and Country Club. About half a mile of Jamison Creek headwaters and about 0.2 miles of a seasonal headwater channel of Hare Creek, both Boulder Creek tributaries, are also within BBRSP boundaries but were not visited for the purposes of this resource inventory.

The two reaches of Boulder Creek in BBRSP provide somewhat different habitats. The downstreammost section, totaling about one third of a mile, flows year-around. The stream here forms a series of pools and cascades amongst a substrate dominated by bedrock and small boulders; the gradient is steep enough to transport most fine sediments downstream, though silt and mud and debris accumulate in a few places. Streamside areas are typically steep slopes of redwood forest, but some small streambank terraces occur which often are associated with springs, seeps, and small patches of wetland vegetation. A small tributary joins Boulder Creek within the Park; permanent tributary flow may exist at the confluence, but most of this tributary is seasonal and outside Park boundaries. This tributary, like some other seasonal and stormwater drainageways in the area, is incised into the adjacent terrace.

The longer, upstream portion of Boulder Creek is seasonal stream; about half a mile is within the Park downstream from the Highway 236 (headwater) crossing. The gradient is steep and the narrow channel is incised through second-growth redwood forest. Small substrate material, plus accumulations of woody debris (of various sizes) from the surrounding redwood forest, characterize this reach of stream.

Other Regionally-Important Streams

Gazos Creek, Whitehouse Creek, Cascade Creek, Green Oaks Creek, and Año Nuevo Creeks (northwest of BBRSP) are streams notable for significant aquatic resources. However, relatively minor portions of these waters (relatively short segments of seasonal headwater channels) occur within BBRSP boundaries (Rischbieter and Waldron 1998). Instead, many of the most significant aquatic resources occur downstream in Año Nuevo State Park and State Reserve (also Butano State Park, in the case of Gazos Creek). The aquatic habitats of these waters have not been described in any single compilation (such as a DPR Resource Inventory), but information at varying levels of detail may be available from the Año Nuevo unit office or Bay Area District files. The DFG completed habitat surveys on most Año Nuevo streams in 1995, and on Gazos Creek in 1993 (J. Nelson, pers. comm.), but they did not extend inland to BBRSP property and thus do not warrant inclusion in this Inventory.

Scott Creek (southwest of BBRSP) is also a stream of major regional significance. However, only about 0.1 mile of the main stem of Scott Creek is within BBRSP; the easiest access is by permit, on foot via a dirt road (the last mile is unmaintained), over Big Creek Lumber Company land. A quarter-mile BBRSP-portion of a tributary upstream from the falls, locally known as "Bannister Gulch", is also within the Park but is very steep (averaging over 1,000' per mile) and was not visited during this resource inventory.

The Park reach of Scott Creek is in a transition range between productive lower reaches (characterized by lower gradient, habitat complexity and diversity, and a well-developed riparian forest) and steepening headwater reaches that generally provide less diverse (and less productive) habitat. Within and near the Park, the steep-walled canyon of second growth redwood and dense shrub undergrowth confine Scott Creek with negligible floodplain development. The portion within the unit is characterized by bedrock and boulder substrates and various pool, riffle, and step-pool habitat types. A three-step cascading waterfall is located about 0.1 mile downstream from DPR property and presents a barrier to most upstream fish migration, but these falls appear to be passable by steelhead under most normal flow conditions because there are deep pools between the steps. A DPR field visit to this reach in June 2000 indicated that high flows in seasons following a 1997 DFG survey (J. Nelson, pers. comm.) may have rearranged boulders in this area and reduced the height of other falls and cascades (potential barriers to steelhead migration) in this reach.

Unnamed and/or Other Seasonal Streams

About 15 minor unnamed streams, most tributary to Waddell Creek or its tributaries, occur within BBRSP but were not surveyed during this inventory. They are predominantly seasonal, but may have permanent surface flow in their lowest reach in cases where they are tributary to permanent streams. In general, they are characteristically steep and have typically become filled with forest debris in the absence of a regular fire regime. In areas of previous road development or past logging activity they are often filled with deposits of sediment of varying depths.

Small/intermittent streams can provide habitat for fish, including spawning habitat for anadromous fish, near their termini at larger permanent streams.

Sempervirens Reservoir

Sempervirens Reservoir is a man-made impoundment constructed in the steep-sided canyon of Sempervirens Creek in 1951 for water supply in Big Basin. The water level is regulated by a 42-foot high dam and has a regulable capacity of about 77 acre-feet. Normally held full to spillway elevation, the reservoir provides lacustrine habitat up to 33 feet deep. Roughly triangular in shape, the shoreline has little irregularity except for a short peninsula on the northwest side. Littoral zones near the shoreline are narrow and limited: the average depth of the reservoir is about 19 feet though the surface area is only about 4 acres. Nearshore areas are vegetated by rooted aquatic species, predominantly <u>Potomageton</u> and <u>Myriophyllum</u> (along the dam) and dense narrow stands of <u>Typha</u> (other margins of reservoir). Algae and other plant species occur, especially along the dam, but were not identified.

The reservoir stratifies in summer but does not freeze in winter (warm monomictic). Summer surface temperatures can exceed 70°F but lower strata persist between 40°F and 45°F. Dissolved oxygen typically remains high in the epilimnion, approximately 9 to 10 ppm at 10 foot depth. However, the hypolimnion becomes anaerobic during summer and hydrogen sulfide concentrations build at the bottom. A summary of water quality data from Sempervirens Reservoir is compiled in the Big Basin State Park Watershed Sanitary Survey (Carroll 1996).

Springs and Seeps

Persistent or otherwise important springs and seeps were not surveyed for the purposes of this inventory. However, several were observed in the canyons of the Park and they are known to be an important source of water for wildlife and hydrophytic plant communities. Water quality parameters of such springs in the Santa Cruz mountains often vary but the range of conditions at BBRSP were not assessed. Good quality water is known to be produced by Pine Mountain Spring, once a developed source for BBRSP. There are also apparently springs below Sempervirens

Reservoir which produce a zone of colder water along the reservoir's northwest side (D. Carroll, pers. comm.).

AQUATIC COMMUNITIES

The aquatic communities of BBRSP are rich and moderately diverse. Eleven species of fish, at least four species of amphibians, three species of reptiles dependent on aquatic habitats, and well over 100 taxa of aquatic insects and other aquatic invertebrates have been recorded in the Park. Aquatic habitats also support many species of aquatic and semiaquatic birds. The greatest diversity occurs in the lowest mile of Waddell Creek, but many species are widespread.

The descriptions of BBRSP aquatic communities which follow are mostly derived from information collected and reports published by non-DPR researchers. Some fish sampling by DPR staff was conducted for the purposes of this resource inventory and is summarized in Appendix AQ-I. Aquatic invertebrate taxa recorded in 1998 during a study by BBRSP staff are listed in Appendix AQ-IV. Appendix AQ-I also indicates many waters for which little or no specific aquatic resource information apparently exists.

Waddell Creek and Lagoon

The fishery of Waddell Creek has been the subject of in-depth study intermittently since the 1930s. At that time, Shapovalov and Taft (1954) began their landmark study on the life history of steelhead and silver (coho) salmon. Their definitive paper is a most valuable resource describing coho and steelhead life history and these species' relationships to the greater Waddell Creek aquatic community. More recent monitoring and research has been conducted by San Jose State University (Department of Biological Sciences) under the direction of Dr. Jerry J. Smith. However, until this resource inventory, little data had been collected from waters in the Park which are upstream from areas accessible to anadromous fish.

Rainbow trout is the most widespread fish in Waddell Creek and BBRSP. In the lowest few miles of the creek it is present in its anadromous form (steelhead), but resident (non-anadromous) populations exist in many waters upstream from waterfalls which prevent steelhead access. Steelhead/rainbow trout were once objects of great recreational interest in Waddell Creek, but fishing is no longer permitted upstream of Highway 1 since the 1980s. Coho salmon are also historically fish of recreational interest; the populations in Waddell Creek represent one of the southernmost of their range. As is the case in most Western streams, records suggest that anadromous fish spawning runs today consist of fewer individuals than they did historically. In the 1930s and 1940s, records show that adult coho returned annually to Waddell Creek in numbers ranging from about 100 to over 500 adults, and steelhead in annual numbers typically between 300 and 500 (Shapovalov and Taft 1954). Today, adult steelhead numbers are probably less than half this. Coho are also greatly diminished and vary from year to year for reasons which will be discussed below.

Both resident rainbow trout and steelhead spawn during late winter and spring. Steelhead typically begin their migration from the ocean during the first high flows of the fall or winter (after the lagoon is breached) and in most cases attempt to return to their natal stream. It is not unusual for them to return to the same point in the stream from which they emerged as fry. Successful rainbow trout spawning requires areas of clean gravel with moving water; eggs typically hatch in about 4 weeks (dependent upon water temperature). Suitable spawning habitat exists in many areas of Waddell Creek and tributaries.

Juvenile rainbow trout require low-velocity stream margins for initial rearing and then riffles and pools for feeding and cover. Juvenile steelhead will spend one to three years in freshwater, often slowly migrating downstream, before becoming smolts and entering the ocean. In general, the larger the smolt at the time of emigration to the ocean, the greater the chances are that it will return as an adult to spawn. Steelhead typically spend one or two years in the ocean before returning to spawn. Unlike salmon, steelhead usually do not die after spawning and can return to the ocean to repeat their spawning migration again in the next year(s).

Steelhead can access all of the main stem of Waddell Creek, about 1.5 miles of the East Waddell (to a 30-foot waterfall), up to six miles of the West Waddell (dependent on distribution of accumulations of logs and debris which can often comprise barriers), and the lower reaches of many Waddell tributaries until a waterfall is encountered. Upstream of these barriers, resident rainbow trout occur in many (but not all) streams. Above waterfalls, small trout populations observed are effectively isolated between the waterfall (barrier) and intermittently dry stream areas upstream. Thus, recruitment of new individuals in upstream reaches is limited to natural reproduction and immigration from limited upstream areas. Population size can also be limited by the small and confined habitats. Spawning, rearing, and other habitat needs of such resident trout are similar to steelhead, except they can complete their entire life cycle within just a few hundred feet (or less) of stream.

Resident rainbow trout were collected from upper East Waddell Creek, in the vicinity of the BBRSP sewage treatment plant, in May of 1996. Some were collected also from upper West Waddell Creek, in the vicinity of the Santa Cruz-San Mateo county line and the Gazos Creek Road crossing, during the same period. Length-frequency distributions of resident rainbow trout collected and population estimates (Van Deventer and Platts 1989) are presented in Appendix AQ-II.

Coho salmon are not as widely distributed as steelhead because they rarely migrate into steeper reaches of streams (gradient >2%). Thus, they do not typically occur more than about half a mile up the East Waddell, nor in the West Waddell upstream from

the confluence of Henry Creek (about 2.5 miles up the West Waddell; they also occur in Henry Creek).

The timing of coho migration and spawning is frequently a few weeks earlier than that of steelhead. Suitable spawning habitat is similar in character to that requires by steelhead. Optimal habitat for juveniles consists of deep pools with complex habitat composed of large woody debris, a condition typical of old-growth forest and riparian woodland. After about a year in the stream, juveniles (smolts) migrate to the ocean where they typically spend two years before returning to their natal stream. Females invariably follow this 3-year cycle, but precocious males will often return to their natal stream after only one year in the ocean (Shapovalov and Taft 1954). Coho, like most salmon, spawn once and die soon thereafter.

The constraints of a 3-year maturation cycle impart a cyclical variability to the population size of coho salmon. In Waddell Creek, the strongest year-class returned in 1993 and 1996. A weaker year-class (lower numbers of spawners thus less reproduction) recurred in 1992 and 1995. No coho spawning or reproduction was observed for the 1991, 1994, or 1997 year-classes (Smith 1998). Attempts are underway to help "fill in" the missing year classes using precocious, hatchery-reared females, but many events can lead to diminished reproductive success (and thus weak spawner returns three years later) in any given year. For example, because of the coho's relatively early spawning period, eggs and larvae are susceptible to the ravages of winter freshets which can scour streambed gravels. While such decimation of a year-class can happen overnight, rebuilding of the impacted year-class can take many seasons (spaced three years apart). Natural and unnatural disturbances can also recur, resulting in decades of dramatic population fluctuation from year to year.

The 1999 year-class was expected to be strong (following 1993 and 1996), but initial survey results indicated an inexplicable absence of salmonids in the main stem Waddell Creek that fall. So dramatic was this unexpected void in the distribution of fish that DFG investigated the possibility of a fish kill downstream from Camp Herbert (J. Nelson, pers. comm.). No definitive evidence was located.

Stream-dwelling salmonids feed mostly on drift organisms, but they also take active bottom invertebrates. Such a diet will include larval and adult stream and terrestrial insects, crustaceans and mollusks, and occasionally smaller fish and other vertebrates (Moyle 1976). A variety of substrates, stream habitat types, and woody debris and detritus all contribute to suitable habitat for diverse aquatic insects and other invertebrates (Appendix AQ-IV).

Other fish species which compete for some of these same food resources in Waddell Creek are prickly and coastrange sculpin (Cottus asper and C. aleuticus, respectively), and threespine stickleback (Gasterosteus aculeatus). All are native species which are common in the main stem of Waddell Creek and spend their entire life cycle there or in the lower reaches of Waddell tributaries (the upstream limit distribution of their distribution is not known, but none apparently occur in headwater areas where resident rainbow trout were collected).

Prickly and coastrange sculpins occupy a wide range of bottom habitats. They live in waters ranging from fresh to salt, in streams ranging from small, cold and clear to large, warm, and turbid. They are opportunistic feeders on all benthic animals of an ingestible size. In general, sculpin adults of these species spawn in pools and lagoons near the mouth of coastal streams. The Waddell lagoon provides excellent habitat. Eggs are typically laid under rocks and logs during spring; males guard eggs until hatching is complete. Juveniles move upstream as soon as they are large enough to swim against the current. Either species of sculpin may be important in the diet of larger salmonids, but their cryptic coloration and bottom-dwelling and nocturnal habits make sculpins generally unavailable to kingfishers and other avian predators (Moyle 1976).

Threespine stickleback are an important forage for larger fish and avian predators. Stickleback are small, rarely exceeding 2.5 inches in length. They are quiet-water fish, living in weedy pools and backwaters, or among debris, over bottoms of sand and mud. Threespine stickleback require cool water (below 75°F) and relatively clear water conditions since they are visual feeders. Freshwater populations feed primarily on bottom organisms or organisms living on aquatic plants (Hagen 1967; Moyle 1976).

Stickleback populations can be heavily infested with intermediates stages of bird tapeworms. These larval tapeworms can grow to occupy most of the body cavity of the fish, causing them to swim sluggishly near the surface of the water. This in turn makes them more vulnerable to kingfishers and herons. Digestion introduces the larval tapeworm into the intestine of these piscivorous birds where it grows to adulthood. Tapeworm segments, containing ova, are excreted in the bird's feces. Ingestion of these segments by fish will complete the worm's life cycle (Moyle 1976).

Tidewater gobies are intermittently established in Waddell Creek. This native fish lives near the mouths of coastal streams throughout much of California, though its range and the number of occurrences has been sharply reduced in recent decades (Moyle 1976). Tidewater gobies were extirpated from Waddell Creek in 1973 by a flood, reintroduced by DFG (from a population in Scott Creek, the next coastal drainage south) in 1991, and severely reduced in number by the flood of December 1995 (Smith et al. 1997). Subsequent floods have apparently prevented the population from enlarging.

Tidewater gobies inhabit water from fresh to brackish. They prefer upper ends of lagoons, in slow-moving waters or pools well away from the main current. Emergent and submerged vegetation provides cover and forage opportunities; they probably feed on small organisms though algae may be taken as well. They can complete their life cycle in fresh water, as they spawn on substrates of coarse sand (Moyle 1976). However, some venture out into salt water, as they have recolonized some coastal streams after having apparently been absent for many years.

Additional euryhaline/estuarine fish species have been recorded from the Waddell Lagoon by various investigators in past years (Appendix AQ-III). Starry flounder (Platichthys stellatus), staghorn sculpin (Leptocottus armatus), and topsmelt (Antherinops affinis) are occasionally common. All are generally benthic feeders, the topsmelt is vegetarian (Moyle 1976). Except for staghorn sculpin, which may sometimes migrate upstream into fresh water, the distribution of these species in Waddell Creek is limited and they are relatively minor elements of the aquatic community.

The only non-native fish likely to occur in Waddell Creek are striped bass (Morone saxatilis) and golden shiner (Notemigonus crysoleucas); neither is apparently common. Striped bass are established in the Sacramento-San Joaquin River system after being introduced during the late Nineteenth Century from Atlantic streams and bays. They spend part of their life cycle in salt water and reportedly occasionally stray into Waddell Creek though they do not reproduce there (Shapovalov and Taft 1954). Golden shiner are established in Sempervirens Reservoir where they probably were carelessly introduced by fishermen using them as live bait. Because Sempervirens Reservoir normally overflows, golden shiner may periodically occur in downstream waters (Sempervirens Creek, Blooms Creek, East and main Waddell Creeks). A schooling fish preferring warm, slow water, it is conceivable that golden shiner could become well-established in Waddell Lagoon. Golden shiners compete with juvenile salmonids for food and, although they can provide forage for salmonids, salmonid production is typically reduced when golden shiners are present.

Small numbers of two species of native amphibians, California newt (Taricha torosa) and Pacific giant salamander (Dicamptodon ensatus), were collected while sampling for fish in Waddell Creek within the Park. Foothill yellow-legged frogs (Rana boylii) have been reported in Waddell Creek (Shapovalov and Taft 1954), and the California red-legged frog has been recently studied in and around Waddell Lagoon/Hoover Marsh (Smith et al. 1997). Additional information about these and other native amphibian species is presented in the Animal Life section of the BBRSP Resource Inventory.

Smith et al. (1997) also described important elements of the aquatic reptile community associated with Waddell Creek, primarily in the lower reaches. Additional information about these and other native reptile species is presented in the Animal Life section.

As mentioned briefly above, the productivity of the Waddell Creek system supports a reasonably rich variety of aquatic invertebrates. Shapovalov and Taft (1954) produced a comprehensive list of invertebrates occurring within the basin, but a station on West Waddell Creek (about half a mile upstream of the Timms Creek confluence) was specifically described in 1998 during benthic macroinvertebrate community assessment (Appendix AQ-IV). Several orders of aquatic insects represent most of the diversity. The introduced signal crayfish (Pacifasticus leniscululus), a Crustacean, is the largest invertebrate, and probably the most conspicuous though it rarely appears in Waddell Creek in large concentrations (it is widely distributed in permanent water throughout the watershed). Individual insect species are an assortment of grazers, predators and scavengers; the crayfish, which can grow to over 8" in length, is primarily a scavenger. Almost all are important sources of food for fishes, amphibians, reptiles, birds, and mammals.

Henry Creek and West Waddell Tributaries

Henry Creek is notable as the upstreammost Waddell Creek tributary that supports coho salmon spawning. Returning adult coho are guided into the mouth of Henry Creek by water sluicing through a low lateral bedrock "chute" which extends out into the West Waddell. A sloping bedrock falls, about 10 feet high, prevents coho passage further up the West Waddell. Steelhead are the only other fish species known to occur in Henry Creek.

Other relatively-large West Waddell tributaries, such as Berry Creek and Kelly Creek, support steelhead in their lower reaches. Above Berry Creek Falls, resident rainbow trout are the only fish known to be present. The upstream limit of their distribution is not known.

East Waddell and Tributaries

Coho salmon periodically spawn in the lower reaches of the East Waddell, but the large watershed upstream from this point can result in high flows which have frequently destroyed redds. Smith (1998) makes note of this occurring in 1992 and 1995. Steelhead can access over a mile of lower East Waddell and juveniles are normally common. The ranges of other fish species (if present) in the East Waddell are not known.

Resident rainbow trout are abundant upstream of the waterfall on East Waddell Creek. Dozens, or perhaps a couple hundred, were observed just in the one unusually large pool immediately downstream of the BBRSP wastewater treatment plant. The density of rainbow trout in the riffle zones upstream from that pool was estimated to be about 1,000 trout/mile, based on sampling conducted in 1996, suggesting it is a relatively productive system (Appendix AQ-II). No other fish species were collected in this area, but a few crayfish were collected and some unidentified salamanders were observed in an early post-hatching stage (with an egg-sac still attached). The macroinvertebrate community of the East Waddell was described from two stations in 1998, one above and one below the wastewater outfall. The aquatic communities at these two points were similar, however the proportion of predator invertebrates and overall taxa richness was slightly lower below the outfall. However, both sites supported a greater abundance of invertebrates than the 1998 West Waddell station, perhaps suggesting organic enrichment of East Waddell waters is occurring (Appendix AQ-IV). Sources of organic enrichment could include upstream BBRSP campgrounds and the wastewater treatment plant. Past water quality testing has indicated a rise in coliform bacteria occurs in the vicinity of the campgrounds; relatively high levels also have been measured in upper Blooms Creek (Rischbieter 1998).

Rainbow trout also dominate the aquatic community of several waters above the East Waddell. They are normally distributed throughout Sempervirens Creek with the greatest numbers occurring below Sempervirens Falls. They are present in lower and middle reaches of Union Creek, but apparently not above the maintenance-area road crossing. They are relatively abundant (four age classes have been observed) in Opal Creek to a point at least half a mile upstream from "Barnes Kiosk"; this upper area is used by Opal Creek trout for spawning. Rainbow trout also occur in Blooms Creek throughout the portion within BBRSP. California newts and other unidentified salamanders are also conspicuous in all these streams.

Elliot Creek

Resident rainbow trout are present in lower Elliot Creek, upstream from the Highway 1 culvert, but not within BBRSP boundaries. However, within BBRSP Elliot Creek provides habitat for amphibians and invertebrates. In June 1997 unidentified larval amphibians were observed in the shallow, sedimented pool formed by the diversion dam at the Park boundary. Several species of invertebrates, dominated by a Heptageniid mayfly nymph (Ephemoptera), Dipterans, and Hemipterans (<u>Gerris</u>), were also present in this portion of stream. The remains (empty matrix) of an amphibian egg mass was also present; collectively these observations indicate that this small stream provides important habitat for several life history stages of at least one species of amphibian. Communities such as these represent an important refuge for amphibians: amphibian populations often thrive in the absence of fish (which can be predators). However, in small streams they also are often easier prey for terrestrial animals, where they can often be caught more easily by reptiles, birds, and mammals. The ecological interactions of amphibians with terrestrial wildlife is discussed in more detail in the Animal Life section of the BBRSP Resource Inventory.

Other Regionally-Important Streams

Portions of other regionally-important streams within BBRSP are small but not altogether insignificant. An awareness of the aquatic resources of such streams is important in guiding activities in the respective watersheds, and perhaps to allow cooperative efforts toward aquatic resource protection with neighbors. However, this Resource Inventory will not describe the aquatic communities of other streams within BBRSP in much detail, for several reasons. Nevertheless, some general information is appropriate and relevant to BBRSP General Planning.

Scott Creek, immediately south of Waddell Creek, is notable as the southernmost stream currently with a natural run of wild coho salmon. Hatchery-reared fish are also maintained there, with the primary objective of propagating genetically-wild stock for population supplementation in Scott Creek, and other nearby streams. While other fishes found in Waddell Creek also occur in Scott Creek, probably only steelhead (or resident rainbow trout) occur in the 0.1 mile-long segment, almost 7 miles from the mouth, which is within BBRSP. Segments of Scott Creek tributaries within BBRSP, upstream from this point, are too steep (and/or too far up into the headwaters) to support a fish population but are an important source of water for other wildlife.

Boulder Creek and the San Lorenzo River once supported wild coho; the San Lorenzo was commonly regarded as the southernmost extent of coho range. The drought of 1976-77 caused extirpation of the naturally-spawning population (Brown et al. 1994) and attempts are ongoing to restore the coho runs through hatchery augmentation. Some coho returned to Hare Creek, downstream from the BBRSP headwater section, as late as the mid 1990s (J. Nelson, pers. comm.). On Boulder Creek, barriers reportedly prevent steelhead access to the headwaters within BBRSP, but Pacific lamprey may occur in these upstream areas, and perhaps also resident rainbow trout. No sampling of these areas occurred for the purposes of this resource inventory, but a more thorough discussion of the aquatic communities of the San Lorenzo River can be found in the Castle Rock State Park Aquatic Resource Inventory (Rischbieter 1996).

Coho runs have been established on Gazos Creek, and steelhead occur naturally in Gazos (including Old Womans Creek), Año Nuevo, Whitehouse, Butano, and Pescadero Creeks. Most of these streams have waterfalls in their middle reaches which limit steelhead passage, but resident rainbow trout occur above most falls (G. Strachan, pers. comm.) and in the lower reaches of Cascade Creek (P. Keel, pers. comm.). Other native fish and amphibians also occur in these streams, and the Cascade, Green Oaks, and Butano Creek systems include reservoirs which contain various non-native, warmwater species as well. However, fish do not occur in the portions of these streams (headwaters) currently under BBRSP ownership.

Sempervirens Reservoir

The only major lentic habitat in BBRSP supports two species of fish, both introduced into this habitat. The rainbow trout in Sempervirens Reservoir, though regionally a native species, most recently colonized the reservoir in 1995 following their escape from rearing pens used to hold steelhead for the Monterey Salmon and Trout Project (D. Carroll, pers. comm.). Trout and some warmwater game species (non-native) were probably introduced in earlier decades but apparently did not persist. Reservoir operations can often influence the status and persistence of fish populations; past populations here may have been extirpated on occasions when the reservoir was drained for maintenance.

The existing rainbow trout population reproduces successfully at the reservoir's inlet. The growing delta of sediment at the head of the reservoir contains deposits of gravel amongst sand which are suitable spawning habitat. Like steelhead, these trout would be expected to spawn in late winter/early spring. Fry emerging from the gravel in spring school in the inlet stream and gradually disperse into the reservoir. At this stage they are relatively easy prey for larger fish, amphibians, and other larger aquatic predators.

Golden shiner also occur in Sempervirens Reservoir, most likely the result of anglers who allowed live bait to escape. (Park staff do not allow at the reservoir but some unauthorized angling probably occurs.) Schools of these fish are abundant around the reservoir's margins and they are probably an important forage species for the trout, piscivorous bird and reptiles, and perhaps amphibians. They also compete with trout (and presumably amphibians) for food (Moyle 1976).

Unlike the lotic habitats in the vicinity of Sempervirens Reservoir, the rainbow trout share dominance in this aquatic community with two species of amphibians. Both native California red-legged frog and non-native bullfrog coexist in Sempervirens Reservoir. This coexistence in itself is somewhat unusual: bullfrogs usually outcompete the smaller native species where they have become established and are a large part of the reason that populations and range of the latter have sharply declined. Introduced fish can also reduce native amphibian populations: while trout fry are preyed upon by frogs, larger trout opportunistically prey upon tadpoles and even small frogs. However, several surveys for red-legged frog during the mid- and late-1990s suggest the population in Sempervirens Reservoir may be the largest in this area of Santa Cruz County (R. Seymour, pers. comm.).

Lentic habitats can also be a source of nutrient enrichment for watersheds. Unlike downstream waters, a relatively large amount of primary production occurs in Sempervirens Reservoir. Algae and zooplankton are thus more of the foundation of this aquatic community, whereas stream-dwelling communities depend, to a larger degree, on nutrient import from terrestrial systems.

Other Aquatic Habitats

The only other permanent stream and aquatic community in BBRSP, not otherwise discussed above, is Finney Creek. Adjacent to the Elliot Creek watershed, Finney Creek is probably important habitat for amphibians and some invertebrates. Stream survey of Finney Creek within BBRSP is difficult: the channel is steep, overgrown, and fallen logs are common. The similarity of Finney Creek habitat to Elliot Creek suggests that the aquatic communities might also be similar.

Seasonal streams are numerous in the Park but few were visited during this Resource Inventory. Most form the headwaters of the permanent streams discussed above but two drain directly to the Pacific Ocean immediately north of the mouth of Waddell Creek. Seasonal steams are still usually valuable habitat for amphibians and invertebrates. This is especially true where seasonal streams are not separated from adjacent wildlands by urbanization, agriculture, or other competing land use. Seasonal or isolated occurrences of surface water are also usually important sources of water for wildlife and hydrophytic plant species. Though the Aquatic Life inventory did not include efforts to locate or describe the extent of resources such as springs and seeps, occurrences of wetland plants typical of such waters are discussed in greater detail in the Plant Life section.

SENSITIVE SPECIES

Several listed (threatened or endangered) aquatic species, and others of State special concern, have been recorded in Big Basin Redwoods State Park. The National Marine Fisheries Service has listed Central California populations of steelhead (August 1997) and coho salmon (October 1996) as Threatened under the federal Endangered Species Act. The latter is also State listed as Endangered. The tidewater goby (federally Endangered) was listed in 1994, but the U.S. Fish and Wildlife Service has recently proposed "de-listing" it. The California red-legged frog, a federally Threatened species, is present in Sempervirens Reservoir and Hoover Marsh. The Southwestern pond turtle is a State and federal Species of Special Concern. Other listed species are addressed in the Animal Life or Plant Life sections, as appropriate.

Silver (Coho) Salmon

The Monterey Bay Area is historically at the southern end of the native range of coho salmon. The last remaining wild populations are in Scott Creek and Waddell Creek; the next nearest is in Marin County. Both of these streams have been the subject of periodic reintroduction programs, and there is some debate that the Waddell Creek population might in reality date back only to the fishery studies of the 1930s (Shapovalov and Taft 1954; R. Briggs, pers. comm.). Shapovalov and Taft (1954) released thousands of juvenile coho into Waddell Creek over several years, and salmonid bones are not found in prehistoric middens of the Pajaro-Salinas vicinity (Gobalet 1990), suggesting they were not available to local Native Americans. The San Lorenzo River, the southernmost recorded spawning stream (Snyder 1908), lost its last run of wild coho during the 1976-77 drought and today supports a hatchery-maintained population (Brown et al. 1994). A run has also been established in Gazos Creek.

The causes of the decline of coho salmon in California are multiple and interacting but were broadly categorized by Brown et al. (1994) as falling into four categories: loss of stream habitat through watershed disturbances and water withdrawals from streams; interactions with hatchery fish (genetic, competitive, and diseases); overexploitation (ocean and stream, sport and commercial fisheries); and climatic factors such as drought and oceanic conditions. In Waddell Creek, the relatively early timing of coho spawning makes redds vulnerable to complete scour by winter freshets.

Currently, efforts are underway by the California Resources Agency to plan for coastal salmon community/habitat preservation through the Natural Community Conservation Program (NCCP) process. The Department of Parks and Recreation was a signatory to the related Coastal Salmon Framework Agreement in 1995. The objective of these cooperative programs was protection of salmon and related species and habitats prior to a need for listing under the Endangered Species Act(s), but listing was deemed necessary by the National Marine Fisheries Service nonetheless.

Steelhead

Steelhead have been managed as depleted resources by the Department of Fish and Game since the 1980s. Extensive losses of anadromous fish rearing habitat have occurred throughout the state as the expanding human population has placed more demands on the limited aquatic resources. In recognition of the severely depleted anadromous fisheries, the Fish and Game Commission has adopted a steelhead habitat enhancement policy to protect native waters and restore degraded habitat. In 1988 the California legislature passed the Salmon, Steelhead Trout and Anadromous Fisheries Program Act directing DFG to double the populations of anadromous fish, including steelhead and coho salmon, by the year 2000. Unfortunately, restorations actions and management success at the State level were not sufficient to avoid listing under the Endangered Species Act.

Tidewater Goby

The tidewater goby was originally listed in 1994 when it was believed that only a handful (about 40) populations remained within a range where they were previously much more common (the California Coast). Goby populations had been sharply reduced by habitat loss and degradation, predation by non-native species, and extreme weather and streamflow conditions.

However, the U.S. Fish and Wildlife Service states, in a Proposed Rule published in the Federal Register on June 24, 1999, that it has been determined that north of Orange County there are more populations than were known at the time of the listing, that the threats to those populations are less severe than previously believed, and that the tidewater goby has a greater ability than was known in 1994 to recolonize habitats from which it is temporarily absent. Thus, USFWS has proposed to remove the northern populations (north of Orange County) of the tidewater goby from protection under the Endangered Species Act.

Nonetheless, history shows that the existence of the tidewater goby population in Wheedle Lagoon is tenuous. Activities around and upstream from the lagoon have the potential to significantly affect the goby population, especially when numbers are depressed following natural disturbances.

California Red-legged Frog

The California red-legged frog is one of two subspecies of red-legged frog found in California. It inhabits quiet pools of streams, marshes, and ponds. Its current range is from Marin County to Baa California along coastal areas and from Shasta County south throughout the Sierra Nevada foothills, but this represents only about 30% of its historic range. A further description of the habitat requirements and life history of this species can be found in the Animal Life section.

The decline in red-legged frogs has been caused by a number of factors acting singly or in combination: habitat loss and alteration (reservoir construction, channelization, grazing, urbanization, etc.), over exploitation/harvest, and introduction of exotic predators (primarily fish and bullfrogs). Normally, they will inhabit natural or artificial impoundments with suitable habitat if predators are not abundant. Their successful coexistence with the bullfrogs in Sempervirens Reservoir is an atypical but fortunate case.

NATURAL CONDITIONS

The waters and watersheds of BBRSP show many signs of past disturbance. Like the fine examples remaining in Big Basin proper, much of the rest of the Waddell Creek watershed was also once old-growth redwood forest. Roads were built and most areas were logged decades ago. The canyon slopes and streambanks were stable and passed significantly less sediment through Waddell Creek in any single storm event. Stream channels contained much more large woody debris and diverse, complex habitat for native species. Originally, hydrology and water quality were unaffected by water and wastewater developments; then came a period of more intense use and agriculture which diverted stream water. However, natural summer streamflow may once have been lower (though perhaps cooler and steadier) than today because of the greater evapotranspiration typical of a heavily-vegetated watershed (Dunne and Leopold 1978).

Natural Disturbances

Fire, flood, and drought are natural periodic events in many areas of California. A discussion of the fire history of BBRSP is included in the Plant Life section. Fire can accelerate erosion of soils and consequently increase stream sedimentation. Runoff from burned watersheds can also increase nutrient input to aquatic systems. Although such adverse impacts on the aquatic community have occurred irregularly in the past, they are probably more severe over the last century because of additional unnatural disturbances (habitat destruction, water withdrawals, etc.).

Flood and especially drought can have a significant impact on stream communities such as those in BBRSP. Droughts reduce the extent of permanent habitat available, making organisms compete for less habitat and fewer resources. The significant droughts in recent decades never been known to completely dewater lower Waddell Creek, but an analysis of apparently-decreasing streamflow since the 1930s (Briggs 1989) suggests that lower Waddell Creek may be seasonally-dry during drought years in the not-too-distant future. The advancement of regrowth of the redwood forest and associated vegetation, and the increased evapotranspiration generated by that regrowth, may remove enough water from the watershed that surface flow will naturally become seasonally intermittent. It is not known to what degree these predicted hydrologic changes might affect the resilience of aquatic and riparian populations over the long term.

Floods normally have only short-term impacts on aquatic habitats and communities. Native species and aquatic communities within the unit are normally well-adapted to peak stream flows which occur during severe winter storms. Typically, headwaters with limited watershed area are less severely impacted by flood compared to downstream areas where cumulative flows exert great forces. As above, however, flood impacts are probably greater today than in the past because of disturbances related to land use (primarily sedimentation from logging and road construction). This may be the case with tidewater goby population in Waddell Lagoon, which was sharply reduced by the floods of 1997. It is possible that periodic extirpation and eventual recolonization is a natural phenomenon, especially among anadromous and euryhaline aquatic species.

Unnatural Disturbances

Historic and ongoing disturbances within the BBRSP region are relatively well-documented. Large-scale disruptions, such as logging and road-building, normally no longer occur on Park lands, but terrestrial and aquatic communities are still influenced by past actions. Both major and minor watersheds which were once subject to such disturbance are still eroding at a faster-than-normal rate and contribute to sedimentation of pools and substrates. Aquatic habitat is consequently reduced and degraded, though probably not to the degree typical of past decades.

In addition to disturbance of vegetation and soil, earlier road-building practices did not take into account the need for fish passage through culverts. Small/intermittent streams can provide habitat for fish, including spawning habitat for anadromous fish, near their termini at larger permanent streams. However, within BBRSP, at least one impassible culvert prohibits fish migration into an unnamed Waddell Creek tributary entering from the left bank in Section 26. Such conditions are often found in areas which were roaded during earlier logging efforts, and where roads are not regularly maintained.

The aquatic habitat of Waddell Creek was once subject to relatively large water withdrawals. Agricultural operations occasionally dewatered portions of the main stem of Waddell Creek as late as the 1980s. This impacted aquatic communities in the stream and the lagoon, where water quality frequently depends on freshwater inflow. The lagoon itself was periodically breached, occasionally at times detrimental to native species depending on lagoon habitat.

Degradation of water quality in Sempervirens Creek and downstream still occasionally occurs today as a result of the operation of Sempervirens Reservoir. Regulated discharge of anaerobic water from the reservoir has the potential to result in fish kills in the creek; poor water quality or dewatering of the stream may also tend to displace organisms downstream as they seek more hospitable habitat. Other impacts to BBRSP water quality have also periodically been attributed to leaching of residential effluent into Blooms Creek, and residual chlorine in the discharge into the East Waddell from the Park's water treatment plant.

RECOMMENDATIONS

The aquatic resources of BBRSP are vast and not easily described in a single compilation. Many opportunities exist to further describe and study the range of special interest species. Many waters are so remote and difficult to access that numerous opportunities to document and describe habitat characteristic still exist. Items of additional information that would significantly enhance this aquatic resource inventory include field visits to the "unsurveyed streams" listed in Appendix AQ-I, biological sampling of upper reaches of major streams and their tributaries to determine upstream limits of fish distribution, occurrence of native amphibians, and more precise determination of lineal extent of permanent flow in streams.
Because of the status of the California red-legged frog under the Endangered Species Act, monitoring of this species should be conducted at Sempervirens Reservoir. This information, collected as described in the USFWS survey protocols, will assure that the impact of dam operation and maintenance activities on this species is avoided. Similarly, support of ongoing collaborative efforts to monitor the listed fisheries of Waddell Creek and Lagoon will ensure that management decisions and Park operations occur without contributing to "take", as defined in the Endangered Species Act.

The watershed of Waddell Creek and aquatic habitat of BBRSP is important in a regional context. Many State, federal, local and private agencies have made efforts to repair damage from past and ongoing land use practices. Depleted fisheries are the target of numerous restorative efforts, efforts which have included projects on State Park land. The resource inventory/general planning process, and DPR management actions, could contribute positively to region-wide watershed planning and sensitive-species conservation and restoration in this large area afforded State Park protection.

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APPENDIX AQ-I

Big Basin Redwoods State Park Aquatic Survey Record

Appendix AQ-I. Waters within Big Basin Redwoods State Park, with notes regarding survey information available.

STREAM	MILES	PERSISTENCE	SURVEY INFO	COMMENTS
Waddell Creek (main stem)	5.8	P	DFG, SJSU: SH, SS, SC, RLF, SAL	2 disjunct sections; Park ownership to bank or centerline in some reaches
East Branch Waddell Creek	2.5	P	DPR, DFG: SS, SH, SC, RT, SAL	3 disjunct sections; crayfish also seen (near BBRSP Wastewater Plant)
Last Chance Creek	0.6	P		Includes mouth
1 Unnamed Trib.	0.5	I		BBRSP ownership of this watershed almost entire
Opal Creek	3.5	P	DPR: RT, SAL	Entire
Rogers Creek	0.4	P		Entire
Maddocks Creek	0.6	P	DPR	Entire
3 Unnamed Tribs.	1.8	P, I		Entire
Blooms Creek	3.0	P, I	DPR: RT, SAL	2 disjunct sections, including mouth
Sempervirens Creek	2.1	P	DPR: RT, GS, RLF, BULL	Entire; includes Sempervirens Reservoir
Union Creek	1.8	P	DPR: RT	Entire
1 Unnamed Trib.	0.7	I	DPR	Entire
3 Unnamed Tribs.	1.3	P, I		Entire; headwater reaches, mapped as "permanent" on USGS quad
West Branch Waddell Creek	5.5	P	DPR, DFG: SS, SH, SC, RT, SAL	Entire
Henry Creek	1.2	P, I	DPR, DFG: SH, SS, SAL	Entire; about 1 mile of permanent stream
1 Unnamed Trib.	0.7	I		Entire
Berry Creek	1.5	P	DPR: RT	Entire
"West Berry Creek"	1.2	P		Entire; unnamed on USGS quad
Kelly Creek	1.0	P	DPR: RT	Entire
Timms Creek	0.4	P		Entire
3 Unnamed Tribs.	1.8	P, I		Entire
Gazos Creek (unnamed trib.)	0.2	P?		Headwater reach, mapped as "permanent" on USGS quad
Cascade Creek	0.5	I	DFG	Portions of 3 headwater forks
Green Oaks Creek	0.3	I	DFG	2 disjunct headwater portions
Ano Nuevo Creek	0.7	I	DFG	Upstreammost reach is in BBRSP
1 Unnamed Trib.	0.3	I		Headwater reach
Finney Creek	0.9	P, I	DPR: SAL	Upper half of stream and watershed in BBRSP
Elliot Creek	1.5	P, I	DPR: SAL	Most of upper stream and watershed in BBRSP
1 Unnamed Trib.	0.2	I		Lowest reach of only Elliot tributary
Scott Creek	0.1	P	DPR, DFG, SJSU: SH, SS	Roadside reach near middle of watershed.
4 Unnamed Tribs.	0.5	P, I		7 disjunct portions; various areas (upper, lower) of watersheds, but no mouths.
Boulder Creek	1.2	P, I	DPR, DFG: SS, SH, PL, SC, SAL	2 disjunct sections; intermittent one is uppermost headwater reach.
Hare Creek	0.2	I		Uppermost headwater reach
Jamison Creek	0.5	I		Uppermost headwater reach
1 Unnamed Trib.	0.1	P		Lowermost reach and mouth
2 Unnamed Pacific Ocean Tribs.	0.3	I	DPR	One includes mouth
Total (miles):	45.4			

KEY:

MILES = Miles of stream in Big Basin Redwoods State Park

PERSISTENCE = "Permanent" or "Intermittent"/seasonal stream

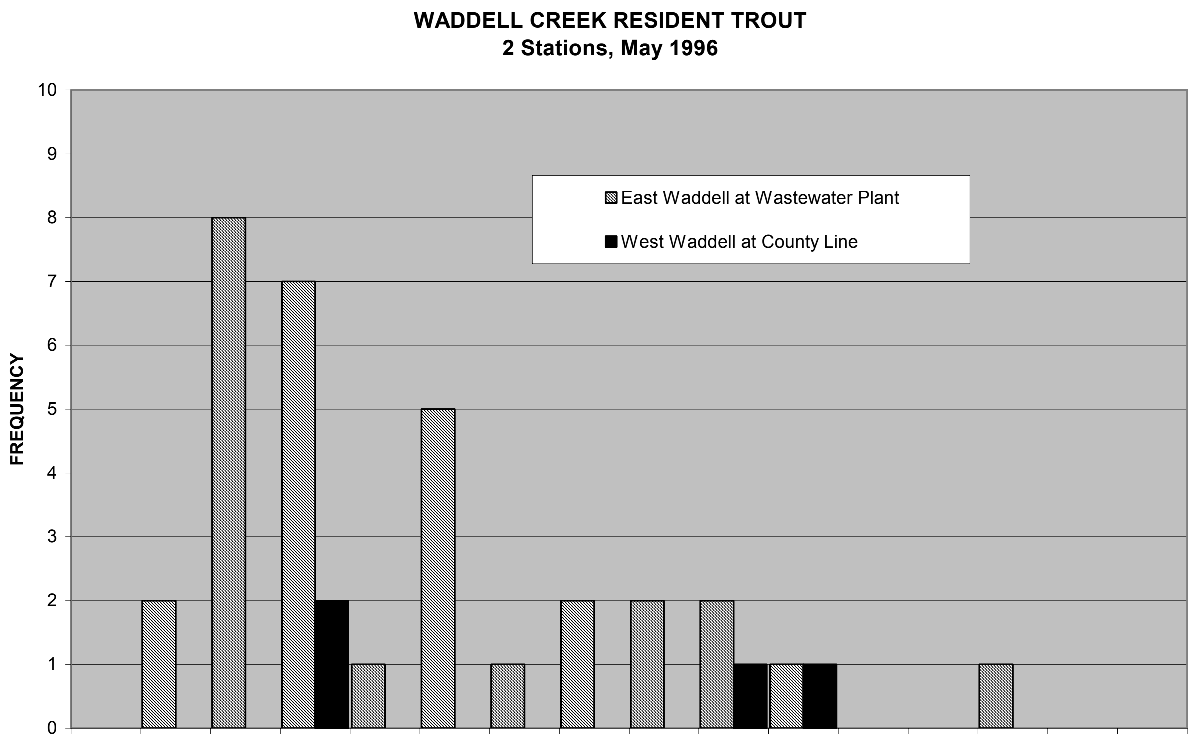
SURVEY INFO: DFG habitat survey or SJSU fishery sampling or DPR site visit and/or sampling; aquatic species observed or otherwise known to occur.

SPECIES CODES			
	SH =	Steelhead	
	SS =	Silver (Coho) Salmon	SAL = Unidentified Salamander
	RT =	Resident Rainbow Trout	RLF = Red-legged Frog
	PL =	Pacific Lamprey	BULL = Bullfrog
	TG =	Tidewater Goby	
	TS =	Threespine Stickleback	
	SC =	Sculpin (usually, both "Prickly" and "Coastrange" present)	
	GS =	Golden Shiner	

APPENDIX AQ-II

Length-Frequency Distributions
and
Trout Population Estimates

for
Stations Sampled in Waddell Creek, May 1996



STATION LOCATION	NUMBER COLLECTED	POPULATION ESTIMATE	CONFIDENCE LIMIT	STATION LENGTH
E. WADDELL @ WWT PLANT	32	40	56	197 feet
W. WADDELL @ COUNTY LINE	4	4	4	115 feet

APPENDIX AQ-III

Fishes of the Waddell Creek Watershed
Santa Cruz County, California

KEY:

N - Native within Big Basin Redwoods State Park
I - Introduced to Waddell Creek watershed
X - Observed in Big Basin Redwoods State Park, 1996-2000
O - Species occurring in other nearby waters

FAMILY - SPECIES

Petromyzonidae	
Lampetra tridentata — Pacific lamprey	O
Salmonidae	
Oncorhynchus mykiss — Rainbow/steelhead trout	N, X
Oncorhynchus kisutch — Silver (coho) salmon	N, X
Oncorhynchus tsawytcha — King (chinook) salmon	O
Cyprinidae	
Notemigonus crysoleucas — Golden shiner	O, I, X
Gasterosteidae	
Gasterosteus aculeatus — Threespine stickleback	N, X
Cottidae	
Cottus asper — Prickly sculpin	N, X
C. aleuticus — Coastrange sculpin	N

Leptocottus armatus	N
Staghorn sculpin	
Perichthyidae	
Morone saxatilis	I
Striped bass	
Gobiidae	
Eucyclogobius newberryi	
Tidewater goby	N, X
Pleuronectidae	
Platichthys stellatus	
Starry flounder	N
Antherinidae	
Antherinops affinis	
Topsmelt	N

APPENDIX AQ-IV

Invertebrate Taxa of Waddell Creek
Santa Cruz County, California

From:

1) Shapovalov and Taft (1954)

2) King (1998)

Scientific name	Common name	Literature reference	Habitat	Stream	Lagoon	Eaten by steelhead	Eaten by silver salmon
ARTHROPODA—Continued							
Class Insecta—Continued							
Order Plecoptera	Stoneflies						
Fam. Perlidae n		Shepherd 1928	A	X		X	
Alloperla sp.		Shapovalov MS.	A	X		X	
Order Trichoptera l, p, a.	Caddisflies	Shepherd 1928	A	X		X	
Fam. Rhyacophilidae		Shepherd 1928	A	X		X	
Glossosoma sp. l		Shepherd 1928	A	X			
Agapetus sp. l		Shepherd 1928	A	X			
Fam. Hydroptilidae		Shepherd 1928	A	X		X	
Hydroptila sp. l		Shepherd 1928	A	X		X	
Fam. Philopotamidae		Shepherd 1928	A	X			
Chimarrha sp.		Shepherd 1928	A	X			
Fam. Odontoceridae		Shepherd 1928	A	X		X	
Nerophilus californicus Hagen l		Shepherd 1928	A	X		X	
Psilotreta sp. l		Shapovalov MS.	A	X		X	
Fam. Hydropsychidae		Shepherd 1928	A	X		X	
Hydropsyche sp. l		Shepherd 1928	A	X		X	
Fam. Sericostomotidae l, p		Shepherd 1928	A	X		X	
Brachycentrus sp.		Shepherd 1928	A	X			
Lepidostoma cinereum Banks l		Shepherd 1928	A	X		X	
Atomyia unicolor Banks (?)		Shepherd 1928	A	X			
Notidobia nigricula McLachlan (?) l		Shepherd 1928	A	X		X	
Notidobia sp.		Shapovalov MS.	A	X		X	
Fam. Limnephilidae l		Shepherd 1928	A	X		X	
Limnophilus sp. l		Shapovalov MS.	A	X		X	
Halesus sp.		Shepherd 1928	A	X			
Genus I sp.		Shepherd 1928	A	X			
Glyphopsyche sp. (?) l		Shepherd 1928	A	X		X	
Apatania sp.		Shepherd 1928	A	X			
Order Homoptera	Leafhoppers, aphis, etc.						
Fam. Cercopidae a		Shepherd 1928	T	X		X	
Fam. Jassidae a		Shepherd 1928	T	X		X	
Fam. Chermidae a		Shepherd 1928	T	X		X	
Order Hemiptera	True bugs						
Fam. Corixidae a		Shepherd 1928	A	X		X	
Fam. Notonectidae a		Shepherd 1928	A	X		X	
Fam. Reduviidae a		Shepherd 1928	T	X		X	
Fam. Coredidae a		Shepherd 1928	T	X		X	
Fam. Saldidae a		Shepherd 1928	T/	X		X	
Fam. Gerridae	Water striders	Needham 1935	A	X			
Fam. Belostomatidae	Giant water bugs						
Lethocerus americanus (Leidy)		Shapovalov MS.	A	X			
Abedus hungerfordi De Carlo		Shapovalov MS.	A	X			
Order Coleoptera	Beetles						
Fam. Pyrochoridae a		Shepherd 1928	T	X		X	
Fam. Carabidae a		Shepherd 1928	T	X		X	
Fam. Histeridae a		Shepherd 1928	T	X		X	
Fam. Dytiscidae a		Shepherd 1928	A	X		X	
Fam. Cryptophagidae a		Shepherd 1928	T	X		X	
Fam. Staphylinidae a		Shepherd 1928	T	X		X	
Fam. Scolytidae a		Shepherd 1928	T	X		X	
Fam. Curculionidae a		Shepherd 1928	T	X		X	
Fam. Parnidae l, a		Shapovalov MS.	A	X			
Order Diptera	True flies	Needham 1940			X		
Fam. Cecidomyiidae l		Shepherd 1928	T	X		X	
Fam. Scatophagidae a		Shepherd 1928	T	X		X	
Fam. Muscidae a		Shepherd 1928	T	X		X	

Scientific name	Common name	Literature reference	Habitat	Stream	Lagoon	Eaten by steelhead	Eaten by silver salmon
PROTOZOA							
Class Ciliata							
Spirostomum		Needham 1940	A		X		
Euplotes		Needham 1940	A		X		
Pleuronema		Needham 1940	A		X		
Colpidium		Needham 1940	A		X		
Prorodon		Needham 1940	A		X		
Oxytricha		Needham 1940	A		X		
ROTIFERA		Needham 1940	A		X		
ANNELIDA							
Class Chaetopoda							
Order Oligochaeta		Needham 1940			X		
		Shepherd 1928		X		X	
ARTHROPODA							
Class Crustacea							
Order Ostracoda		Needham 1940	A		X		
Order Isopoda							
Exosphaeroma oregonensis (Dana)		Needham 1940	A	(X)	X	X	
		Shapovalov MS	T	X		X	
	"Pill bugs"	Shepherd 1928		X		X	
Order Copepoda		Needham 1940	A		X		
Salmincola californiensis Dana		Shapovalov MS	A	X			
Order Amphipoda							
Gammarus confervicolis (Stimpson)	Scud	Needham 1940	A	(X)	X	X	
Corophium spinicorne Stimpson		Needham 1940	A		X		
Order Mysicacea							
Neomysis mercedis Holmes		Needham 1940	A		X		
Order Decapoda							
Crago sp.	Shrimp	Shapovalov MS.	A		X		
Pacifastacus klamathensis	Crayfish	Shapovalov MS.	A	X			
Class Diplopoda	Millipeds	Shapovalov MS.	T	X		X	
Class Insecta							
Order Corrodentia	Psocids, bark lice, etc.						
Fam. Psocidae a		Shepherd 1928	T	X		X	
Order Ephemerida n	Mayflies	Shapovalov MS.	A	X		X	
Fam. Heptageniidae n		Shepherd 1928	A	X		X	
Fam. Baetidae n		Shepherd 1928	A	X		X	
Baetis sp. n		Shapovalov MS	A	X		X	
Paraleptophlebia sp. n		Shapovalov MS.	A	X		X	
Order Odonata	Dragonflies Damselflies Damsel fly a	Shepherd 1928	A	X		X	
Order Neuroptera	Dobson flies, ant lions, etc.	Shapovalov	A	X			
Fam. Myrmeleonidae l	Ant lions	Shepherd 1928	T	X		X	
Fam. Sialidae							
Sialis sp.		Shapovalov MS.	A	X		X	

Scientific name	Common name	Literature reference	Habitat	Stream	Lagoon	Eaten by steelhead	Eaten by silver salmon
ARTHROPODA—Continued							
Class Insecta—Continued							
Order Diptera—Continued							
Fam. Phoridae a		Shepherd 1928	T	X		X	
Fam. Chironomidae l, p		Shepherd 1928	A	X		X	
l, a		Shapovalov MS	A	X		X	
Fam. Mycetophilidae a		Shepherd 1928	T	X		X	
Fam. Syrphidae l, a		Shepherd 1928	T	X		X	
Fam. Simuliidae l, p, a		Shepherd 1928	A	X		X	
l		Shapovalov MS	A	X		X	
Simulium sp.		Needham 1934b	A	X			
		Needham 1940	A	X			
Fam. Tipulidae l		Shepherd 1928		X		X	
Fam. Tabanidae l		Shepherd 1928	T	X		X	
Fam. Dixidae							
Dixa sp. l		Shapovalov MS		X		X	
Order Lepidoptera l		Shepherd 1928		X		X	
Order Hymenoptera							
Fam. Chalcididae a		Shepherd 1928	T	X		X	
Fam. Vespidae a		Shepherd 1928	T	X		X	
Fam. Apidae a		Shepherd 1928	T	X		X	
Fam. Bombidae a		Shepherd 1928	T	X		X	
Class Arachnida		Shepherd 1928		X		X	
Order Acarina							
Fam. Hydrachnidae	Water mites	Needham 1940	A		X		
MOLLUSCA							
Class Pelecypoda							
Order Eulamellibranchia							
Margaritifera margaritifera falcata (Gould)	Freshwater mussel	Shapovalov MS	A	X			

Macroinvertebrate Taxonomic List for Samples Collected in August 1998 from the east and west forks of Waddell Creek, Santa Cruz County.

PHYLUM **Class** Order **Family** *Genus species*			West Fork Waddell Creek			East Fork Waddell Creek Above WWTP			East Fork Waddell Creek Below WWTP		
BAS #:			215	216	217	221	222	223	218	219	220
	TV[1]	FFG[2]									
ARTHROPODA											
Hexapoda											
Coleoptera (Adults)											
Dytiscidae											
sp. 1	5	p	–	–	–	1	–	–	–	–	–
sp. 2	5	p	–	–	–	–	–	1	–	–	–
Elmidae											
Cleptelmis sp.	4	c	–	–	–	–	–	–	–	–	1
Narpus sp.	4	c	1	–	–	–	–	1	–	–	–
Optioservus sp.	4	g	19	7	9	7	18	14	8	7	18
Zaitzevia sp.	4	c	1	1	3	–	5	5	1	1	–
Hydraenidae											
Hydraena sp.	5	g	11	2	14	1	–	–	–	5	–
Hydrophilidae											
Ametor sp.	5	c	–	–	–	–	–	–	–	1	–
Coleoptera (Larvae)											
Elmidae											
Ampumixis sp.	4	c	–	1	–	1	–	–	1	3	–
Narpus sp.	4	c	2	4	2	–	2	1	–	–	–
Optioservus sp.	4	g	27	3	43	17	16	14	21	23	28
Zaitzevia sp.	4	c	2	2	1	4	9	13	3	4	5
Psephenidae											
Acneus sp.	4	g	–	–	–	1	–	–	–	–	–
Diptera											
Ceratopogonidae											
Atrichopogon sp.	6	c	2	2	7	2	–	6	–	–	1
Probezzia sp.	6	p	1	1	1	2	1	2	–	1	1
Chironomidae	6	c	27	24	54	37	56	49	32	31	23
Dixidae											
Dixa sp.	1	c	–	2	1	–	–	–	–	–	–
Meringodixa sp.	2	c	–	1	–	–	–	–	–	–	–
Empididae											
Chelifera sp.	6	p	1	–	1	3	2	–	–	–	–
Trichoclinocera sp.	6	p	–	–	–	–	–	1	–	–	–
Psychodidae											
Maruina sp.	1	g	–	–	–	1	–	–	–	–	–
Simuliidae	6	f	14	95	14	73	33	53	72	58	20
Tipulidae											

PHYLUM Class Order **Family** *Genus species*		*BAS #:*	West Fork Waddell Creek			East Fork Waddell Creek Above WWTP			East Fork Waddell Creek Below WWTP		
			215	216	217	221	222	223	218	219	220
	TV[1]	FFG[2]									
Antocha sp.	3	c	–	–	–	–	–	–	2	2	7
Dicranota sp.	3	p	2	1	4	2	2	1	–	–	1
Hexatoma sp.	2	p	1	1	2	–	–	–	–	–	–
Limonia sp.	6	s	2	–	–	–	–	–	–	–	–
Tipula sp.	4	s	–	1	–	–	–	–	–	–	–
undetermined	5	c	–	–	1	1	–	–	–	–	–
Ephemeroptera											
Baetidae											
Baetis sp.	5	g	50	43	38	18	20	14	27	35	44
Diphetor sp.	5	s	11	4	5	1	1	2	3	1	2
Ephemerellidae											
Serratella sp.	2	c	–	–	–	–	–	1	–	–	–
Heptageniidae											
Epeorus sp.	0	g	–	–	1	–	–	–	–	–	–
Ironodes sp.	4	g	8	10	3	2	–	2	–	–	–
Leucrocuta sp.	1	g	–	–	–	1	–	–	1	–	1
Rhithrogena sp.	0	g	–	–	–	13	17	13	24	16	21
undetermined	2	g	–	–	–	6	18	12	3	–	7
Leptophlebiidae											
Paraleptophlebia sp.	4	c	–	–	1	–	1	1	–	1	1
Plecoptera											
Chloroperlidae											
Sweltsa sp.	1	p	1	1	3	1	3	4	3	1	3
Leuctridae											
Despaxia sp.	0	s	16	6	3	–	1	1	–	–	–
Nemouridae											
Amphinemura/Malenka sp.	2	s	29	11	17	17	7	9	9	16	14
Soyedina sp.	2	s	3	–	–	–	–	–	–	–	–
Zapada sp.	2	s	–	–	1	–	–	5	4	2	–
Peltoperlidae											
Soliperla sp.	2	s	–	1	–	–	–	–	–	–	–
Perlidae											
Calineuria californica	1	p	12	13	20	1	1	4	4	1	–
Hesperoperla sp.	2	p	–	6	–	2	3	2	–	1	–
Perlodidae											
Skwala sp.	2	p	–	–	–	–	–	1	–	–	–
Trichoptera											
Apataniidae											
Apatania sp.	1	g	–	–	–	–	–	–	–	–	1
Brachycentridae											
Micrasema sp.	1	g	18	4	6	45	27	16	10	12	23
Glossosomatidae											
Agapetus sp.	0	g	–	–	–	5	1	1	8	4	10

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			215	216	217	221	222	223	218	219	220
	TV[1]	FFG[2]									
Anagapetus sp.	0	g	–	–	–	–	–	–	–	–	1
Glossosoma sp.	0	g	1	–	1	–	2	–	–	1	–
Hydropsychidae											
Hydropsyche sp.	4	f	10	17	11	14	18	37	43	57	34
Parapsyche sp.	1	f	–	–	2	–	1	–	–	1	–
Hydroptilidae											
Ochrotrichia sp.	4	c	5	9	3	1	1	2	–	1	4
Lepidostomatidae											
Lepidostoma sp.	1	s	–	–	–	–	–	–	1	1	1
Philopotamidae											
Wormaldia sp.	3	f	2	7	10	1	2	1	2	1	–
Rhyacophilidae											
Rhyacophila sp.	0	p	8	10	12	5	5	8	2	2	1
Sericostomatidae											
Gumaga sp.	3	s	–	1	1	–	–	–	–	–	–
Uenoidae											
Neophylax sp.	3	g	–	–	–	–	–	–	1	2	3
Neothremma sp.	0	g	–	–	–	–	–	–	–	–	3
Odonata											
Cordulegastridae											
Cordulegaster dorsalis	0	p	1	1	–	–	–	–	–	–	–
Chelicerata											
Arachnoidea											
Acari (water mites)	5	p	1	1	4	4	11	3	6	3	13
Pelecypoda	8	f									
Corbiculidae											
Corbicula fluminea	10	f	–	1	–	–	–	–	–	–	–
ANNELIDA											
Oligochaeta	8	c	–	–	6	2	12	6	6	–	3
NEMATODA	5	p	–	–	–	4	–	2	–	–	1

[1] TV: Tolerance Values

[2] FFG: Fuctional Feeding Groups