FINAL REPORT

Implications of Capitol Lake Management for Fish and Wildlife

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Capital Lake Adaptive Management Program Steering Committee

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Executive Summary

This report provides an evaluation of some biological consequences of four management options for Capitol Lake, which include:

1) Status Quo - no change from existing conditions;
2) Managed Lake - maintenance of a lake about 13 feet (4 meters) in uniform depth;
3) Estuary - 5th-Avenue Dam removal resulting in a dynamic, steady-state estuary; and
4) Dual Basin - 5th-Avenue Dam removal and splitting the North Basin into an estuary and a Reflection Pool.

The Status Quo Option maintains Capitol Lake as a shallow, largely freshwater pool. The Managed Lake Option maintains a deeper lake, which requires regular dredging; the Estuary Option re-establishes tidal flushing within the constraint of human-built infrastructure, i.e., a 500-foot opening to the bay; and the Dual Basin Option divides the north basin into two areas, one that sustains tidal flushing and the other that will be serves a saltwater Reflection Pool.

We evaluated these options based on potential changes in:

1) species or species assemblages supported,
2) ecosystem types and some of their most important functions and processes.

To accomplish these tasks, we conducted an extensive search of peer reviewed and gray literature, and interviewed various species, habitat, general ecology, and restoration experts. We were generally limited by a lack of specific studies of Capitol Lake and estuaries similar to Budd Inlet, as well as by a poor understanding of species-habitat association that can readily be translated into population level responses to the type of habitat changes considered here. We caution readers to consider those limitations when interpreting information contained in this report.

Management that includes some estuarine restoration (Estuary and Dual Basin Options) are anticipated to: 1) increase the area, and enhance functions and processes associated with an ecosystem type at higher risk in the Puget Sound Ecoregion (i.e. estuarine wetlands) than the lake options (Status Quo and Managed Lake); 2) favor more "Priority Habitat and Species (PHS) species and economically important species but less state-listed species than the lake options; and 3) support fewer exotic species than the lake options. However, we have significant uncertainty associated with some species response information based on a lack of systematic faunal data from Capitol Lake especially since the cessation of regular non-flood control drawdowns in 1996, and based on a lack of knowledge about inter-year variability in Capitol Lake salinity, which directly affects the suitability of the lake as habitat for amphibians, bats, and aerial-foraging insectivorous birds. For most species we have only general habitat association data based on correlative rather than cause and effect information, and we do not have a good general understanding of habitat amounts necessary to support populations of most species.

We do not anticipate dramatic changes in fish and wildlife response associated with sea level rise *per se*. Perhaps the biggest change associated with sea level rise is related to increased possibility of salt-water intrusion into the lake (Status Quo). For example, small increases in salinity could render the lake incapable of producing insects upon which aerial-

foraging birds and bats rely. Small increases in salinity may also make the lake unsuitable habitat for amphibians. While we did not examine other potential effects of climate change, we suspect that rising temperature and changes in hydrology may have greater potential to affect fish and wildlife associated with Capitol Lake than sea level rise.

1 Introduction

1.1 Historical Background and Physical Setting of Capitol Lake

Prior to Euro-American immigration, the southern end of Budd Inlet was a tidal estuary that extended upstream from the location of the 5th-Avenue Dam to approximately 0.25 miles (0.4 kilometers) below the base of Lower Tumwater Falls (Haring and Konovsky 1999). From 1853, when Isaac Ingalls Stephens, the first territorial governor, made Olympia the territorial capital (Howard 1963), to 1951, when the dam creating Capitol Lake was built, this estuary sustained progressive human encroachment resulting from port-based activities and development of associated industries. Olympia was strategically located between the south end of Puget Sound and the north end of overland shipping and immigration routes from the Columbia River and Willamette Valley. Over the 36 years from 1853 to statehood (1889), Olympia harbor represented the critical point of connection for delivery of goods needed by interior communities in southwest Washington (Hannum 2002). Upon statehood, designation of Olympia as the permanent capital helped reduce its economic dependence and community focus on port business. Moreover, concurrent development of regional railroads (Hannum 2006), and subsequently highways, made transportation increasingly land-based. These changes led to the current Budd Inlet landscape and the development of a modest-sized commercial port, and four recreational marine facilities located north of 5th Avenue.

Prior to 1869, the Deschutes River and its tributaries flowed unrestricted into south Budd Inlet, where Capitol Lake now exists. The Deschutes River delta consisted of alluvial deposits, and limited area with tidal marshes and braided channels. Though the precise historical extent of tidal marsh and mudflat environments is poorly understood, a repeated theme of early observers is the extensive nature of mud flats across much of south Budd Inlet. The May 1792 visit to Budd Inlet by Peter Puget, the first explorer to leave a written record, was notable for its description of extensive mudflats in the vicinity of present-day Olympia (Stevenson and Fowler 1997). Extensive mudflats were the reason the Giddings wharf, built in 1854, had to extend nearly 4,800 feet to reach a ship-navigable depth in Budd Inlet. A pre-dredge, pre-fill 1876 navigational chart of Olympia harbor reveals that though the fringes of the eastern portion of south Budd Inlet had some marsh, mud flats dominated the inlet (Stevenson and Fowler 1997).

In 1869, the 4th-Avenue Bridge connecting downtown Olympia to the westside area was built (City of Olympia 2008; see also Glover 1879, Stevenson and Fowler 1997; Hannum 2002). This represented the first structure to impose some restriction on tidal exchange into the area that would ultimately become Capitol Lake. The 1876 navigational chart also shows a narrow piling-supported roadway between Olympia and Tumwater at the present location of the Interstate 5 Highway Bridge that separates the Middle and South Basins (Stevenson and Fowler 1997), so a second point existed relatively early that imposed further restriction on tidal-affected flow near the mouth of the Deschutes River.

In 1878, the Thurston County Railroad Construction Company installed the Olympia-Tenino narrow gauge rail line on a trestle paralleling the west shoreline of the North Basin (Miller 1921, Hannum 2002). This trestle was located some distance from the shoreline due to landowner opposition to having the railway hug the west side of south Budd Inlet (Hannum 2002). Lack of treatment of pilings with preservatives (pre-creosote era) led to this trestle becoming dangerous, and in 1886, the rail line was relocated to the solid ground and created berm north of Percival Point (Hannum 2002); only a short connection at the Percival Creek outflow remained on pilings. Some of these tracks were abandoned in 1916 (Hannum 2002) and this route ultimately became part of the bermed substructure for the Deschutes Parkway (Figure 1). Except for the narrow connection to the Middle Basin beneath the bridge on the Deschutes Parkway, this berm now physically circumscribes Percival Cove, which is fed by Percival Creek (Figure 1).

Initial attempts at dredging Budd Inlet to improve its depth for shipping occurred in 1893, when the Army Corps of Engineers dredged the area near the Olympia wharf (City of Olympia 2008). Fill from this effort was placed largely beneath the 4th-Avenue Bridge, although some was also placed along the west margin of Budd Inlet both north and south of the bridge, which narrowed the connection for tidal exchange into south Budd Inlet.

Much of the apparently limited area with tidal marsh in south Budd Inlet was lost during the placement of fill creating new land where the Port of Olympia and the lower portion of Olympia is now located (Hammun 2006, City of Olympia 2008). Fill came from the dredging of Budd Inlet in 1909-1910, a movement led by P. H. Carlyon to create a port of sufficient depth for shipping (Hannum 2006). By 1911, the topography of Olympia had changed dramatically; dredged fill added some 29 blocks to the downtown area (Stevenson and Fowler 1997, City of Olympia 2008), and sloughs associated with the outflow areas of Indian and Moxlie Creeks to the east and north of the city almost vanished. A portion of this fill expanded the area where 4th- and 5th-Avenues now sit, further narrowing the connection for tidal exchange beneath the 4th-Avenue Bridge. Additional fill placed in this area came from foundation areas of State Capitol Campus buildings constructed in the 1920s and 1930s (Johnston 1988). Creation of a Port District in Thurston County (i.e., the Port of Olympia) was spurred by the 1909-1911 dredge-and-fill efforts, which resulted in additional land and better navigation opportunities (Stevenson and Fowler 1997).

In 1921, a concrete bridge replaced the wooden-pier-supported 4th-Avenue Bridge (Stevenson and Fowler 1997); the latter structure had been repaired several times since 1869. In 1929, a trestle-supported railway that ultimately became part of the Burlington-Northern Santa-Fe system was built across the mouth of the Deschutes River in a position that now separates the Middle and North Basins of Capitol Lake (Hannum 2002; Figure 1). Except for the area crossing the Deschutes River, a berm ultimately replaced this trestle, resulting in a third point at which tidal exchange was narrowed.

In 1951, Army Corps of Engineers' construction of a tidewater barrier (i.e., the 5th-Avenue Dam in downtown Olympia) formed Capitol Lake (Figure 1). This completed a plan originated in 1911, wherein capitol architects Wilder and White envisioned a Reflection Pool to enhance the appeal of the State Capitol and its campus (Moffatt and Nichol 2007). Associated with this primary objective was the elimination of odors associated with the release of raw sewage into south Budd Inlet, aesthetic problems thought to be linked to tidal estuaries (mud flats were viewed as unsightly), removal of the unsightly shanty development near the Capitol, and development of a lake environment that could double as a centerpiece for recreation (WSDGA 1997, WSDGA 2002). The original design stated

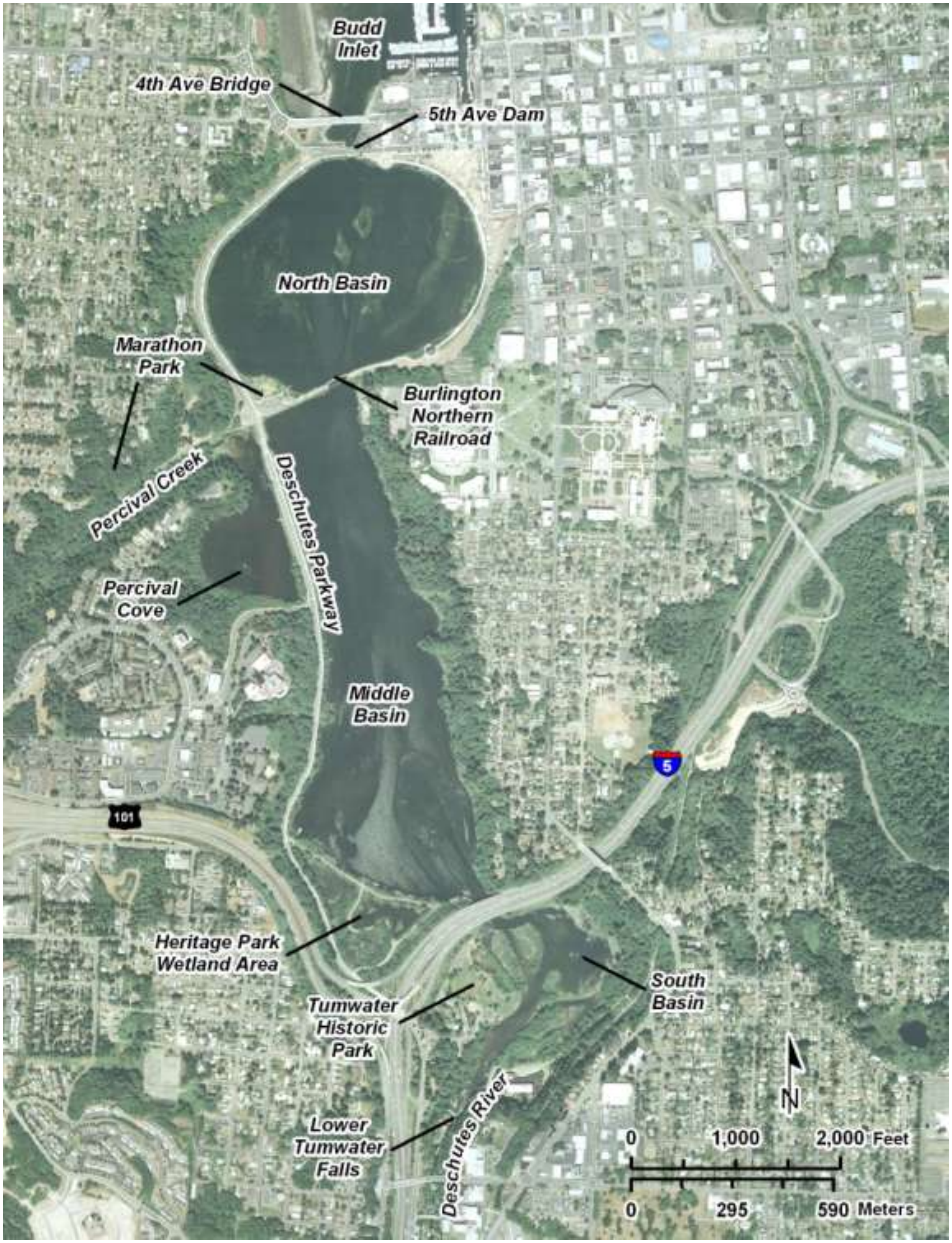

FIGURE 1. 2006 Aerial photograph of Capitol Lake from the National Agricultural Inventory Program. Major locations discussed in the text are labeled (scale: 1 inch = 1,200 feet [366 meters]).

"A tide lock at the Boulevard [to the west[1]] would form a lake and the whole effect would be visible from most parts of the city as well as from the sound" (from Wilder and White [1911] in Johnston 1988). Though alternative plans for a Reflection Pool separate from the river channel were proposed, ultimately, a dam was constructed that created a single 320-acre (130-hectare) reservoir following the Wilder and White plan. Although the foci of fish and wildlife agencies were salmon and steelhead at that time, anadromous fish use of the Deschutes River was limited to only the short river reach below Tumwater Falls (a complete fish barrier) and Percival Creek (Figure 1). All remaining streams associated with Deschutes River drainage (Adams, Ellis, Mission, Moxlie/Indian, and Schneider Creeks) that flow into Budd Inlet do so north of the 5th-Avenue Dam, i.e., outside of the Capitol Lake footprint.

The Washington State Department of General Administration (WSDGA) operates and maintains the 5th-Avenue Dam outlet of Capitol Lake, which has two radial gates, a fish gate (weir), and a siphon to stabilize the lake level, maintain relatively freshwater conditions, and control flooding (Roberts et al. 2004). An automated system opens the radial gates, whereas WSDGA personnel manually adjust the fish weir seasonally and adjust the radial gates in the event of anticipated high Deschutes River discharge (URS Group, Inc. and Dewberry 2003). The general operational strategy has been to maintain Capitol Lake at a desired level (Davis et al. 1998). When the lake rises above the desired level, the gates open as long as the difference in water level between the lake and Budd Inlet is at least one foot. Should the lake drop below the desired level or the difference in water level between the lake and Budd Inlet drop below one foot, the gates automatically begin to close. Except for planned drawdowns discussed below, flood control activities also involve variable drawdowns in response to the anticipated magnitude of elevated flows (L. Kessel, pers. comm.).

In 1954, the length of the Deschutes River accessible to anadromous fish increased over two orders of magnitude when fish ladders bypassing Tumwater Falls were completed, opening 83 river miles [133 river kilometers] of the Deschutes Basin (Haring and Konovsky 1999). In 1962, a trapping facility designed to intercept migrating fish was constructed atop this ladder. Intercepted adult salmonids were either passed upstream or utilized in hatchery production.

In 1956, the Interstate-5 Bridge crossing Capitol Lake was built (C. Keegan, pers. comm.). The footprint for this structure resulted in some constriction of flow of the Deschutes River, its position defining the boundary between the Middle and South Basins of Capitol Lake (Figure 1).

Between construction in 1951 and 1998, the Deschutes River transported an estimated 22,000 cubic meters (32,700 cubic yards) to 42,000 cubic meters (54,900 cubic yards) of sediment each year (George et al. 2006). Most of this sediment load (estimated at 1,245,500 cubic meters [1,629,000 cubic yards]) over this 47-year period was deposited in Capitol Lake as a result of reduced tidal flushing associated with the dam. Though an estimated 234,600 cubic meters (306,900 cubic yards) of this material was dredged from Capitol Lake over the intervals 1975-1979 and 1984-1986 combined (George et al. 2006), this undoubtedly represents but a small fraction of the sediment deposited in Capitol Lake. As a consequence, Capitol Lake is now shallower and smaller in aerial extent than it was

[1] This is 4th-Avenue.

historically. Measurements obtained in 2004 revealed an average reduction in depth of 1.1 meters (3.6 feet) relative to immediately pre-dam levels in 1949. This change in depth is estimated to have reduced the volume of Capitol Lake by 60% since construction of 5th-Avenue Dam (George et al. 2006), a change also linked to a reduction in the current surface area of about 270 acres (109 hectares; Roberts et al. 2004).

Bank erosion along the Deschutes River contributes more than 80 percent of sediments reaching Capitol Lake, mostly independent of human activities (Raines 2007). However, historic timber practices in the Deschutes Basin likely also contributed. Today, forestry continues, and contemporary practices substantially reduce, but do not eliminate, sediment input. Modeling revealed that fine sediment from about 600 miles (964 kilometers) of unpaved roads in the upper Deschutes watershed represent an average of 9 percent of the annual total fine sediment influx for the period 1972-2003 (Raines 2007). Agriculture and urbanization of the mid- and lower watershed also represent potential sources of sediment, the individual contributions of which have not been assessed. These activities can also increase peak runoff by extending drainage networks and reducing soil percolation. Developments in Thurston County have been required to mitigate for peak flow effects by the addition of stormwater retention ponds since at least 1994 (S. Lindblom, pers. comm.)[2], but older developments typically lack such mitigation.

Besides local landscape changes, warming patterns associated with climate change may be changing the hydrological processes that directly influence the hydrographic basin in which Capitol Lake is located. In the Pacific Northwest[3], long-term (20th-century) temperature data reveal warming trends to be greatest in the maritime zone, the climatic zone in which the Deschutes Basin lies (Mote 2003). Additionally, precipitation over the same period seems to have increased (Mote 2003). Warmer air can hold more water, and thus potentially trigger more severe individual storm events (Miles et al. 2000). Coarse-level data over the interval 1959-1997 for Northern Hemisphere mid-latitudes (30-60 degrees North latitude, which encompasses the latitudinal range in which the Deschutes Basin lies) reveal an increase in storm intensity despite a statistically significant decrease in storm frequency (McCabe et al. 2001). These data exclude the last 10 years, during which extreme regional events have been recorded. Thus, if these patterns correctly predict the climatic trend, the Deschutes River lies on a trajectory that will progressively increase its capacity to move sediments into Capitol Lake and Budd Inlet (Mote et al. 2003).

The current shallow water condition of Capitol Lake contributes directly or indirectly to a suite of additional factors. Large woody debris moved by the Deschutes River can strand in lake shallows and mud flats, sometimes becoming visible during summer low-flows. Though water quality has improved considerably, especially in summer, since cessation of the use of Capitol Lake for the receipt of raw sewage, reduced water levels can exacerbate the low seasonal fecal coliform counts as well as phosphate pollution in the lake (Roberts et al. 2004). Sources of phosphate in Capitol Lake are incompletely understood, but typical

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[2] Thurston County implemented existing regulations on stormwater ponds with developments under County Ordinance 10610, Section 15.05.010 in 1994. The manual associated with these regulations was adopted in April 1994 and planning for this manual extends back to 1991. Little existed prior to that time, though a Stormwater Program Guidance for Puget Sound Basin (1992) provided some guidance.

[3] Defined as lying between 42 and 55 degrees North latitude and west of 111 degrees West longitude Mote (2003).

annual mortality of Three-spined Stickleback (*Gasterosteus aculeatus*; Bell and Foster 1994), which are productive in Capitol Lake (Entranco 1997), plus upstream non-point agricultural sources, may contribute (Roberts et al. 2004). In turn, increased phosphate levels promote aquatic weed growth. The aquatic exotic invasive, Eurasian watermilfoil (*Myriophyllum spicatum*) dominated this growth in the recent past (TCPHSS 2004), but a combination of herbicide treatment and focused removal efforts have produced reasonable levels of control. Nonetheless, floating beds of other rooted and floating aquatic vegetation have generally increased annually (K. Hamel, pers. comm.). The relatively rapid turnover of water in Capitol Lake was historically viewed as a factor that would favor improved water quality (Orsborn et al. 1975), however, if relatively rapid turnover increases phosphate delivery from external non-point sources, it may augment the problem. Shallow water also increases lake vulnerability to solar heating (Roberts et al. 2004), which may further encourage aquatic vegetation, and impact fish habitat and water quality. This may occur directly through changes in temperature or indirectly by promoting hypoxic or even locally anoxic conditions (Eisner et al. 1994, Roberts et al. 2004), particularly during the cyclic Three-spined Stickleback mortality events (Bell and Foster 1994).

A last feature important to understanding complexities in Capitol Lake is the historic pattern of non-flood control drawdowns that began in 1968 (Entranco 1997). Capitol Lake was lowered from its summer operating level (+6.4 feet above mean sea level [MSL]) to the tide gate sill elevation (-7.0 feet MSL), then typically refilled with saltwater. Objectives of these drawdowns were to:

1) control algae and aquatic plant growth through exposure to saltwater (since 1968);
2) assist juvenile salmonid out-migration (prior to 1985);
3) facilitate construction, operation, and maintenance activities for the lake, shoreline, and nearshore parks (Entranco 1997); and
4) reduce predatory fish presence (cannibalistic yearling Chinook salmon, selected warmwater species [mostly largemouth bass], and northern pikeminnows; K. Keown, pers. comm.).

Drawdowns occurred up to three times annually through 1984, and twice annually through 1995, each episode spanning a few days (usually three). Under the right conditions (i.e., low freshwater inflows and wind promoting mixing), increased salinity levels would typically last 3-5 weeks, and would affect up to 90% or more of the lake surface area in the North and Middle Basins. Before 1996, saltwater had been used to refill Capitol Lake after drawdown except in 1992 when freshwater was used. Though regular non-flood control drawdowns were discontinued in 1996 (L. Kessel, pers. comm.), a planned drawdown occurred in 1997 (Entranco 1997) to provide data to model the effects of drawdown (Aura Nova et al. 1998). When subsequent planned drawdowns occurred, refill was modified to support the aquatic and wetland Habitat Mitigation Plan for Heritage Park, which required maintaining freshwater (salinity <0.5 parts per thousand [ppt]) in the upper 5-6 feet of the water column in the North Basin and most of the Middle Basin (Roberts et al. 2004). To accomplish this, refill was freshwater-dominated. A major planned drawdown occurred in 2002-2003 after the 2001 Nisqually earthquake to enable 4th-Avenue Bridge repair (L. Kessel, pers. comm.); and a lesser drawdown occurred during the July 2004 application of the herbicide Triclopyr to control aquatic plant growth (Thurston County Public Health and Social Services 2004).

1.2 Prior Faunal Surveys and Research

Though many studies have addressed issues linked to restoring Capitol Lake, few have addressed the fauna. Orsborn et al. (1975) provided data on plankton and benthic organisms obtained in 1974 and 1975. Entranco (1997) provide data on the fish fauna and selected predators based on surveys conducted during drawdowns in 1996 and 1997; and in their Appendix C, they provide a faunal list based on a single field trip conducted on 29 October 1975. However, some aspects of the 1975 faunal list may be questionable since unidentified lizards and turtles are listed as amphibians. Herrera (2004) developed an inventory of vertebrates and invertebrates of Capitol Lake, but except for bird data obtained from Audubon Society Christmas counts that incorporates the Capitol Lake area (the Capitol Lake pool and surrounding area), their vertebrate data are based largely on regional lists that make limited effort to resolve either habitat conditions specific to Capitol Lake or the specific habitat needs of the species they listed. In a few cases, presence is implied for species not known to occur in the region. Selected invertebrate data that Herrera (2004) provided are Capitol Lake-specific, but given the mode of development of vertebrate data, these data must be viewed with caution. Garono et al. (2006) provided information that predicts the formation of species assemblages associated with habitats under the Estuary option based on a generic species list and sampling of habitats in nearby estuaries.

1.3 Objectives

Planners and interested parties began considering the restoration of Capitol Lake during the 1990s, prior to the inception of the Capital Lake Adaptive Management Program (CLAMP), whose Steering Committee first met in 1997 (CLAMP 1999). These efforts led to a suite of reports on the biological, economic, cultural, and physical aspects of the ecosystem in which Capitol Lake is located (Washington State Department of General Administration [WSDGA] 2002). The most recent of these efforts, described by Moffatt and Nichol (2007), examined three restoration options in addition to evaluating the status quo. Based on direction from the CLAMP Steering Committee, we consider three of the alternatives described by Moffatt and Nichol (2007), including the status quo, plus an alternative (Managed Lake) they did not address. These alternatives include:

1) Status Quo - No change from existing conditions. Management of Capitol Lake would continue as it has during the last few years. Though no dredging would be immediately planned under this alternative, sedimentation of Capitol Lake through the Deschutes River would continue at an annual pace at least approximating the recent past, so ultimately some dredging will be required just to maintain Capitol Lake in its existing shallow condition. Moffatt and Nichol (2007) considered this alternative, but did not label it.
2) Managed Lake - Maintenance of a managed lake with a uniform depth of 13 feet (~4 meters). This alternative, defined by CLAMP Steering Committee (WSGA 2008), is a managed condition that would have a nominally uniform depth of 13 feet throughout the Middle and North Basins of Capitol Lake. Dredging would be required to attain this depth, and maintaining this depth would require periodic dredging. Moffatt and Nichol (2007) did not address this alternative.
3) Estuary - Removal of the 5th-Avenue Dam resulting in a dynamic steady-state estuary. This alternative, which would replace the 5th-Avenue Dam with a roughly

500-ft (150-m) long bridge, would require some initial dredging as well as periodic dredging for maintenance. This alternative would revert the whole of Capitol Lake to an estuary within the constraint of human-built infrastructure, i.e., a 500 foot opening to the Budd Inlet. This is Alternative A of Moffatt and Nichol (2007).

4) Dual Basin - 5th-Avenue Dam removal and partitioning a Reflection Pool from the estuary. This alternative would also replace the 5th-Avenue Dam with a roughly 500-ft (150-m) long bridge, but it would also retain the east side of the North Pool of Capitol Lake (i.e., Reflection Pool) as a saltwater body by building a dike with flap tide gates between this pool and the rest of what was formerly Capitol Lake, which would become an estuary. This alternative would also require initial and periodic maintenance dredging, and is Alternative D of Moffatt and Nichol (2007). Moffatt and Nichol (2007) explored the option of a freshwater Reflection Pool, but rejected it in favor of the saltwater pool based on cost and logistics. As described therein, flap tide gates would maintain a relatively stable water level in this Reflection Pool.

The overarching objective of this report is to estimate likely changes in the patterns of fish and wildlife use across four management options, and changes in the major ecosystem types and their associated functions and processes. Our assessment addresses primarily larger animals, represented mostly by vertebrates. We address microfauna when characterizing differences in ecosystem processes among options.

2 Methods

To provide policy makers with a useful approach for evaluating options relative to tradeoffs for fish and wildlife habitat, we conducted an extensive search of peer-reviewed and gray literature, and interviewed various experts with knowledge of particular species, habitats, general ecology, and restoration. We distilled this information into two analysis tools: 1) a species assessment, and 2) an ecosystem assessment.

2.1 Species Assessment

For the species assessment, we selected species for which we had relatively unambiguous evidence of presence at Capitol Lake (i.e., range maps overlap the Capitol Lake area) and that used the Lake for at least one seasonal interval (e.g., summer or winter residents). We did not include species that used Capitol Lake irregularly (would use Capitol Lake for less than one seasonal interval) or that used Capitol Lake infrequently, defined here as species which would find only marginal habitat under all of the four management options. We also excluded species for which we could not determine habitat use or preferences under any of the management options, i.e., available data for the species too limited or ambiguous to allow evaluation; excluded species and reasons for exclusion are listed in Appendix I.

We provide a series of tables that show species responses to alternatives based largely on expert opinion applied to literature derived species-habitat association data. A species response was judged as positive, neutral, or negative relative to the Status Quo Option. For example, a positive response for a species for a particular management option indicates an improvement in habitat quality and/or quantity based on our assessment relative to the Status Quo. We also talk about improvements in habitat quality/quantity in terms of "species use", which can mean one or more of the following: 1) appearance of a new species from the surrounding area (e.g., in Budd Inlet) that moved into Capitol Lake because a favorable change in habitat conditions, 2) the same number of individuals of a species spending more time in an environment because habitat improvement favors that species, and 3) more individuals of species appear in an environment because habitat change favors that species. We do not address animal colonization dynamics but rather assume all species whose geographic range included Capitol Lake have opportunity to use habitat if it is present in one or more of the options.

We ranked the degree of response as positive (+ or ++) or negative (- or --). Two levels of positive or negative were intended to help differentiate between the Dual Basin and Estuary Options in a relative sense. We did not attempt to further quantify the "level of response" given the nature and scope of this assessment. We also provide an assessment of our confidence in scoring by indicating two levels of uncertainty, low and high. High uncertainty reflects relatively large data gaps. We offer suggestions in the Discussion on how to better "inform" these comparisons (where uncertainty was high), if that step is deemed necessary.

Because the value humans place on the presence and/or abundance of species is context dependent (notwithstanding species listed under the Endangered Species Act [ESA]), we provide additional information for judging "species importance" including federal and state listing status, identification of economic importance, and their "Priority Habitat and Species (PHS) status. The PHS list is a catalog of habitats and species that the Washington Department of Fish and Wildlife (WDFW) considers priorities for conservation. *Priority Species* are identified as needing protection due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance; and *Priority Habitats* as needing protection based on the conclusion that these habitats provide elements with unique or significant value to a diverse assemblage of species. *Priority Species* include State Endangered, Threatened, Sensitive, and Candidate species; animal aggregations considered vulnerable; and those species of recreational, commercial, or tribal importance that are vulnerable.

2.2 Ecosystem Assessment

For the ecosystem assessment, we characterized the type of ecosystems that would be present in each of the four alternatives and the degree to which those types have changed from (early European settlement, circa 1850) to current day. We first estimated the absolute area of estuary versus freshwater lake ecosystem types in Washington State and then compared recent trends in aerial extent of each type. We used the Puget Sound Update (Puget Sound Action Team [PSAT] 2007) for data on estuaries, and a combination of the Washington State Department of Ecology's "Trophic State Census of Washington State Lakes by Satellite Imagery" (Butkus 2004) and "Inventory of Dams in the State of Washington" (Washington Department of Ecology 1994) for data on freshwater lakes. We also indicate how alternative management scenarios affect some of the most important functions and processes associated with each ecosystem type. While ecosystems (also generally referred to as environments, land-cover type, community type, landscapes) do not have the same regulatory status as species listed under ESA, they are increasingly used in conservation planning as higher-level elements of biodiversity. In particular, they are used for assessments that recognize that in the absence of complete (or even good species) data, conserving all types of ecosystems should conserve a large proportion of species, their interactions (e.g., predation, herbivory, mutualisms—the products of co-evolution), and the important processes and functions provided by those ecosystems.

3 Results and Discussion

3.1 Species Present and their Responses

We first treat vertebrates, then invertebrates. We address all groups within these two categories in alphabetical order to avoid any implication of greater relative importance to any particular group. Species excluded based on the criteria previously discussed are presented in Appendix I.

3.1.1 Vertebrates

Vertebrates from five groups (amphibians, birds, fishes, mammals, and reptiles) are known from the Capitol Lake area.

3.1.1.1 Amphibians

No formal surveys for amphibians have been conducted on Capitol Lake (L. Hallock, pers. comm.; W. Leonard, pers. comm.; K. McAllister, pers. comm.); and available data are all anecdotal. In a list of fauna based on animals seen or signs of their presence from a 29 October 1975 field trip by Charles Lindberg and Christopher Dlugokenski, unidentified frogs were seen; however, their list also includes “lizards” and “turtles” under amphibians, so question may exist even about their coarse-level identification ability. Electroshocking surveys associated with the 1997 drawdown of the lake done on 22 July revealed 6 frogs in the lake-influenced habitat of the South Basin and 3 additional frogs in adjacent the riverine-influenced habitat, but none of the animals were identified to species (Entranco 1997). No frogs were recorded during the 1996 drawdown surveys (Entranco 1997).

The American Bullfrog (*Lithobates catesbeianus* [formerly *Rana catesbeiana*]) is an exotic species, likely introduced into Washington State during the 1930s, and is the only amphibian species that has been unambiguously identified from Capitol Lake proper (Table 1; L. Hallock, pers. comm.; W. Leonard, pers. comm.; K. McAllister, pers. comm.; L. Salzer, pers. comm.). Lisa Hallock (pers. comm.) saw American Bullfrogs during the summer in the South Basin attracted to flies on floating dead fish following a fish kill. American Bullfrogs have also been recorded a number of times in the Middle and South Basins over the years (W. Leonard, pers. comm.; K. McAllister, pers. comm.; L. Salzer, pers. comm.; WDFW database).

An aggressive predator, post-metamorphic American Bullfrogs will readily prey upon native amphibians and small surface-active fish (Bury and Whelan 1980). Bullfrog larvae (tadpoles) can outcompete larvae of native amphibians (Kupferberg 1997). Moreover, American Bullfrogs have anti-predator devices (e.g., unpalatable larvae) that allow them to co-exist with predatory fish (Kruse and Francis 1977) since they originally co-evolved in fish-rich habitats in eastern North America (Bury and Whelan 1980). They can also carry the lethal aquatic fungus, *Batrachochytrium dendrobatidis*, which causes *chytridiomycosis*, a decimating disease that has caused declines in many amphibian species globally. Thus, the American Bullfrog is an undesirable species in context of conserving native amphibians.

Table 1. Anticipated responses of amphibians to management options for Capital Lake. Species indicated by an E are exotics. All options are evaluated relative to the status quo (current conditions), which was designated as zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence.

Species (Standard English Name)	**Scientific Name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
American Bullfrog (E)	*Lithobates catesbeianus*	0	0	L	-	L	--	L

Responses to Options: Native amphibian species may use Capitol Lake[4], but they would be expected to use only freshwater portions of the lake and adjoining freshwater environment and ponds in the Heritage Park Interpretive Area and the Tumwater Historical Park for breeding. However, the Status Quo Option supports predatory fish that likely limit the use of Capitol Lake proper for breeding of native amphibian species and thus would continue to favor American Bullfrog presence. The Managed Lake Option would probably not differ greatly from the Status Quo Option except that a deeper open-lake condition might reduce American Bullfrog numbers by increasing the effectiveness of bullfrog predators on vulnerable life stages through a reduction in hiding cover. Unless dredging systematically maintains a deeper open lake profile, this pattern would slowly revert toward conditions resembling the Status Quo.

The Estuary and Dual Basin Options would likely considerably reduce amphibian use of the Capitol Lake pool. Amphibians have permeable skins, limited capability to osmoregulate (i.e., almost no ability regulate salt intake), and would dehydrate if exposed to even moderately brackish water (Boutelier et al. 1992). Amphibian survival would depend on the extent of freshwater prism maintained from sources entering the estuary (Deschutes River, Percival Creek) and possible small seeps and springs on the estuary perimeter. We expect little difference between these two options because regardless of whether the North Basin is partitioned, all parts of the North Basin pool under either option would have aquatic habitat with salinity unfavorable to amphibians.

3.1.1.2 Birds

Available data on birds utilizing Capitol Lake come largely from the Black Hills Audubon Society Christmas counts and surveys and from other irregular surveys and fieldwork. Entranco (1997) provided a list of birds recorded by the Black Hills Audubon Society from the area between Interstate 5 and Tumwater Falls (i.e., the South Basin; Figure 1). That list was partitioned into permanent, spring and summer, and winter residents; and indicated which species were recorded during a single day (29 October 1975) field reconnaissance, which species were regarded as unusual for the area, and which species had been recorded since 20 October 1975. Herrera (2004) provided additional Black Hills Audubon Society data based on a Christmas count from 14 December 2002, and two late winter-early spring (3 March and 7 May) and five fall (14, 20, and 27 October; and 4 and 9 November) dates in 2003.

Fifty-two species of birds that are either permanent or seasonal residents have a significant association with aquatic environments or resources of Capitol Lake. We discuss these birds in groupings based on their feeding or foraging patterns because ecosystem changes under alternative options are expected to affect at least some of these groupings differently.

3.1.1.2.1 Aerial-foraging Birds

Six species of aerial-foraging birds, five species of swallows and Vaux's Swift (*Chaetura vauxi*), make significant use of Capitol Lake as foraging habitat (Table 2). All six are

[4] William Leonard (pers. comm.) has observed Long-toed Salamanders (*Ambystoma macrodactylum*), Pacific Chorus Frogs (*Pseudacris regilla*), and Northern Red-legged Frogs (*Rana aurora*) in pools adjoining Percival Creek in Marathon Park beginning about 0.25 miles (0.4 kilometers) upstream from Percival Cove, but not in Percival Cove proper, which represents part of the Capitol Lake pool.

Table 2. Anticipated responses of aerial-foraging birds to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Barn Swallow	*Hirundo rustica*	0	0	L	-	L	-	L
Purple Martin	*Progne subis*	0	0	L	0	L	0	L
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	0	0	L	-	L	-	L
Tree Swallow	*Tachycineta bicolor*	0	0	L	-	L	-	L
Violet-green Swallow	*Tachycineta thalassina*	0	0	L	-	L	-	L
Vaux's Swift	*Chaetura vauxi*	0	0	L	--	L	--	L

Nearctic migrants and all six forage almost exclusively on flying insects, though the Tree Swallow (*Tachycineta bicolor*) also eats berries (Bull and Beckwith 1993, Sibley 2001). Based on their abundance in the bottom substrate, Capitol Lake is currently an important source of emerging flying insects (see Invertebrates section).

Responses to Options: For these aerial foraging birds, the Managed Lake Option is likely to be similar to the Status Quo Option except that dredging operations may temporarily depress the insect food base. Insect production for aerial-foraging birds may also decline if the Managed Lake Option enhances fish species that forage on aquatic insect life stages.

The Estuary and Dual Basin Options would likely result in a major shift over a large proportion of the Capitol Lake pool (the North and much of the Middle Basins) from an insect-dominated benthos to one dominated by marine worms, crustaceans, and molluscs (see Invertebrates section), and thus, produce considerably fewer invertebrates for aerial-foraging birds. We would expect production of flying insects to continue in the freshwater (≤ 0.5 ppt) portions of the South and Middle Basins, but the overall level of insect production in Capitol Lake would decrease and insect community composition may change. Hence, a decline in the numbers of aerial-foraging birds under the Estuary Option is probable. The lack of difference between the Estuary and Dual Basin Options is based on the fact that regardless of whether the North Basin is partitioned, all parts of the North Basin pool under either option would develop aquatic habitat with salinity unfavorable to insect production.

3.1.1.2.2 Diving Birds (Non-Waterfowl)

Seven non-waterfowl diving bird species make significant use of the Capitol Lake area (Table 3). Pigeon Guillemots, Double-crested Cormorants, and Belted Kingfisher are year-round residents; remaining species are exclusively winter residents in the Capitol Lake area (Entranco 1997, Herrera 2004; J. Evenson, pers. comm.). These seven species fall into five groups (numbers of species in each in parentheses): alcids (1), cormorants (1), grebes (3), kingfishers (1), and loons (1). Though all dive to forage, they differ in their mode of diving and in the types of microhabitats they use. Except for some species of grebes, most are primarily fish eaters (Sibley 2001).

Pigeon Guillemots (*Cepphus columba*) forage in marine waters, where they focus on forage fishes and consume a greater variety of small fish species than most alcids (Ainley et al. 1990, Hayes and Kuletz 1997, Litzow et al. 2000). Like other alcids, they feed entirely by pursuit diving, where they use but their wings to “fly” underwater (Sibley 2001), and typically catch either schooling forage fish, like Pacific Sand Lance (*Ammodytes hexapterus*), or those close to the bottom, foraging in areas more inshore than most alcids (Ewins 1993, Sibley 2001). Two Pigeon Guillemot colonies exist in Budd Inlet; a colony of 40-50 birds is located along the bluffs at Gull Harbor, and a smaller colony exists north of the ship pier at the Port of Olympia (J. Evenson, pers. comm.).

The Double-crested Cormorant (*Phalacrocorax auritus*) forages on schooling fish typically well above the bottom and uses habitats in both fresh and marine waters (Sibley 2001). In the lower Columbia River estuary, the dominant prey of Double-crested Cormorants was juvenile salmonids or herring (primarily juvenile Pacific herring [*Clupea pallasii*]) and juvenile shad (*Alosa sapidissima*) depending on the year (Collis et al. 2002).

Table 3. Anticipated responses of diving birds (non-waterfowl) to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Pigeon Guillemot	*Cepphus columba*	0	0	L	+*	H	+*	H
Double-crested Cormorant	*Phalacrocorax auritus*	0	+*	H	+*	H	+*	H
Western Grebe	*Aechmophorus occidentalis*	0	0*	H	0*	H	0*	H
Horned Grebe	*Podiceps auritus*	0	0	L	+*	H	+*	H
Pied-billed Grebe	*Podilymbus podiceps*	0	0	L	--	H	--	L
Belted Kingfisher	*Megaceryle alcyon*	0	+*	H	-*	H	-*	H
Common Loon	*Gavia immer*	0	+*	H	+*	H	+*	H

Of the three species of grebes, the larger Western Grebe (*Aechomorphus occidentalis*) is a nocturnal forager on medium-sized fishes, especially juvenile Pacific Herring, *Clupea pallasii* (Clowater 1993). In contrast, the two smaller species tend to consume more aquatic invertebrates (Wetmore 1924, Sibley 2001). Crustaceans and small fishes dominate Horned Grebe (*Podiceps auritus*) winter diet, with some mollusks and plant material (Stedman 2000), whereas Pied-billed Grebes (*Podilymbus podiceps*) consume aquatic insects (especially bugs [Hemiptera], beetles [Coleoptera], and nymphs of dragonflies [Odonata]), small fishes (including juvenile carp and minnows [Cyprinidae], juvenile catfishes [Ictaluridae], sculpins [Cottidae], and Three-spined Sticklebacks), and frogs and tadpoles (especially ranids; Wetmore 1924, Munro 1941). Pied-billed Grebes, more frequent in fresh than salt water, tend to forage more among rooted aquatic plants and beneath mats of floating vegetation than Horned Grebes (S. Pearson, pers. comm.).

Belted Kingfishers (*Ceryle alcyon*) feed almost entirely on small fish that they capture underwater following a dive from an aerial position in stream, estuarine, and lake habitats (Sibley 2001). Though Belted Kingfishers use a broad range of environment types, they prefer calm clear waters free of dense mats of aquatic plants or floating debris (Hamas 1994). Aquatic plants, floating debris, or silt stirred up by heavy rains or wave action can hamper foraging by obscuring visibility. When foraging on large lakes or coastal waters, Belted Kingfisher selected sheltered locations where wave action was limited (Hamas 1994). Belted Kingfishers have been consistently observed below the 5th-Avenue Dam taking schooling forage fish species (S. Pearson, pers. comm.). They may concentrate here because the dam tends to concentrate forage fish prey.

Common Loons (*Gavia immer*) are fish consumers (Reimchen and Douglas 1980) that favor species with an erratic swimming behavior (Barr 1996). As a consequence, species like Yellow Perch (*Perca flavescens*) and selected centrarchid fish species are favored prey. Salmonids are eaten, but their straight-line escape tactics often helps them evade capture (Evers 2007). Salmon are rarely eaten in environments where prey alternatives to salmonids like Yellow Perch exist (Evers et al. 2004).

Responses to Options: The Managed Lake Option is unlikely to differ greatly from the Status Quo Option except that the four fish-consuming species (Common Loon, Belted Kingfisher, Double-crested Cormorant, and Western Grebe) may respond positively to a potential improvement in forage conditions in freshwater environments. We have a relatively high degree of uncertainty about the improvement in habitat quality/quantity associated with the Managed Lake Option for fish-eating birds because of the complexity of potential interactions among prey fish species with concurrent change in conditions (e.g., vegetation structure under the Managed Lake Option).

The Estuary and Dual Basin Option will likely to result in a strong negative response for the freshwater vegetation-requiring Pied-billed Grebe. The Belted Kingfisher may also exhibit a negative response to these options if removal of the 5th-Avenue Dam disperses forage fish prey or increases hiding cover for forage fish. In contrast, both these Options may incrementally increase either foraging area or conditions for the Pigeon Guillemot and Horned Grebe.

Habitat for species that are known to use both fresh and marine waters (Common Loon, Double-crested Cormorant, and Western Grebe) are not expected to show a significant change, but our inability to predict changes in prey fish species makes nearly all of these options fairly uncertain. In general, diving birds are expected to respond to the Dual Basin Option in a manner similar to the Estuary Option. High uncertainty in species responses reflects inability to confidently predict changes in prey species in a stable saltwater Reflection Pool with reduced tidal constraints.

3.1.1.2.3 Gulls and Terns

Four gulls taxa and one tern species make significant use of the Capitol Lake area (Table 4). The Western/Glaucous-winged Gull (*Larus occidentalis* × *glaucescens*) represents a hybrid swarm of year-round resident birds (S. Pearson, pers. comm.), so we treat it as one unit. Bonaparte (*L. philadelphia*), Mew (*L. canus*), and Ring-billed Gulls (*L. delawarensis*) are winter visitors, and the Caspian Tern (*Sterna caspia*) is a non-breeding resident (S. Pearson, pers. comm.). Except for the Ring-billed Gull, which prefers freshwater, remaining taxa are flexible in their use of fresh- versus saltwater.

All gull species are omnivorous opportunists that consume a wide variety of fish, marine invertebrates, insects, garbage, and carrion, often robbing prey from or the nests of other birds, including individuals of their own species (Sibley 2001). The least generalized of the gulls is Bonaparte's, which winters in Puget Sound and is reported to feed on insects, other small invertebrates, and small fish (Tangren 1982).

In contrast, the diet of the Caspian Tern's diet consists primarily of fish and occassionally crayfish and insects (Cuthbert and Wires 1999). In the Columbia River estuary, juvenile salmonids made up nearly three-fourths of Caspian Tern prey, and herring and shad accounted for another roughly 10% (Collis et al. 2002).

Responses to Options: Except the Ring-billed Gull, we expect no significant change in gull habitat among management options, reflecting their dietary and habitat generzliation. The Ring-billed Gull is anticipated to respond negatively to the loss of freshwater conditions with the two estuarine options.

The small fish-consuming Caspian Tern is expected to experience a loss in easy foraging habitat with the loss of the 5th-Avenue Dam and restoration of a mobile salt wedge under the two estuarine options. Presence of the Reflection Pool under the Dual Basin Option is unlikely to significantly alter this loss.

3.1.1.2.3 Shorebirds and Probing Foragers

Eight species of shorebirds and probing foragers (hereafter shorebirds) make significant use of the Capitol Lake area (Table 5). All eight species require either relatively fine-grained substrates that become exposed (e.g., at low tide) or extremely shallow water (typically no more than a few centimeters in depth) for visual or probing-type foraging, and shift among sites as these habitats become available (Brennan et al. 1985, Dekker and Ydenberg 2004). Though considerable variation exists in prey species consumed by these shorebirds, even within Puget Sound, they all consume small invertebrates that dwell on or near the substrate surface; the dominant groups including annelid worms, amphipods, and ostracods (Brennan et al. 1990).

Table 4. Anticipated responses of gulls and terns to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Mew Gull	*Larus canus*	0	0	L	0	L	0	L
Ring-billed Gull	*Larus delawarensis*	0	0	L	--	L	--	L
Western/Glaucous-winged Gull	*Larus occidentalis*	0	0	L	+*	H	+*	H
Bonaparte's Gull	*Larus philadelphia*	0	0	L	0	L	0	L
Caspian Tern	*Hydroprogne caspia*	0	0	L	-	L	-	L

Table 5. Anticipated responses of shorebirds to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Greater Yellowlegs	*Tringa melanoleuca*	0	0	L	+	L	++	L
Spotted Sandpiper	*Actitis macularia*	0	0	L	+	L	+	L
Dunlin	*Calidris alpina*	0	0	L	+	L	++	L
Western Sandpiper	*Calidris mauri*	0	0	L	+	L	++	L
Least Sandpiper	*Calidris minutilla*	0	0	L	+	L	++	L
Killdeer	*Charadrius vociferus*	0	0	L	+	L	+	L
Short-billed Dowitcher	*Limnodromus griseus*	0	0	L	+	L	++	L
Long-billed Dowitcher	*Limnodromus scolopaceus*	0	0	L	+	L	++	L

Responses to Options: Currently, shorebirds only use Capitol Lake during drawdowns or summer low flows that expose fine-substrate bars or shorelines (J. Buchanan, pers. comm.). We anticipate that the Managed Lake Option would provide habitat similar to the Status Quo Option, and that probing shorebirds would use Capitol Lake when drawdowns or low flows expose foraging substrates.

In contrast, we anticipate that shorebird habitat in the Capitol Lake area would increase under both the Estuary and Dual Basin Options, and the Estuary Option would likely of support greater numbers of shorebirds given the greater expected exposed foraging area on a regular basis. Only the Killdeer (*Charadrius vociferus*) and Spotted Sandpiper (*Actitis macularia*) are unlikely to respond differently to these two options.

3.1.1.2.4 Raptors

Four species of raptors are permanent residents or make significant seasonal use of Capitol Lake (Table 6). Two, the Merlin (*Falco columbarius*) and the Peregrine Falcon (*Falco peregrinus*), consume birds primarily, though the Merlin can sometimes focus on large insects; the Osprey (*Pandion haliaetus*), consumes fish almost exclusively; and the Bald Eagle (*Haliaeetus leucocephalus*), consumes mostly fish and other birds, frequently as carrion, and often by robbing Osprey and other species (Sibley 2000, 2001).

In coastal areas similar to Capitol Lake, Merlins focus primarily on small shorebirds (few records exist of successful captures of shorebirds larger than 70 g [Preston 1995]), such as Dunlin (*Calidris alpina*) and Western Sandpiper (*Calidris mauri*) (Page and Whitacre 1975, Boyce 1985, Dekker 1988, Buchanan et al. 1988). Shorebirds are particularly vulnerable during migratory stopovers, where heavy food loading necessary to complete long migratory flights diminishes the level of flight performance important in predator escape and evasion (Ydenberg et al. 2004).

In the coastal Pacific Northwest, Peregrine Falcons focus on small alcids, shorebirds, and small ducks, which average slightly larger than the prey of Merlins (Beebe 1960, Dekker 1988, Dekker and Ydenberg 2004). Shorebirds are more vulnerable to Peregrine Falcon the few hours immediately following high tides when they congregate in narrow shoreline zones exposed on outgoing tides (Dekker and Ydenberg 2004).

Osprey also take prey over a particular size ranges, typically < 1,000 g (Poole 1989), which results in particular fish species being vulnerable. Comparisons of the ecology of fishes taken by Ospreys over their geographic range reveals that benthic-feeding fish seem to be the easiest to catch, but can be effectively caught only in shallow water, and that non-predatory (i.e., non-piscivorous) fish seem easier to catch than than predatory ones (Swenson 1979). Osprey typically forage most successfully where water is relatively transparent (Sibley 2001).

In contrast, Bald Eagles are generally more generalized in their prey requirements than the other three raptors. They consume a variety of food (Stinson et al. 2001) and rob prey from other species (Fischer 1985). In a tidally influenced system, Bald Eagles foraged in tidal mudflats devoid of aquatic vegetation more often than expected based on availability, and avoided areas of deep water (>3 m; Thompson et al. 2005). Further, Bald Eagles tend to forage more often during ebb tides with foraging activity peaking just before low tide (Thompson et al. 2005).

Table 6. Anticipated responses of raptors to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Merlin	*Falco columbarius*	0	0	L	+	L	++	L
Peregrine Falcon	*Falco peregrinus*	0	0	L	+	L	++	L
Bald Eagle	*Haliaeetus leucocephalus*	0	0	L	+	L	+	L
Osprey	*Pandion haliaetus*	0	0	L	0*	H	+	L

Responses to Options: How alternative options affect the raptor habitat depends largely on whether significant shifts occur in the availability of their focal prey. By virtue of greater tidal exposure of mudflats and fine-grained substrates and thus increases in shorebirds, we anticipate that the Estuary Option, and to a lesser degree, the Dual Basin Option will increase foraging opportunities for Merlins and Peregrine Falcons. We also expect that the greater area for foraging available during ebb tides will favor Bald Eagles. Osprey are likely to benefit most from conditions that improve visibility into the water column, which is anticipated if estuarine conditions replace the existing low transparency waters of Capitol Lake.

We anticipate that the Managed Lake Option will not differ greatly from the Status Quo Option for Merlin and Peregrine Falcon, but the Managed Lake Option may provide slightly better habitat than the Status Quo Option for Osprey and Bald Eagle if it improves water column visibility as explained above.

3.1.1.2.5 Wading birds

Two wading bird species, Great Blue Heron (*Ardia herodias*) and Green Heron (*Butorides virescens*) make significant use of the Capitol Lake area (Table 7). Both are year-round residents and sit-and-wait predators that forage in shallow water and along shorelines of fresh, brackish, or salt water, or in certain types of open terrestrial habitats (Butler 1995, Davis and Kushlan 1994).

Great Blue Herons consume mostly fish, but also amphibians, invertebrates, reptiles, mammals, and birds (Kushlan 1978, Verbeek and Butler 1989). In estuaries, Great Blue Herons often prey upon highly visible, near-surface active forage fish species, like Shiner Perch (*Cymatogaster aggregata*; Butler 1993).

Green Herons also typically eat fish but prey selection is broad, and includes amphibians and diverse invertebrates (Davis and Kushlan 1994). Green Herons prefer foraging in or near dense vegetation, but will feed in the open when food is available (Davis and Kushlan 1994).

Responses to Options: The Managed Lake Option would not add shoreline foraging habitat for either these herons relative to the Status Quo Option, so differences in response between these options are not anticipated.

In contrast, the Estuary and Dual Basin Options are anticipated to add significant shoreline habitat that would change constantly with the tides and likely improve foraging conditions. Though we expect the response to be positive for both species, we expect a greater response for Great Blue Heron due to its favoring open conditions (Butler 1995).

Table 7. Anticipated responses of wading bird habitat to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Great Blue Heron	*Ardea herodias*	0	0	L	+	L	+	L
Green Heron	*Butorides virescens*	0	0	L	+	L	+	L

3.1.1.2.6 Waterfowl

Sixteen species of waterfowl (coots, ducks, geese) make significant use of the Capitol Lake area (Table 8). Technically not waterfowl, the American Coot (*Fulica americana*) is related to rails. We include it with waterfowl due to its similarities with waterfowl.

Canada Geese (*Branta canadensis*) are herbivores with a diverse non-woody diet. During fall and winter, when migatory individuals remain at Capitol Lake, most rely on foods richer in carbohydrates than at other seasons (Mowbray et al. 2002). In Pacific Northwest coastal waters, Canada Geese prefer eelgrass (*Zostera marina*). In more silt-laden waters (much of Budd Inlet and South Puget Sound) that limit eelgrass, the saltmarsh grasses *Puccinellia americana* and *Spartina* spp. may substitute (Erskine 2000). Despite the fact that historical alteration has removed nearly all the graminoid saltmarsh associated with the Capitol Lake area, Canada Geese frequent the Capitol Lake area during fall and winter. This may reflect a pattern similar to Mallards that roost in intertidal areas and estuaries located near croplands or fields, but feed in those croplands or fields by day (Hirst and Easthope 1981, Lovvorn and Baldwin 1996).

Northern Pintails (*Anas acuta*) use the Capitol Lake area as well as other freshwater, brackish, and marine wetlands during the winter where they feed on aquatic plant seeds, pond weeds, aquatic insects, crustaceans, and molluscs (Austin and Miller 1995). In estuarine southeastern Alaska (Stikine River Delta) and northwestern California (Humbold Bay), small clams dominated the animal portion of Northern Pintail diet, and seed heads of sedges (*Carex* sp.) and other graminoids dominated the plant portion of the diet (Yocum and Keller 1961, Hughes and Young 1982).

During overwintering, American Widgeon (*Anas americana*) use freshwater marshes, rivers, lakes, impoundments, estuaries, saltwater bays, and agricultural lands. However, they are found primarily in areas with an abundance of submergent and emergent vegetation (Mowbray 1999). Almost entirely herbivorous during overwintering, the American Widgeon consumes stems and leafy parts of aquatic plants, leafy parts of upland grasses and clovers (*Trifolium* spp.), and leafy parts and seeds of various agricultural crops (Bellrose 1980).

Mallards (*Anas platyrhynchos*) are generalized consumers (omnivorous and opportunistic; Drilling et al. 2002), and year-round residents in the Capitol Lake area (Entranco 1997). Mostly herbivorous in winter, Mallards increase their intake of animal food, such as aquatic invertebrates (e.g., midge and other aquatic fly larvae, dragon naiads, caddisfly larvae, aquatic snails and freshwater shrimp) and terrestrial earthworms during other seasons. Shifts in diet may simply reflect reduced winter availability of animal foods (Drilling et al. 2002). In some cases, estuaries may simply be used as roosting sites while foraging in nearby areas. For example, in the Puget Sound-Georgia Basin area, Mallards roost in intertidal areas and estuaries located near croplands, but feed almost exclusively in corn and potato fields (Hirst and Easthope 1981, Lovvorn and Baldwin 1996).

Gadwall (*Anas strepera*), a species that winters in the Capitol Lake area, can be found in coastal freshwater and brackish marshes, reservoirs, beaver ponds, and farm ponds during the overwintering interval (Leschack et al. 1997). Gadwalls typically feed in wetlands on submerged aquatic vegetation, seeds, and aquatic invertebrates. Feeding occurs from the

Table 8. Anticipated responses of waterfowl to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Canada Goose	*Branta canadensis*	0	0	L	-*	H	-*	H
Northern Pintail	*Anas acuta*	0	0	L	0	L	0	L
American Wigeon	*Anas americana*	0	0*	H	--	L	--	L
Mallard	*Anas platyrhynchos*	0	0	L	0	L	0	L
Gadwall	*Anas strepera*	0	0*	H	--	L	--	L
Lesser Scaup	*Aythya affinis*	0	0*	H	--	L	--	L
Ring-necked Duck	*Aythya collaris*	0	0	L	--	L	--	L
Bufflehead	*Bucephala albeola*	0	0	L	+	L	+	L
Common Goldeneye	*Bucephala clangula*	0	0	L	+	L	+	L
Barrow's Goldeneye	*Bucephala islandica*	0	0	L	0	L	0	L
Black Scoter	*Melanitta nigra*	0	0	L	+	L	+	L
Surf Scoter	*Melanitta perspicillata*	0	0	L	+	L	+	L
Hooded Merganser	*Lophodytes cucullatus*	0	0	L	0*	H	0*	H
Common Merganser	*Mergus merganser*	0	0*	H	-*	H	-*	H
Ruddy Duck	*Oxyura jamaicensis*	0	0*	H	0*	H	0*	H
American Coot	*Fulica americana*	0	0*	H	--	L	--	L

water surface to a depth of 30 centimeters (about 1 foot; White and James 1978, Paulus 1984).

Lesser Scaup (*Aythya affinis*), a diving duck that winters in the Capitol Lake area, occurs mainly in fresh to brackish coastal bays and estuaries during overwintering (Austin et al. 1998). Winter diet varies geographically, likely reflecting local difference in food abundance. Along the Columbia River in Oregon and Washington, 99% (by volume) of the diet is vegetative parts of waterweeds (*Elodea*; 51%) and pondweeds (*Potamogeton*; 27%); the remaining 21% are seeds from six aquatic plants (Thompson et al. 1988). In contrast, molluscs, typically clams, dominate Lesser Scaup winterdiet in estuaries, but opportunism in the dietary is frequent (Austin et al. 1998).

Ringed-necked Duck (*Aythya collaris*), another diving duck that winters in the Capitol Lake area, uses a variety of wetland types, but seldom occurs in habitats with salinities > 5 ppt and water depths > 1.5 m (~5 feet; Hohman and Eberhardt 1998). Though Ringed-necked Ducks are omnivorous, their winter diet is predominantly moist-soil and freshwater aquatic plant seeds and tubers (Hohman and Eberhardt 1998).

Bufflehead (*Bucephala albeola*), the smallest diving duck that winters in the Capitol Lake area, utilizes predominantly shallow saltwater areas during overwintering, such as secluded coves, harbors, and estuaries; open coastlines are avoided (Erskine 1972, Stott and Olson 1973, Vermeer and Morgan 1992). Bufflehead feed in open, shallow water (ca. < 3 meters [~10 feet] deep) primarily on aquatic invertebrates (insects, crustaceans, molluscs), though some seeds are eaten (Gauthier 1993). Bufflehead never dive through emergent or dense submergent vegetation (Erskine 1972), but often feed along stands of emergent vegetation (Bergan and Smith 1989). In estuaries, Bufflehead often feed in shallow water over mudflats exposed at low tide (Gauthier 1993).

Common Goldeneye (*Bucephala clangula*) are diving ducks that winter primarily in the marine waters of shallow coastal bays, estuaries, and harbors wherever adequate food exists (Bellrose 1980, Vermeer 1982). Winter diet is largely crustaceans and mollusks (Munro 1939), so Common Goldeneye preferentially forage over sandy, gravel, rocky, or boulder substrates in shallow water where such prey is frequent (Vermeer 1982, Duncan and Marquiss 1993).

Barrow's Goldeneye (*Bucephala islandica*) is a diving duck that winters mostly in marine habitats along at least partly protected rocky shores (i.e., bays, harbors, fjords or inlets), typically over mussel (*Mytillus*) beds (Eadie et al. 2000). Molluscs, primarily mussels, make up most of the winter diet (78% by volume) in marine habitats; small amounts of vegetation (algae) also consumed (Munro 1939, Koehl et al. 1982, Vermeer 1982). Overwintering may occur in harbors where mussels associated with are extensive piers and wharfs (Campbell et al. 1990) are found. These conditions can be found in Budd Inlet.

The Black Scoter (*Melanitta nigra*), among the least studied ducks, has poorly understood overwintering habitat needs (Bordage and Savard 1995). In Puget Sound, it seems to prefer sandy substrates (Hirsch 1980). In Washington, hard rock clams (*Protothaca* sp., including the Native Littleneck Clam [*Protothaca staminea*]) accounted for 17% and 36% of foods, respectively, in January and February (Bellrose 1980). Crustaceans, goose barnacles (*Lepas* spp.), and claw shrimps (*Limnadia lenticularis*) were another 17% of prey. In British Columbia, Black Scoters ate mostly marine mollusks, especially selected bivalves (Blue

Mussels [*Mytilus trossulus*], Manila Clams [*Tapes philippinarum*], Native Littleneck Clams, Heart Cockle [*Clinocardium nuttalli*], Soft-shell Clam [*Mya arenaria*]), but also gastropods, acorn barnacles (*Balanus glandula*), and polychaete worms (Vermeer and Bourne 1984).

The Surf Scoter (*Melanitta perspicillata*) occurs only as an overwinter visitor in the Pacific Northwest, where it utilizes shallow marine coastal waters < 10 m (~33 feet) deep, usually over substrates of pebbles (= small gravel) and sand (Goudie et al. 1994). Coastal and pelagic surveys indicate that vast majority of scoters (mainly Surf Scoter) wintering on the Canadian Pacific Coast occur within 1 kilometer (0.6 miles) of land (Vermeer 1981). In coastal British Columbia, Surf Scoters eat mostly mollusks, especially Blue Mussels, Manila clams, Native Littleneck Clam, Heart Cockles, and Soft-shell Clams, but also gastropods (Asian Hornsnails [*Batillaria attramentaria*], Checkered Periwinkles [*Littorina scutulata*], Dog Whelks [*Nassarius mendicus*]), acorn barnacles, and polychaetes (Vermeer and Bourne 1984).

Hooded Mergansers (*Lophodytes cucullatus*) breed in Washington, but they only overwinter in Puget Sound (Dugger et al. 1995). During overwintering, they occupy shallow, freshwater and brackish bays, estuaries, and tidal creeks and ponds. Unlike other mergansers, which eat almost exclusively fish, Hooded Mergansers have a more diverse diet (Dugger et al. 1995). A November to March nationwide sample of 138 Hooded Mergansers had fish (44%; species not identified unknown) and crayfish (22%; *Cambarus* spp.) as a collective two-thirds of all prey items, and aquatic insects (13%), other crustaceans (10%), amphibians (6%; mostly *Rana* spp.), and some vegetation and a few molluscs in the remaining third (Cottam and Uhler 1937).

The Common Merganser (*Mergus merganser*) overwinters along the Washington coast (Mallory and Metz 1999), where it tends to use on freshwater portion of bays and estuaries; (Bellrose 1980). Dietary studies of Common Merganser during the overwintering season are lacking, but a sample of 61 Common Mergansers from coastal British Columbia consumed mostly sculpins (54%), Three-spined Stickbacks (16%), small salmonids (11%), Yellow Perch (6.3%), and other fish and other items (collectively 12.7%; Munro and Clemens 1932).

The Ruddy Duck (*Oxyura jamaicensis*) overwinters in Puget Sound, where it represents the northernmost proportion of Ruddy Ducks that overwinter along the Pacific Flyway (Brua 2002). During migration and winter, Ruddy Ducks use mainly open waters in association with submergent vegetation (Bergan and Smith 1989, Korschgen 1989). Ruddy Ducks consume primarily aquatic insects, crustaceans, zooplankton, and other invertebrates, but also eat small amounts of aquatic vegetation and seeds (Brua 2002). Most studies show midge larvae (Chironomidae) are important food, but this result may be biased toward type and location of food studies conducted.

American Coots are year-round residents in Puget Sound (Entranco 1997). Though American Coots breed in a wide variety of freshwater wetlands, they tend prefer wetlands with heavy stands of emergent aquatic vegetation along the shoreline (Brisbin and Mowbray 2002). American Coot diet is diverse, but aquatic vascular plants and algae dominate, principally pond-weeds (*Potamogeton*, *Najas*, *Ruppia*), non-grass graminoids (*Eleocharis*, *Scirpus*, *Cyperus*, *Carex*), algae (*Chara*, *Nitella*, and filamentous forms), and wild and domestic grasses. Other terrestrial vegetation, grains, aquatic invertebrates (molluscs, crustaceans, insects and their larvae) and vertebrates (fish, tadpoles, even some carrion) are also eaten.

Responses to Options: Differences in response among waterfowl species are expected to be a consequence of differences in the aquatic vegetation or habitat structure among options, differences in the forage base (invertebrates or fishes) resulting from changes in aquatic vegetation and habitat structure, or some combination of these.

The Managed Lake Option is not expected to differ substantially from the Status Quo Option for these species except where these two options differ in terms of floating aquatic vegetation and water clarity. If the amount of floating aquatic vegetation is reduced, we expect a negative response by of species foraging on or in that vegetation (i.e., American Widgeon, Gadwall, Lesser Scaup, Ruddy Duck, and American Coot). Similarly, increased water clarity may assist waterfowl that actively forage on fish or selected invertebrates, resulting in some increased use (i.e., both merganser species, but especially Common Merganser because of its near-exclusive freshwater focus).

We expect that both estuarine options will result in negative responses by several waterfowl species. The negative response is due to some reduction of submergent or floating aquatic vegetation beds and an increase in the spatial extent of the high salinity prism. In particular, we antipate that American Widgeon, Gadwall, Lesser Scaup, Ruddy Duck, and American Coot habitat will be reduced. In contrast, we expect positive responses from both scoters, Bufflehead, and Common Goldeneye because of an increase in sandy substrates supporting bivalves (scoter food) and incremental increases in shallow-water habitat harboring small crusteaceans and molluscs (Bufflehead and Common Goldeneye food). The Estuary and Dual Basin Options provide similar scoter habitat since both options have similar amounts of sandy substrates. That is, relative to the Estuary option, the Reflecting Pool will reduce the area of mudflat but not sandflat. Habitat for Bufflehead and Common Goldeneye may be incrementally reduced under the Dual Basin Option relative to the Estuary Option due to presence of the Reflection Pool, but this condition is uncertain.

Habitat generalist species (e.g., Northern Pintail, Mallard, Barrow's Goldeneye) that can use freshwater and marine habitats are not expected to differ among options.

3.1.1.3 Fishes

We discuss fish in anadromous, freshwater, and marine groupings separately. Some fish species with alternative life history strategies are treated in more than one grouping (e.g., resident versus sea-run Cutthroat Trout [*Oncorhynchus clarki*], anadromous versus freshwater Three-spined Stickleback [*Gasterosteus aculeatus*]).

3.1.1.3.1 Anadromous Fishes

Considerable information exists about anadromous fish species using Capitol Lake, but most data are for salmonid fishes managed for food or sport. Seven species of anadromous fishes are though to have significant habitat in the Capitol Lake area (Table 9) of which five are salmonid fishes of economic, commercial, or cultural importance.

Table 9. Anticipated responses to management options of anadromous fishes to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Three-spined Stickleback	*Gasterosteus aculeatus*	0	-	L	+*	H	++	L
Sea-run Cutthroat Trout	*Oncorhynchus clarki*	0	0	L	+*	H	+	L
Steelhead Trout	*Oncorhynchus mykiss*	0	+*	H	+*	H	++	L
Coho Salmon	*Oncorhynchus kisutch*	0	0*	H	+*	H	++	L
Chum Salmon	*Oncorhynchus keta*	0	0*	H	+*	H	++	L
Chinook Salmon (Deschutes)	*Oncorhynchus tshawytscha*	0	0*	H	+*	H	++	L
Chinook Salmon (S Puget Sound)	*Oncorhynchus tshawytscha*	0	0*	H	+*	H	+	L
Starry Flounder	*Platichthys stellatus*	0	0*	H	+*	H	++	L

Beach-seine data collected 7 July, 18 August, and 15 September 2003 from the southwest margin of Budd Inlet about 0.5 mile (0.8 kilometer) north of the 5th-Avenue Dam revealed Three-spined Stickleback, presumably the anadromous form based on the marine samples, to be the most abundant species (Steltzner 2003). Cooksey (2006) also found Three-spined Stickleback to be among the four most abundant non-salmonid fishes in the Duwamish estuary. Three-spined Sticklebacks that Entranco (1997) described from Capitol Lake did not come with data allowing their identification as the anadromous form. Anadromous and freshwater Three-spined Stickleback appear to be reproductively isolated (McPhail 1994) and available data on Three-spined Stickleback largely predate period when Capitol Lake was managed more as a freshwater lake, so how much of the anadromous form currently uses Capitol Lake is unclear.

Prior to the presence of Capitol Lake, anadromous salmonid use of the area for freshwater spawning and rearing was limited to Percival Creek, and the short reach of the Deschutes River below Tumwater Falls (Haring and Konovsky 1999). Historic use of Percival Creek was likely more extensive than the Deschutes River with Coho Salmon (*Oncorhynchus kisutch*), Chum Salmon (*Oncorhynchus keta*) and sea-run Cutthroat Trout spawning and rearing in that watershed. Smolts of marine-rearing salmonids, primarily Chinook Salmon (*Oncorhynchus tshawytscha*) and Chum Salmon (Groot and Margolis 1991), likely used the estuary.

Anadromous salmonids have had access to the upper Deschutes River since 1954 when a fish ladder was constructed around Tumwater Falls. A fish trap located at the top of this ladder is used to intercept hatchery-reared fall-run Chinook Salmon. A small number (<200) of these hatchery Chinook Salmon (<200), as well as all Chum, Coho, and Sockeye Salmon, and Steelhead and Sea-run Cutthroat Trout are released upstream. Though the Deschutes River supported a significant run of Coho Salmon and Steelhead Trout in the 1990s, these runs have declined severely over the past five years (P. Topping, pers. comm.). Since this pattern parallels declines of these species across other South Puget Sound drainages and hatcheries, the cause is more likely to be associated with conditions in South Puget Sound marine waters rather than conditions in the Deschutes River, Capitol Lake or south Budd Inlet (S. Steltzner, pers. comm.; P. Topping, pers. comm.; F. Leishner, pers. comm.). This decline of anadromous salmonids has paralleled a resurgence of resident (i.e., freshwater) Cutthroat Trout in the Deschutes River above Tumwater Falls (L. Phillips, pers. comm.). Currently, Percival Creek has a small number of spawning Chum Salmon that may be strays from much larger chum runs elsewhere in the South Puget Sound (L. Phillips, pers. comm.).

Since 1953, Chinook Salmon and Coho Salmon (various stock for both) have been planted in the upper Deschutes River and in Percival Creek; and Steelhead Trout (*Oncorhynchus mykiss*) have also been planted in the upper Deschutes River (K. Keown, pers. comm.). In the early 1960s, Percival Cove was used for open-water and net-pen rearing of fall-run Chinook Salmon, and to a lesser extent, Coho Salmon (K. Keown, pers. comm.). From 1966 to 1971, Percival Creek averaged over 3,000 adult fall-run Chinook Salmon (WDF 1973). This number was likely enhanced by the Percival Cove net-pen rearing since by the mid-1970s, more than a million fall-run Chinook yearlings and 12 million fingerlings were released from this facility. Wild Coho and Chum Salmon continued to utilize Percival Creek as well (WDF 1973).

Operation of the Percival Cove rearing pens stopped in spring 2007. As a result, one of the primary current uses of Capitol Lake by anadromous salmonids is as a migratory conduit to and from the Deschutes River (including the Tumwater Falls acclimation and trap facility) and Percival Creek. Some juvenile rearing, especially of Chinook and Chum Salmon, likely occurs in the lake outside the summer time period, however, no systematic effort has been made to document this pattern. Juvenile Chinook Salmon released from the Tumwater Falls facility appear to rear for 6-10 days in Capitol Lake in spring (Steltzner 2007). High water temperatures are likely to limit summertime rearing in Capitol Lake, but this pattern is also undocumented.

Starry Flounder (*Platichthys stellatus*) is an anadromous species that was recorded during the fish surveys conducted during the 1996 drawdown of Capitol Lake, but was not observed during the 1997 drawdown surveys (Entranco 1997). As a bottom-dwelling flatfish, Starry Flounder eats predominantly benthic organisms such as worms and clams (Orcutt 1950, Horton 1989), and, is especially vulnerable to exposure to contaminants (Spies and Rice 1988, Stehr et al. 1998). In Puget Sound, flatfish, among them Starry Flounder, display a range of biological effects due to chemical contaminant exposure, including reproductive dysfunction, depressed immune function, and development of toxicopathic diseases; some evidence exists that flatfish from urban areas of Puget Sound have reduced survival as a consequence of increased infectious and toxicopathic diseases (Johnson et al. 1998). Despite its bottom-dwelling habit, it is vulnerable to predation by Osprey in water with adequate transparency (Swenson 1979), which may reflect its inshore movement behavior, often into very shallow water during the summer, whereas Starry Flounder move into deeper water in the winter (Horton 1989). Adults spawn at the freshwater interface in the upper estuary, often at or near the first riffles leading into the estuary (Orcutt 1950, Horton 1989), and disproportionate upper estuary use exists when all life stages are considered (Rooper et al. 2006). Cooksey (2004) found Starry Flounder to be one of the four most abundant non-salmonid fishes in the Duwamish estuary. Lack of data prevents understanding the status of Starry Flounder under the current largely freshwater lake conditions in Capitol Lake.

Responses to Options: We anticipated small differences between the Manage Lake Option and current conditions (Status Quo Option) for the balance of anadromous fishes, but the basis of these differences is mix of factors that both favor and disfavor anadromous fishes. If high temperatures limit the area of rearing habitat for juvenile salmon, deeper water could increase the area of cool water refuges. However, incrementally improved visibility resulting from reduced turbidity and less development of vegetation that may occur with deeper water could also improve habitat conditions for large predatory fish such as Northern Pikeminnow (*Ptychocheilus oregonensis*), Smallmouth Bass (*Micropterus dolomieu*) and Largemouth Bass (*Micropterus salmoides*), and fish-eating birds such as Double-crested Cormorant, Common Merganser, Common Loon, and Caspian Terns, all of which now occur in Capitol Lake and all of which are known predators on juvenile salmon (Munro and Clemens 1932, Beamesderfer et al. 1996, Collis et al. 2002, Bonar et al. 2005, Evers 2007). Similarly, increased transparency may favor greater visibility that could enhance Osprey predation on Starry Flounder (Swenson 1979), but the greater depth over much of the lake may limit Osprey predation on this bottom-dweller. A deeper lake is likely to improve hypoxic conditions that occur locally in Capitol Lake, especially during summer in low flow years during Three-spined Stickleback mortality events (Roberts et al. 2004). Salmonids encountering prolonged hypoxic conditions may sustain sublethal effects like reduced reproductive success (Karna 2003). A deeper lake will result in longer summer water residence time, but that this effect may have on rearing salmonids is also unclear. It has the potential to increase the migration interval by a small increment, but this effect may not be significant given the relatively small size of Capitol Lake. However, rearing salmonids may intentionally increase their residence time in Capitol Lake if the deeper lake provides more favorable food resources coupled with more favorable temperatures; Chinook Salmon migrated most rapidly in low discharge years associated with higher temperatures and most rapidly within years as water temperatures increased (Keefer et al. 2004). This pattern is unpredictable because at least one tradeoff may exist between increasing residence time to foraging on a more favorable resource base and exposure to a potentially increased levels of predation, a pattern also has the potential to be influenced by the relative risk of predation in the lake and the adjacent marine system (i.e., whether predation risk in the lake is greater or lesser than in the adjacent marine system). We view the 5th-Avenue Dam as having a neutral effect on all anadromous fishes because the condition of the dam would not differ between these two options, it would be present in both cases and unmodified in the Managed Lake Option. Given the complexity of competing conditions, we cannot confidently score anadromous fish response under the Managed Lake Option as different from the Status Quo Option. In scoring these two options the same, we recognize a high degree of uncertainty.

The focal difference between both estuarine options and the Status Quo Option is removal of the 5th-Avenue Dam that will restore a fair semblance of the estuarine tidal flux. We expect a positive response by the balance of anadromous fishes as a consequence of the 5th-Avenue Dam removal. This positive response is expected because of a combination of factors including: 1) the elimination of the bottleneck (expected to reduce predator levels on anadromous fishes by fish-eating birds, fishes, and mammals[5], and facilitate passage of anadromous fishes during their entry for spawning, exit from spawning [Starry Flounder and Three-spined Stickleback only[6]], and exit of juveniles); 2) restoration of the mobility of the salt wedge over something approaching its potential reach (expected to improve rearing conditions for juveniles and also facilitate passage during the life-stage specific entries and exits of the difference anadromous species mentioned above); and 3) restoring a saline prism to a significant area of the previous Capitol Lake footprint (expected to contribute to improving foraging conditions through elimination of the freshwater vegetation biomass, and reduction of predation by birds, fishes, and mammals associated with freshwater conditions). However, this reduction in predation may be replaced by an increase in predation by marine-based predators. We also expect that water quality for the life stages of anadromous species will be improved and that anadromous species will be exposed to fewer conditions where contaminants and toxins may be concentrated, though some degree of uncertainty exists about the latter effect.

We expect the Estuary Option to perform slightly better than the Dual Basin Option based uncertainty about the pattern of mobility for anadromous fishes in and out of the Reflection

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[5] An estuary with continuous tidally driven changes in the salt wedge will require predators to constantly refocus their search for new prey concentrations rather than congregating at a migratory bottleneck for extended periods.

[6] Unlike the salmon species in this system, which are semelparous (i.e., die after breeding once) and hence have no exist migration of adults, both Starry Flounder and Three-spined Stickleback can breed more than once.

Pool to allow it to serve as potential foraging and rearing habitat. Uncertainty exists here because of the mobility through flap tide gates.

3.1.1.3.2 Freshwater Fishes

Limited information exists on the freshwater fish fauna of Capitol Lake. Most data available was obtained during fish stranding and electroshocking surveys completed as an approval condition for the Hydraulic Project Application to conduct drawdowns of Capitol Lake in 1996 and 1997 (Entranco 1997). The rest are scattered records from the WDFW database. The 1996-1997 drawdown surveys were spatially (South Basin and Percival Cove only) and temporally restricted (22 July-3 August 1996; 22-25 July 1997) and remaining records are few, so available data may underestimate the current species composition of freshwater fish in Capitol Lake. Historically, summer drawdowns of Capitol Lake stranded thousands of freshwater fish, mostly three-spined stickleback, speckled dace, common carp and sculpins (J. Fraser, pers. comm.), but an unknown number of freshwater fish may have also been displaced into marine waters during these drawdowns.

Sixteen freshwater fish species may have a significant presence in Capitol Lake (Table 10). Of these 16, six are introduced species (Brown Bullhead [*Ameiurus nebulosus*], Common Carp [*Cyprinus carpio*], Largemouth Bass [*Micropterus salmoides*], Smallmouth Bass [*Micropterus dolomieu*], Rainbow Trout [*Oncorhynchus mykiss*], and Yellow Perch [*Perca flavescens*]) that probably entered Capitol Lake at least in part through the Black Lake Ditch from Black Lake (S. Jackson, pers. comm.)[7]. Rainbow Trout in Capitol Lake may have originated in part from this pathway, but thousands of small Rainbow Trout being recorded from Capitol Lake during gillnet surveys in 1955 (Engstrom-Heg 1955) probably also reflect early stocking efforts. At least some of the failed stocking efforts of Rainbow Trout in Capitol Lake also occurred as recently as the mid-1990s (S. Jackson, pers. comm.). All six species occur in Black Lake, and both basses and the Rainbow Trout were and continue to be the focus of WDFW fish management efforts there (Jackson and Caromile 1999; S. Jackson, pers. comm.). Black Lake Ditch, which is connected to the north end of Black Lake, flows into Percival Creek, hence into Capitol Lake. The ditch, constructed in the 1920s to drain marshland for agriculture, now drains excess water from Black Lake, providing a movement pathway. Currently, no stocking targeting non-salmonid freshwater fishes exists in Capital Lake (S. Jackson, pers. comm.; L. Phillips, pers. comm.).

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[7] A seventh introduced species, Pumpkinseed (*Lepomis gibbosus*) may also have entered Capitol Lake via the Black Lake Drainage Ditch, but this species was obtained in very low numbers in 1955 (Engstrom-Heg 1955) and was rare in Black Lake in 1999 (Jackson and Caromile 1999) , so we did not consider it here.

Table 10. Anticipated responses to management options of freshwater fishes to management options for Capitol Lake. Species indicated by an E are exotics. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Cutthroat trout	*Oncorhynchus clarki*	0	0	L	--*	H	--	L
Rainbow trout	*Oncorhynchus mykiss*	0	+	L	--*	H	--	L
Common Carp (E)	*Cyprinus carpio*	0	0	L	--*	H	--	L
Peamouth	*Mylocheilus caurinus*	0	0	L	--*	H	--	L
Northern Pikeminnow	*Ptychocheilus oregonensis*	0	+	L	--*	H	--	L
Speckled dace	*Rhinichthys osculus*	0	0	L	--*	H	--	L
Redside Shiner	*Richardsonius balteatus*	0	0	L	--*	H	--	L
Largescale Sucker	*Catostomus macrocheilus*	0	0	L	--*	H	--	L
Brown Bullhead (E)	*Ameiurus nebulosus*	0	0	L	--*	H	--	L
Three-spined Stickleback	*Gasterosteus aculeatus*	0	+	L	--*	H	--	L
Smallmouth Bass (E)	*Micropterus dolomieu*	0	0	L	--*	H	--	L
Largemouth Bass (E)	*Micropterus salmoides*	0	+	L	--*	H	--	L
Yellow Perch (E)	*Perca falvescens*	0	0	L	--*	H	--	L
Prickly Sculpin	*Cottus asper*	0	0	L	-	H	--	L
Riffle Sculpin	*Cottus gulosus*	0	0	L	-*	H	-*	H
Western Brook Lamprey	*Lampetra richardsoni*	0	0	L	--	L	--	L

All these introduced species have documented or suspected undesirable direct or indirect effects, either on segments of the native fauna, aquatic habitats, or some combination of both. Predation by introduced catfish, such as Brown Bullhead, can negatively affect native benthic fish and macroinvertebrate populations (Hendricks 1998, Yamamoto and Tagawa 2000). Common Carp have deleterious effects on aquatic habitats because their benthic grubbing suspends fine sediments and can dislodge rooted aquatic vegetation, often increasing biological oxygen demand and depressing oxygen levels, conditions to which Common Carp are more tolerant than many other aquatic organisms (Wydoski and Whitney 2003). Further, increased turbidity and nutrient loading resulting from Common Carp activity can reduce total zooplankton biomass (Lougheed et al. 1998) that may affect planktivores in the food web. Largemouth Bass are significant predators of out-migrating juvenile Coho Salmon (Bonar et. al. 2005). Smallmouth Bass are significant predators on native amphibians, and where they co-occur with American Bullfrogs, can promote American Bullfrog survival at the expense of native amphibians (Kiesecker and Blaustein 1998). Rainbow Trout have been demonstrated to facilitate the rate of transfer of a pathogen lethal to native amphibian embryos (Kiesecker et al. 2001). Yellow Perch are thought to negatively affect reservoir-inhabiting native trout populations (Mende et al. 1993).

Cutthroat Trout are common in the Deschutes watershed and selected individuals from this population likely come down over the Tumwater Falls to rear in Capitol Lake. Cutthroat Trout in the Deschutes River originate either from the population that was historically present there or the planting of non-anadromous by the Washington Department of Fisheries (the precursor to WDFW) that began in 1933. Engstrom-Heg (1955) recorded moderate numbers of Cutthroat Trout in Capitol Lake during gillnet surveys in 1955. Cutthroat Trout are also present in Percival Creek. Freshwater-dwelling Cutthroat Trout show a marked shift from an invertebrate-dominated to a small fish-dominated diet with increasing size (Nowak et al. 2004). The pattern of freshwater (resident) Cutthroat Trout use of Capitol Lake is unknown, but based on studies in Lake Washington and elsewhere, we would anticipate significant partitioning between smaller versus larger fish, respectively, between the littoral and limnetic zones of the lake (Nowak et al. 2004) and a diet potentially heavily focused on Three-spined Stickleback (Reimchen 1990).

Peamouth (*Mylocheilus caurinus*), one of the few native minnows that tolerates saltwater, occupies both lake and stream habitats (Wydoski and Whitney 2003). Young Peamouth feed on zooplankton and the smallest instars of aquatic insect larvae, and older animals add larger aquatic insect instars, snails, and larvae or juveniles of small fishes, like sculpins (Wydoski and Whitney 2003). A large part of the Peamouth diet in Lake Washington in spring and summer was midge pupae. Spawning occurs in streams or along lake margins on gravel substrates. Peamouth were observed in moderate numbers in the lake portion of the South Basin in Capitol Lake during the 1997 drawdown, but not during the 1996 drawdown (Entranco 1997).

Northern Pikeminnow (*Ptychocheilus oregonensis*), the largest native minnow in the Pacific Northwest, inhabits lakes and relatively low flow habitats in streams, where use habitats that often have the highest local water temperatures (Wydoski and Whitney 2003). This habitat utilization results in Northern Pikeminnow moving to shallows or the pelagic zone of lakes where water is similarly warm in summer. Small Northern Pikeminnow (≤ 10 inches [25 centimeters] long) eat primarily (> 90%) insects, but shift to fish with increasing size. Large

(> 14 inches [36 centimeters] long) Northern Pikeminnow eat 60% fish, and being highly opportunitistic, that diet is diverse (Wydoski and Whitney 2003). Northern Pikeminnow are important predators on salmonid fishes, and can comprise over 90% of their diet during juvenile salmon out-migration intervals (Beamesderfer et al. 1996). The current seasonal temperature profile in Capitol Lake would generally favors Northern Pikeminnow.

Speckled Dace (*Rhinichthys osculus*), a small widespread minnow species, is a habitat generalist (Wydoski and Whitney 2003). Thought it typically inhabits cooler stream waters with currents ranging from slow to swift, it sometimes occurs in lakes. Spawning occurs in rocky riffles. Juveniles feed primarily on zooplankton, whereas adults add aquatic insects, freshwater shrimp, and plant material to the diet (Wydoski and Whitney 2003). Detritus sometimes represents over 50% of the diet (Johnson 1985). Speckled Dace were observed in moderate numbers during the 1997 drawdown surveys in Capitol Lake, but were not detected during the 1996 drawdown surveys (Entranco 1997).

Redside Shiner (*Richardsonius balteatus*) is a small habitat generalist minnow (Wydoski and Whitney 2003). Redside Shiner have been recorded in diverse aquatic habitat types with slow to moderate flow, including large rivers, streams, springs, sloughs, irrigation ditches, ponds, and lakes that usually have water temperatures in the range 55-68°F (12.8-20.0°C). Redside Shiner fry feed on zooplankton and algae, whereas adults feed mostly on insects and snails when in shallow water, and on zooplankton in the water column when in deep water (Wydoski and Whitney 2003). Redside Shiner was common based on gillnetting in Capitol Lake in 1955 (Engstrom-Heg 1995).

Largescale Sucker (*Catostomus macrocheilus*) occupy both lakes and streams, but they are frequently abundant at the mouths of streams entering lakes (Wydoski and Whitney 2003). Largescale Sucker fry eat small zooplankton from near the surface or mid-water, whereas larger fish become bottom dwellers where they increasingly focus on periphyton algae as they increase in size (Wydoski and Whitney 2003). Large Largescale Sucker supplement their diet with diverse bottom organisms, including crustaceans, aquatic insect larvae, annelid worms, and snails as well as detritus. Based on gillnetting in Capitol Lake in 1955 (Engstrom-Heg 1995), Largescale Sucker was common; it was also observed during drawdown surveys of Capitol Lake in both 1996 and 1997 (Entranco 1997).

Several sources have emphasized the overwhelming abundance of Three-spined Stickleback in Capitol Lake and nearby Budd Inlet (Engstrom-Heg, 1955, Entranco 1997; P. Topping, pers. comm.; L. Phillips, pers. comm.). What proportion of the stickleback in Capitol Lake is anadromous versus freshwater resident is unknown, but for this assessment, we assume that some proportion of the Three-spined Sticklebacks that occur in Capitol Lake are the freshwater resident form. Three-spined Stickleback have morphotypes associated with pelagic and benthic feeding modes, and their diet ranges from a predominance of planktonic microcrustaceans (e.g., *Bosmina*, *Daphnia*, *Diaptomus*) for the pelagic morphotype to microsnails, gammarid amphipods, and other benthic or epiphytic microinvertebrates for the benthic morphotype (Hart and Gill 1994).

Prickly Sculpin (*Cottus asper*) are moderate-sized, cryptic bottom-dwelling fishes that typically inhabit lakes and the pools and quiet areas of large coastal streams (Wydoski and Whitney 2003). They can tolerate salinity at least as high as $24^{o}/_{oo}$, which is higher than tolerated by most other typically freshwater sculpin, hence their relative greater abundance of Prickly Sculpin in some estuaries. Like many sculpins, Prickly Sculpin generally sit immobile on the benthic substrate, typically consisting of sand, gravel, or rubble, though juvenile Prickly Sculpin frequently conceal themselves amongst rooted vegetation (Wydoski and Whitney 2003). Prickly Sculpin fry are pelagic or planktonic for a brief interval, during which time they eat plankton and the early instars of drifting emergent aquatic insects. In contrast, juvenile and adult Prickly Sculpin feed on fish eggs and small juvenile fish of many species, including the fry of conspecifics, Redside Shiner, Three-spined Stickleback, Yellow Perch, and Chinook Salmon (Wydoski and Whitney 2003). Based on gillnet surveys, Prickly Sculpin were moderately common in Capitol Lake in 1955 (Engstrom-Heg 1955). Prickly Sculpin were not specifically identified during the 1996-1997 drawdown surveys for fish in Capitol Lake (Entranco 1997), but most of the sculpin found were probably this species because Capitol Lake conditions approach Prickly Sculpin habitat requirements more closely than that of the other local native sculpins.

Riffle Sculpin (*Cottus gulosus*) are small, cryptic bottom-dwelling fishes that typically inhabit the quiet waters and slow riffles of small streams, generally on sand or gravel substrates (Wydoski and Whitney 2003). Though typically in freshwater habitat, Riffle Sculpin are also reported to tolerate salinity about half that of seawater (~$16^{o}/_{oo}$). Riffle Sculpin eat gammarid amphipods, isopods, aquatic insect larvae, and snails; smaller animals eat more crustaceans and larger ones eat more insects and snails (Wydoski and Whitney 2003). Though Riffle Sculpin were not specifically identified during the 1996-1997 drawdown surveys for fish in Capitol Lake (Entranco 1997), based on habitat requirements, some of the sculpin found may have been this species.

Western Brook Lamprey (*Lampetra richardsoni*) is the only lamprey species that typically spends its entire life in freshwater (Wydoski and Whitney 2003). Adults are non-feeding and only ammocoetes (the larvae stage) feed by filtering detritus of its microscopic plant and animal matter. Western Brook Lamprey were identified during the 1996-1997 drawdown surveys for fish in Capitol Lake (Entranco 1997); based on habitat requirements and the sizes of the six individuals found, they may have been larvae.

Responses to Options: Species composition under the Managed Lake Option is not anticipated to differ from the Status Quo Option. However, somewhat improved water quality (increased transparency and better nutrient dispersal) and decrease aquatic vegetation development may incremental favor some freshwater fishes. Uncertainty in this outcome is high because selected predators may also be favored that could cancel this gain.

Both estuarine options are anticipated to substantially reduce, or perhaps in some cases, eliminate populations of lake-dependent freshwater fish species. In the case of Three-spined Stickleback, we would expect a shift in dominance of the anadromous form over the freshwater form. What the magnitude of the change would be under the Dual Basin Option relative to the Estuary Option is uncertain because of the pattern of mobility through the flap gates in and out of the Reflection Pool. This also depends on the management approach used for the Reflection Pool, such as potential needed drawdown for tidal gate maintenance.

3.1.1.3.3 Marine Fishes

Nine marine fish species have some importance in the Capitol Lake area (Table 11). Information on marine fishes is based almost entirely on sampling that has taken place in the marine waters of Budd Inlet well after the creation of Capitol Lake.

Three species (Pacific Sand Lance [*Ammodytes hexapterus*], Shiner Perch [*Cymatogaster aggregata*], and Surf Smelt [*Hypomesus pretiosus*]) are forage fishes: fishes that school and reach high densities and strongly influence the distribution and abundance of diverse marine predators, including seabirds, marine mammals, and piscivorous fishes (Brown and Nettleship 1983; Furness and Barrett 1985; Payne et al. 1986). Major changes in forage fish populations can lead to substantial changes in predator populations, such as the reductions in seabirds, sea lions, and seals after a decline in juvenile walleye pollock (*Theragra chalcogramma*) in Alaska (Springer 1992).

Pacific Sand Lance typically lay eggs in the upper intertidal area of sandy beaches. Eggs become coated with sand, protecting them at low tide, and are tidally dispersed. Upon hatching, tides and currents move the tiny larvae until they are become large enough to school and acquire adult coloration. By day, adult Pacific Sand Lance forage in schools in open water; by night, they burrow in sand. Based on other sand lance species (Auster and Stewart 1986), Pacific Sand Lance is likely planktivorous. An important spawning area for Pacific Sand Lance has been mapped on along the East Bay portion of Budd Inlet north of Priest Point Park (WDFW 2008a, Carrasasquero-Verde et al. 2005).

Shiner Perch, common in all estuaries from San Diego (California) to Ketchikan (Alaska), enter shallow brackish (> 5‰) water to birth live young. Juveniles typically move into less brackish water (0.5-5.0‰) through the summer, and juveniles and adults migrate to deeper marine water to winter (Cooksey 2006). Shiner Perch have a diverse diet that typically includes algae, polychaete worms, copepods, gammarid amphipods, and other crustaceans that are picked mostly off the bottom (Cooksey 2006). Shiner Perch were the most frequently recorded fish species at three of the four points in the 2003 Beach Seine Nearshore Surveys in Budd Inlet, and were especially abundant at the Butler Cover and Gull Harbor stations (Stelzner 2003), and are frequently the most visible fish in large schools below the 5th-Avenue Dam (R. Buckley, pers. comm.; M. Hayes, pers. obs.). Cooksey (2006) found Shiner Perch to be among the four most often recorded non-salmonid fishes in the Duwamish estuary, and Anderson and Chew (1972) and Rodgers (2002) found it to be the most frequently recorded species, respectively, in Big Beef Harbor (eastern margin of Hood Canal) and North Griffin Bay (San Juan Island).

Surf Smelt lay adhesive eggs in shallow water along beaches with a mixture of coarse sand and pea gravel (WDFW 2008b). Tidal exchange typically buries the sand-weighted eggs a few millimeters below the surface. Breeding can occur year-round, and juveniles rear in near-shore waters. Adult Surf Smelt, which seem to display a degree of homing to spawning grounds, feed mostly on plankton. Much of the Budd Inlet margin was Surf Smelt spawning grounds (WDFW 2008b), but recent data suggest loss of spawning area due shoreline armoring (Carrasasquero et al. 2005). Stelzner (2003) recorded Surf Smelt at Butler Cove.

Arrow Goby (*Clevelandia ios*) is a small fish that is a frequent burrow associate of a number of invertebrates in the low intertidal portions of mudflats or sandy mudflats (Ricketts et al. 1985), and has a diet dominated by calanoid copepods (West et al. 2003).

Table 11. Anticipated responses to management options of marine fishes to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Pacific Sand Lance	*Ammodytes hexapterus*	0	0	L	+*	H	++	L
Shiner Perch	*Cymatogaster aggregata*	0	0	L	+*	H	++	L
Surf Smelt	*Hypomesus pretiosus*	0	0	L	+*	H	++	L
Arrow Goby	*Clevelandia ios*	0	0	L	+*	H	++	L
Pile Perch	*Rhacochilus vacca*	0	0	L	+*	H	+	L
Bay Pipefish	*Syngnathus griseolineatus*	0	0	L	+*	H	+	L
Staghorn Sculpin	*Leptocottus armatus*	0	0	L	+*	H	+	L
Tidepool Sculpin	*Oligocottus maculosus*	0	0	L	+*	H	+	L
Sand Sole	*Psettichthys melanostictus*	0	0	L	+*	H	+	L
Speckled Sand Dab	*Citharichthys stigmaeus*	0	0	L	+*	H	+	L

Pile Perch (*Rhacochilus vacca*), a common species that typically occurs along kelp-laden rocky shores, also occurs in developed estuaries around pilings and underwater structures, where they feed on crabs, barnacles, and hard-shelled mollusks (Eschmeyer et al. 1983). Pile Perch was the eighth most frequently recorded of 52 trawl-collected fish species from Yaquina Bay, Oregon (De Ben 1990).

Bay Pipefish (*Syngnathus griseolineatus*) are a shallow subtidal-dwelling species; in Griffin Bay (San Juan Island), where it was among the four most abundant species taken by otter trawl, it was recorded exclusively between 5 and 10 meters (16 and 33 feet) of depth (Rodgers 2002). Bay Pipefish were recorded in modest numbers (1-25) at three of the four points in the 2003 Beach Seine Nearshore Surveys in Budd Inlet (Stelzner 2003).

Pacific Staghorn Sculpin (*Leptocottus armatus*), common estuarine fish throughout the Pacific Coast, lay eggs in winter in moderate to high salinity water. Pelagic larvae metamorphose to benthic juveniles that exhibit a wide range of temperature (10-25°C) and salinity (0.0-67.5‰) tolerance, and move into freshwater in spring (Cooksey 2006). A general movement back to salt water occurs as they grow, but some Pacific Staghorn Sculpin spend their entire lives in the brackish/freshwater estuary. Pacific Staghorn Sculpin eat epibenthic crustaceans and polychaete worms as juveniles, adding fishes to the diet with increasing size (Smith 1980, Cooksey 2006). Cooksey (2006) found Pacific Staghorn Sculpin to be among the four most abundant non-salmonid fishes in the Duwamish estuary. Pacific Staghorn Sculpin were recorded in modest numbers (6-35) at three of the four points in the 2003 Beach Seine Nearshore Surveys in Budd Inlet (Stelzner 2003).

Tidepool Sculpin (*Oligocottus maculosus*) is a resident intertidal species that is found in sheltered areas, and is common in tide pools (Eschmeyer et al. 1983). Tidepool Sculpin tend to return to their home pool when displaced, and are capable of breathing air when out of water (Green 1971). Diet consists of small invertebrates, primarily gammarid amphipods and isopods (Cross 1981).

Sand Sole (*Psettichthys melanostictus*) is a medium-sized bottom-dwelling flatfish that makes significant use of the lower main channels of estuaries (Rooper et al. 2006), which are typically sandy, under conditions that are at least mesohaline ($5^{o}/_{oo}$) in salinity (Haertel and Osterberg 1967). Sand sole seem infrequent in the shallow nearshore (Toft et al. 2004). As small juveniles, sand sole consumes primarily invertebrates, such as very small Pacific Geoduck Clams (*Panopea abrupta*; Goodwin and Pease 1989), but they rapidly switch to a fish-dominated as they increase in size (Haertel and Osterberg 1967).

Speckled Sand Dab (*Citharichthys stigmaeus*) is another medium-sized bottom-dwelling flatfish that immigrates as a juveniles from deeper waters into deep intertidal and shallow subtidal sandy habitats (Yoklavich et al. 1991). Speckled Sand Dabs consume epifaunal crustaceans (Barry et al. 1996) and sand-buried infauna and sometimes have commensal relationships with other fishes, such as selected ray species, that flush infauna into the water column through their digging activities (VanBlaricom 1982).

Responses to Options: We anticipate no major difference in marine fish response to the Managed Lake Option relative to the Status Quo Option. Incremental improvements in freshwater quality that may result in the Managed Lake Option may indirectly result in minor benefits to marine fishes in the former option, but these are unlikely to be significant.

We expect a benefit for marine fishes under both estuarine options as a consequence of the increased area of habitat under a marine/estuarine influence, though the extent of that benefit is expected to vary among marine fish species. For example, we expect a potential greater benefit to shallow nearshore-foraging Shiner Perch than to shallow subtidal-dwelling Bay Pipefish or lower estuary main channel-using Sand Sole because removal of the 5th-Avenue Dam is anticipated to result in relatively limited shallow subtidal area with the appropriate sheltering habitat structure for Bay Pipefish and similarly have little area characterizable as lower estuary main. We expect that the shallow subtidal area will be mostly sandy channel that sustains relatively high water velocities (Garono et al. 2006). We further expect that marine fish will benefit from greater estuarine water exchange with a salt wedge operating continuously over its full spatial range. We expect that this benefit will 1) contribute to reducing predation on marine fishes because they will not concentrate at one location when the dam is removed, 2) improve accessibility to food resources because of the constant redistribution of particulates and small organisms at the wedge interface, and better tidal flushing of contaminants and better nutrient mixing through much of the Budd Inlet water column. We also expect that the improvement in area of spawning habitat will not be substantial because dam removal will expose mostly mudflat, which has substrate too fine for direct substrate spawners like Pacific Sand Lance and Surf Smelt. However, both dredging needed to remove accumulated substrate from Capitol Lake as part of the Dam removal restoration (depending on the dredging profile) and the greater volume of tidal flushing may somewhat coarsen substrates and improve spawning habitats somewhat in West Bay area (G. Bargmann, pers. comm.).

Considerable uncertainty exists as to whether the Dual Basin Option will be approximately equivalent to the Estuary Option for marine fishes. That uncertainty is based on marine fish mobility through the flap gates and management addressing the Reflection Pool.

3.1.1.4 Mammals

No formal surveys for mammals have been conducted on Capitol Lake (R. Beach, pers. comm.; D. Martorello, pers. comm.); and except for some bats, available data are anecdotal. Eleven species of mammals have been recorded that make significant use of the aquatic footprint of the Capitol Lake area.

3.1.1.4.1 Aquatic Mammals

Five aquatic or semi-aquatic mammal species make significant use of the Capitol Lake area (Table 12). Two are grazers; three are carnivores.

Among the grazers, one, the Nutria or Coypu (*Myocastor coypus*) is an exotic that was historically introduced to North America for furbearer culture (Carter and Leonard 2002). In Washington, Nutria were imported in the late 1930s and early 1940s, and feral animals were reported as early as 1941 (Larrison 1943). The species now maintains itself in the wild (Deems and Pursley 1978) and appears to be expanding (Bounds 2000). In many aquatic systems, Nutria have become a nuisance because their feeding activity destroys marsh vegetation, their burrows undermine water management infrastructure, and they feed on agricultural crops (Litjens 1980). Nutria also have been associated with parasites that affect humans and livestock (Moutou 1997) and can adversely affect other wildlife (Gebhardt 1996). Nutria were recorded in Capitol Lake in 1975 (Entranco 1997), but lack

Table 12. Anticipated responses of aquatic or semi-aquatic mammals to management options for Capitol Lake. Species indicated by an E are exotics. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Nutria (E)	*Myocaster coypus*	0	0	L	--	L	--	L
Muskrat	*Ondatra zibethicus*	0	0	L	--	L	--	L
Northern River Otter	*Lontra canadensis*	0	+*	H	0	L	0	L
Mink	*Mustela vison*	0	0	L	0	L	0	L
Raccoon	*Procyon lotor*	0	0	L	0	L	0	L

of data prevents understand whether they remain in Capitol Lake or Capitol Lake harbors resident individuals.

Muskrat (*Ondatra zibethica*) occupies freshwater habitats with emergent vegetation (Allen and Hoffman 1984). Muskrats graze preferentially on selected aquatic plants, especially cattails (*Typha* spp.; Mirka et al. 1996), which seems to be due to the combined high assimilation efficiency and nutritional return of this plant food relative to alternatives (Campbell and MacArthur 1994). Animal tissue, such as freshwater clams, is also eaten and it can contribute positively to Muskrat diet (Neves and Odum 1989, Campbell and MacArthur 1996). As with Nutria, Muskrats were recorded in Capitol Lake in 1975 (Entranco 1997), but we do not if they remain there.

No research has addressed the aquatic or semi-aquatic carnivores, Mink [*Mustela vison*], Raccoon [*Procyon lotor*], and River Otter [*Lontra canadensis*], all of which are known to use Capitol Lake, specifically within the Capitol Lake area (D. Martorello, pers. comm.), and the few Capitol-Lake specific data come entirely from nuisance trapping efforts or the WDFW database. Sign of all three of these carnivores was observed during the 1996-1997 drawdown surveys (Entranco 1997).

Mink are medium-sized carnivores that forage in and along aquatic habitats and take a diversity of aquatic prey, including aquatic birds, crayfishes, various fishes, frogs, Muskrat and other small mammals, and large aquatic insects (Errington 1954, Korschgen 1958, Burgess and Bider 1980). Though Mink use a diversity of aquatic, estuarine, and marine nearshore habitats (Burgess and Bider 1980, Ben-David et al. 1996), habitat use by selected prey species, such as selected waterfowl, can often explain as much about their habitat use patterns as any physical variables (Arnold and Fritzell 1990). In estuarine and marine environments, Mink use shoreline habitats that are less exposed (associated with more overstory cover) and have less wave action than generally available (Ben-David et al. 1996).

Raccoon are medium-sized carnivores that are highly generalized both in diet and patterns of habitat use (Hoffmann and Gottschang 1977, Glueck et al. 1988, Pedlar et al. 1997, Chamberlain et al. 2003). Despite this generalization in diet and habitat use, Raccoon tend to forage along the margins of aquatic habitats, which may reflect the greater availability of food resources in those habitats than nearby alternatives.

River Otter are medium-sized aquatic carnivores that forage in and along aquatic, estuarine, and marine nearshore habitats (Ben-David et al. 1996) and favor selected aquatic prey. Though similar to mink in that they are capable a taking a diversity of aquatic prey, including larger animals, such as turtles; various fishes and crayfishes appear to be preferentially preyed upon (Melquist et al. 1981). Unlike Mink, foraging directly in water and in relatively deep water is more frequent (Melquist et al. 1981), and in estuarine and marine nearshore situations, habitats that are more exposed and that tend to have greater wave action are used (Ben-David et al. 1996).

Responses to Options: We anticipate that aquatic or semi-aquatic mammals will generally experience little change under the Managed Lake Option (relative to the Status Quo Option). River Otter may experience somewhat better foraging conditions, but this outcome is quite uncertain.

In contrast, we expect aquatic mammals linked to freshwater (Muskrat and Nutria) to sustain a reduction in useable habitat under the two estuarine options that is estimated to encompass the roughly two-thirds of the area of Capitol Lake that includes the North Basin and most of the Middle Basin. Whether this reduction would eliminate either species from the area is unclear. In contrast, the three carnivores (Mink, Raccoon, and River Otter) are generalist enough in their behavior and foraging patterns that the switch to estuarine conditions is unlikely to significantly affect any of them. For these species, the difference between the Estuary and Dual Basin Options are insignificant.

3.1.1.4.2 Bats

Available information on bats is almost entirely from surveys and telemetry of the Yuma Myotis (*Myotis yumanensis*) and the Little Brown Bat (*Myotis lucifugus*) conducted by Greg Falxa and his assistants on Capitol Lake in the interval 2003 to 2007, with selected work continued to the present (Falxa 2007; G. Falxa, pers. comm.). This work has documented four species of bats using Capitol Lake (Table 13). Besides the Yuma Myotis and Little Brown Bat, Falxa and colleagues have also documented Big Brown Bats (*Eptesicus fuscus*) and Silver-haired bats (*Lasionycteris noctivagans*) foraging over Capitol Lake, and three other bat species have been detected on Capitol Lake (Appendix I). Herrera (2004) addressed bats at Capitol Lake, but their discussion was based entirely on potential species present and one species listed, the Western Small-footed Myotis (*Myotis ciliolabrum*), is not known to occur in western Washington (G. Falxa, pers. comm.).

Falxa (2007; G. Falxa, pers. comm.) has found that Capitol Lake is extensively utilized by Little Brown Bats and Yuma Myotises. Both species have been radio-tagged from large breeding colonies located at Woodard Bay (>3,000 individuals) and at the Evergreen State College (>500 individuals), so they travel 8-14 kilometers to forage on Capitol Lake. The Yuma Myotis colony at Woodard Bay, the largest known bat colony in Washington State (J. Olmstead, pers. comm.), must be viewed in perspective of the limited effort that has been undertaken to survey for Yuma Myotis statewide (G. Falxa, G. Hayes, pers. comm.). Yuma Bats do not appear to use lakes and ponds more proximate to their colonies, and these wetlands may not provide adequate resources (insect production, lake size), though surveys of all potentially utilizable lakes and ponds have not been done. These two bat species, but especially the Yuma Myotis, are dependent on aquatic insects, typically metamorphosing individuals of volant insects that emerge from the water surface. The stillwater nature of the existing Capitol Lake surface is important for echo-locating emergent insects (G. Hayes, pers. comm.). Based on their numbers in the bottom substrate, Capitol Lake appears to be a rich source of emerging volant insects (see Invertebrates section; Herrera 2004). Yuma Myotis females may be particularly dependent on Capitol Lake when rearing young because of the quantity of insects needed to maintain lactation (G. Falxa, J. Olmstead, pers. comm.).

Responses to Options: The Managed Lake Option is likely to be similar to the Status Quo Option except that the initial dredging effort may temporarily set back the insect food base, particularly if all dredging is completed in one year.

The Estuary and Dual Lake Options would likely result in a major shift over a large proportion of the Capitol Lake area (the North and much of the Middle Basins) from an insect-dominated benthos to one dominated by marine worms, crustaceans, and molluscs, and thus, produce considerably less forage invertebrates for bats. We would expect

Table 13. Anticipated responses to management options of bats to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Big Brown Bat	*Eptesicus fuscus*	0	0	L	0*	H	0*	H
Silver-haired Bat	*Lasionycteris noctivagans*	0	0	L	0*	H	0*	H
Little Brown Bat	*Myotis luciugus*	0	0	L	-*	H	-	L
Yuma Myotis	*Myotis yumanensis*	0	0	L	-	H	--	L

production of volant insects to continue in the freshwater (≤ 0.5 ppt) portions of the South and Middle Basins, but a decline in bat breeding colony numbers may occur if the existing lake is converted to an estuary. We do not anticipate differences between the Estuary and Dual Lake Options for bats because, in both cases, the entire North Basin area will be managed as saltwater.

3.1.1.4.3 Marine Mammals

Two marine mammals are seen at least over seasonally significant intervals in Budd Inlet, the Harbor Seal (*Phoca vitulina*) and California Sea Lion (*Zalophus californianus*; Table 14). Both are predators on fish and other marine organisms (Gearin et al. 1986, Everitt et al. 1981a), and both are protected under the federal 1972 Marine Mammal Act (USFWS 2008), but neither is currently listed.

Harbor Seals are regionally common residents in South Puget Sound and are especially evident near the 5th-Avenue Dam fish ladder the during the August-September fall Chinook Salmon migration, with up to 15 animals visible at once (K. Keown, pers. comm., R. Beach, pers. comm.). Based on the WDFW Seal and Sea Lion Atlas (WDFW 2008c), no haul-out sites for Harbor Seals exist in the area that Capitol Lake now occupies, but two haul-out sites where aggregations of harbor seals have been observed are historically documented in Budd Inlet. One of these sites, a shoal west of Priest Point State Park, was historically used by 2-3 animals is no longer in current use. The site documented in the Atlas that is currently used is located on the west side of Budd Inlet and is associated with a series of log booms. Additionally, small (1-3) groups of seals have been observed through haphazard observation at other points around Budd Inlet. Harbor Seals from these various haul-out sites may be some of the same individuals that visit the 5th-Avenue Dam. Overall, 30-40 Harbor Seals are thought to regularly occupy Budd Inlet (S. Jeffries, pers. comm.).

Whether Harbor Seals are attracted specifically to the availability of fall-run Chinook Salmon, and return to take a toll on the runs of Coho Salmon, Chum Salmon, and Steelhead Trout or for that matter, other marine fish at other times of the year is unclear. In general, seal abundance declines after fall-run Chinook Salmon stop running. However, seals may revisit the 5th-Avenue Dam fish ladder simply as a result of foraging nearby. Availability of readily accessible food at the 5th-Avenue Dam fish ladder may play a role in maintaining more Harbor Seals in south Budd Inlet than might otherwise be present.

California Seal Lions, intermittent visitors to Budd Inlet, are typically seen every second or third year at the 5th-Avenue Dam fish ladder (K. Keown, pers. comm.). California Sea Lions migrate seasonally to Puget Sound waters with peak numbers in winter (Everitt et al. 1980).

California Seal Lions are particularly efficient predators on salmon and other fish species (Everitt et al 1981b, Gearin et al. 1986), and have the capability of taking many adult Chinook Salmon at bottleneck like the 5th-Avenue Dam ladder. However, California Sea Lions have not returned annually to this point and do not appear to be increasing in numbers as they have at other fish ladders (e.g., Bonneville Dam, Chittendale Locks [Everitt et al 1981b, Gearin et al. 1986]); thus, they do not currently appear to be an important predator on salmon and other fish (R. Beach, pers. comm.).

Table 14. Anticipated responses of marine mammals to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Harbor Seal	*Phoca vitulina*	0	0	L	0	L	0	L
California Sea Lion	*Zalophus californianus*	0	0	L	0	L	0	L

Responses to Options: Under both the Estuary and Dual Basin Options, both California Sea Lions and Harbor Seals are likely to be affected by elimination of a easy food source at the 5th-Avenue Dam fish ladder, of which the August-September Chinook Salmon migration appears to be one focus. We anticipate that the concentration point of migrating adult salmon from the 5th-Avenue Dam fish ladder would move to the base of the ladder at the base of Tumwater Falls, and to a lesser extent, the re-established mouth of Percival Creek. Additionally, though both these options would increase habitat for foraging year around, the footprint of the existing Capitol Lake area is shallow compared to the current West Bay condition near the 5th-Avenue Dam fish ladder, providing less cover for large marine mammals, especially at low tide. Further, if predators at the entrance to the Tumwater Falls fish ladder present an issue, this entrance has the potential to be modified to exclude Harbor Seals and California Sea Lions in pursuit of salmon (P. Topping, pers. comm.). Since both species occasionally enter Capitol Lake, but appear to prefer marine waters (R. Beach, pers. comm.; S. Jeffries, pers. comm.; K. Keown, pers. comm.), and the difference in foraging habitat lost under the Dual Basin Option versus the Estuary Option represents largely mudflats, we anticipate that Harbor Seals and California Sea Lions will show little difference in response to these options. Hence, we expect these options to reduce marine mammal predation.

In contrast, based on the limited use of freshwater habitat by both of these marine mammals, we would expect little difference between the response of these two marine mammals to the Status Quo versus Managed Lake Options in context of habitat use and predation levels. If the Managed Lake Option provides somewhat greater visibility as is anticipated (see Lake Ecosystem under Ecosystem section), it may allow somewhat increased predation levels when either species does enter the lake in pursuit of fish. In context of the frequency of its occurrence, we expect this effect to be minor.

3.1.1.5 Reptiles

No formal surveys for reptiles have been conducted on or around Capitol Lake (L. Hallock, pers. comm.; W. Leonard, pers. comm.; K. McAllister, pers. comm.); and available data are all anecdotal.

During the 29 October 1975 field trip by Charles Lindberg and Christopher Dlugokenski, turtles were listed as being seen, but not identified; however, their list of species includes turtles under “amphibians”, so question may exist even about this coarse-level identification (Entranco 1997). The only reptile species for which data exist for Capitol Lake proper is an isolated photo-documented observation of an adult Red-eared Slider (Trachemys scripta) from 19 August 2006 on the east side of the South Basin (WDFW database; Table 15). The Red-eared Slider is an exotic that is a pet industry focus, for years exceeding the volume of all other reptiles in the trade combined (Franke and Telecky 2001; C. Rombough, pers. comm.). Red-eared Sliders have been shown to outcompete European Pond Turtles (Emys orbicularis), a relative of the state-endangered Western Pond Turtle (Actinemys marmorata) for basking sites and to negatively affect their growth rate and survivorship (Cady and Joly 2003, 2004).

Western Pond Turtles are not known from Capitol Lake and were not historically recorded. This may mean little in the absence of surveys, but Western Pond Turtle would have had a low likelihood of having been present in Capitol Lake until its management shifted to that of

Table 15. Anticipated responses of reptiles to management options for Capitol Lake. Species indicated by an E are exotics. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Species (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Red-eared Slider (E)	*Trachemys scripta*	0	0	L	-	L	--	L

a freshwater body in the 1990s. Still, Western Pond Turtles were known to be historically common in freshwater bodies around Sound Puget Sound (Hays et al. 1999).

The only native reptile with some likelihood of using Capitol Lake is the Common Garter Snake (*Thamnophis sirtalis*), an aquatic species the diet of which is dominated by stillwater-breeding amphibians (Fitch 1941, Kephart 1982). American Bullfrogs life stages can be difficult prey for this species to handle (Kupferberg 1994), so if American Bullfrogs are really on the only stillwater amphibian species present in Capitol Lake, the likelihood of Common Garter Snakes occurring there may be reduced.

Responses to Options: Assuming Red-eared Sliders still occur in Capitol Lake, we would expect them to continue to remain there under Status Quo and Managed Lake Options. However, the dredging needed to create the Managed Lake may limit available food for Red-eared Sliders, but we expect this effect to be temporary.

In contrast, the Estuary and Dual Basin Option would either constrain Red-eared Sliders to the freshwater portion of the former lake (i.e., the South Basin, Percival Cover, and perhaps the ponds associated with Tumwater Historical Park) or eliminate them from this system. This pattern is unpredictable because how much freshwater habitat would actually be useable to Red-eared Sliders in the South and Middle Basins under these is unclear.

3.1.2 Invertebrates

Selected studies of invertebrates have been conducted in the Capitol Lake area (Orsborn et al. 1975, CH2M Hill 1978, Herrera 2004). Taxonomic resolution of invertebrate data is variable (i.e., identification of individual taxa varies from species to class), which constrains evaluating responses to alternative management options at those levels. Evaluations that address taxa higher than the species level need should be interpreted cautiously because not all species within selected supra-species groups may respond to the same management option in the same way. However, enough is known about such groups to gauge expected responses with appropriate levels of uncertainty. Another important reason to interpret these data cautiously is the very short time intervals over which they were collected; in some cases, e.g., Herrera (2004), all data were obtained in a single day.

We discuss invertebrates as benthic or plankton because previous studies have sampled only these assemblages. A potential assemblage of invertebrates associated with rooted aquatic vegetation, a dominant seasonal feature of Capitol Lake (see Lake Ecosystem description), has not been a focus of sampling, though benthic sampling using an Eckman dredge, by taking limited amounts of rooted vegetation (Herrera 2004), may have captured some of this assemblage. Since foraging in aquatic vegetation is important to selected vertebrates (e.g. American Coot, Pied-billed Grebes, Ruddy Duck), and this assemblage is anticipated to differ from what has been observed in the benthos (Eggleton 1952, Dineen 1953), our assessment is expected to omit part of the invertebrate fauna. We discuss microfauna as a collective group under estuarine function (see Estuary Ecosystem description).

Monitoring of invertebrates in Capitol Lake conducted in the interval 1974-1978 (Orsborn et al. 1975; CH2M Hill 1978) provides an indication of the assemblage during the time multiple drawdowns were occurring annually and refilling Capitol Lake was occurring mostly with salt water. The Herrera (2004) study, for which the invertebrate sampling occurred in 2003, provides an indication of the assemblage after Capitol Lake was managed more as a freshwater body.

3.1.2.1 Benthic Invertebrates

Over the interval 1974-1978, the six groups dominated the benthic invertebrate fauna of Capitol Lake: Amphipods, Crane Flies (larvae), Chironomid Midges (larvae), Ostracods, Polychaete Worms, and Water Mites (Orsborn et al. 1975; CH2M Hill 1978).

Amphipods identified were in the genus *Corophium*. *Corophium*, a genus with over 50 recognized species, occurs mostly in marine and brackish water environments. In Puget Sound, *Corophium* occurs in the mud to fine sand range of substrate particle sizes in the upper intertdal (+2 to +8 MSL; Weiser 1959).

Crane Flies (superfamily Tipuloideae) are the largest group of flies (>15,000 recognized species; IMBES 2008). Crane fly larvae of a number of species are aquatic and make up a significant portion of the biodiversity along the margins of freshwater aquatic habitats (IMBES 2008).

Chironomid Midges (family Chironomidae) are a large group of flies (> 5,000 recognized species globally; over 700 in North America; Walker 2001). Superficially resembling mosquitoes as adults, they lack wing scales and biting mouthparts (Armitage et al. 1994). A few Chironomid Midge larvae are saline tolerant (Cranston et al. 1990). Due to their often high larval densities in benthic sediments, Chironomid Midge larvae are frequently important prey for fish and other aquatic organisms, and because of variable sensitivity among different species to different water quality parameters (e.g., dissolved oxygen), the presence, absence, or numbers of particular species are particularly sensitive water quality indicators in a given water body (Walker 2001). For example, in the freshwater portion of a restored segment of the Puyallup River estuary (Shreffler et al. 1992), larval Chironomid Midges comprised 42-70% of juvenile fall-run Chinook Salmon diet and 49-96% of juvenile Chum Salmon diet examined over two different years (1987-1988). Based on a sample of 311 juvenile Chinook Salmon taken by gillnet from Capitol Lake in 1955, the pupal stage of the midge, *Chironomus tentans*, constituted 85 percent of the wet weight stomach contents examined (Engstrom-Heg 1955).

Ostracods or Seed Shrimp (class Ostracoda) are large group (> 13,000 recognized extant species globally) of small crustaceans (0.2 to 30 millimeters [0.008 to 1.2 inches] in length) protected by a bivalve-like chitinous or calcareous "shell". Dominant ostracods in the 1970s work in Capitol Lake were identified as belonging the genus *Typhlocypris*, which has over 50 recognized species (Karanovic 2005) comprised entirely of freshwater obligate benthic-dwelling species 1-2 millimeters in length (I. Karanovic, pers. comm.).

Polychaetes Worms identified were in the families Ampharetidae and Nereididae, with representatives of the latter family in the genus *Nereis*. Both polychaete families contain a number soft-bottom-dwelling intertidal and shallow subtidal species that are important prey for many estuarine fishes (e.g., Shiner Perch, Staghorn Sculpin, Starry Flounder; Cooksey 2006). These representatives of both groups occur in brackish to marine waters.

Water Mites (suborder Hydracarina) area a large arachnid group (> 5,000 recognized species) of obligate freshwater species (Cook 1976, Walter and Proctor 1999). Most water mites are parasitic on insects as larvae, but become free-living and predatory as deutonymphs (the stage of development between larvae and adults) and adults. Selected species are parasitic on freshwater bivalve molluscs or crayfishes in their post-larval stages (Walter and Proctor 1999). Many species of Water Mites are benthic, but many other species are epiphytic on submerged vegetation; both benthic and epiphytic forms can make pelagic forays (Walter and Proctor 1999).

During the 1996-1997 drawdowns of Capitol Lake, benthic invertebrates were sampled in the North and Middle Basins and Percival Cove in the same locations each year (Herrera 1997). Six benthic invertebrate groups dominated these samples, but only one, Chironomid Midges, was one of the dominant groups recorded from the 1974-1978 benthic sampling. As the locations of the earlier sampling are unavailable, we cannot effectively interpret the differences between the two periods. The remaining five groups were Caddisflies, Freshwater Oligochaetes, Isopods, Leeches, and Fingernail Clams.

Caddisflies (order Trichoptera) are a large group (~12,000 species) of small moth-like insects (as adults) with aquatic larvae. A few species (from New Zealand and Australia) are unusual among insects in having larvae restricted to saltwater (marine tidal pools), but all other Caddisflies known use exclusively freshwater habitats (Resh and Rosenberg 1984). Larvae are mostly detritivores and many species make protective cases of silk decorated with gravel, sand, twigs or other debris (Resh and Rosenberg 1984). Larvae are also frequently used as biological indicators of water quality because temperate species of Caddisflies are well known and because different species vary greatly in their sensitivity to various types of pollution (Resh and Unzicker 1975, Resh 1993, Dohet 2002).

Freshwater Oligochaetes (subclass Oligochaeta) are a group of freshwater-dwelling worms related to earthworms; some resemble earthworms but are thinner and shorter (Peckarsky et al. 1990). Common in freshwater habitats, Freshwater Oligochaetes have remained largely ignored because of the belief that their identification is difficult. Yet, much work since 1960 has enabled routine identification of most species (Kathman and Brinkhurst 1999). Tubificids (Tubifex Worms), perhaps the best known Freshwater Oligochaetes, typically occur in sediments rich in organic matter, where they graze detritus and its associated microflora, and can reach extremely high densities (many thousands per square meter). Several species flourish in organically polluted waters, so as with Chironomid Midges, presence, absence, or numbers of selected species are sensitive indicators of water quality (Mackie 2001). Like all aquatic oligochaetes, tubificids respire through their skin, but the group is unique in that some species can tolerate anoxia (Kathman and Brinkhurst 1999). As lakes become organically polluted and dissolved oxygen concentrations drop, an increase in tubificids is commonly followed by a drop in the numbers of most benthic organisms. Productivity can vary greatly between years because of changes in mortality associated with major predators (e.g. Chironomid Midge larvae, various fishes).

Isopods (order Isopoda) are a large group (~10,000 recognized species) of crustaceans that occupy diverse freshwater, marine, and terrestrial habitats and vary considerably in size (0.5-500 millimeters [0.2-20 inches] long) though most are small (< 25 millimeters [1 inch] long). It is unclear whether the isopods that (Herrera 1997) references were freshwater or marine species.

Leeches (subclass Hirudinea) are a moderate-sized group (~500 recognized species) of segmented worms that include freshwater, marine, and terrestrial forms (Sawyer 1986). All species of Leeches feed on blood or are predaceous (swallow selected invertebrates whole) (Sawyer 1986). That the Leeches from Capitol Lake came entirely from the South and Middle Basins suggests that they were freshwater species.

Fingernail, Pea, or Pill Clams (family Sphaeriidae [= Pisidiidae]) are small group of ~40 species of freshwater bivalve molluscs < 25 mm long and usually closer to 10 mm or less. They occur world-wide and most bodies of freshwater have at least one species. Fingernail Clams, always hermaphroditic, self-fertilize. Development is direct (no larva) and embryos are brooded in the exhalant chambers of the gills and released as fully formed clams that can be very large, sometimes nearly half adult size.

Based on benthic samples obtained in October 2003 (Herrera 2004), three of the six dominant groups in 1996-1997, namely Chironomid Midges, Fingernail Clams, and Freshwater Oligochaetes, remained dominant; but Nematodes, Ostracods, *Hyalella* Amphipods, and *Physa/Physella* Physid Snails were also important. *Physa/Physella* Physid Snails are an extremely common group of snails in freshwater aquatic systems in general, and Nematodes are an extremely diverse group of worms that include free-living forms that occur in freshwater, marine, and terrestrial habitats.

Besides benthic samples from Capitol Lake, several marine invertebrates that are dominant species on soft-bottomed surfaces have been recorded from Budd Inlet in the WDFW database. These are:

The Green Shore Crab (*Hemigrapsus oregonensis*), a non foodfish species, is the common crab in the higher intertidal of mud flats (Ricketts et al. 1985). In addition, its planktonic larvae and the planktonic larvae of several other crab species can utilize estuaries and nearshore areas as a nursery (D. Lowry, pers. comm.; Telnack and Phipps 2007).

Humpy Shrimp (*Pandalus goniurus*), a species found from the Bering Sea to Puget Sound, is typically found on a muddy or sandy bottom between depths of 1 to 450 meters (3-1476 feet; Jensen 1995). It is typically active at night (Jensen 1995). In addition, its planktonic larvae and the planktonic larvae of several other shrimp species can utilize estuaries as a nursery (D. Lowry, pers. comm.; Telnack and Phipps 2007).

Bay Ghost Shrimp (*Neotrypaea californiensis*) occurs in the sand and muddy sand of bays and estuaries, where it creates multi-branching impermanent burrows in the middle to low intertidal (Ricketts et al. 1985, Jensen 1995). Its planktonic larvae also utilize estuaries as a nursery. Bay Ghost Shrimp feed on organic matter sorted from the sediment, typically by filtering water forced through its burrow with its specialized appendages (Jensen 1995). Bay Ghost Shrimp are regarded as pests on oyster beds (Dumbauld et al. 1996).

Blue Mud Shrimp (*Upogebia pugettensis*) build permanent Y-shaped burrows in lower intertidal with mud or muddy sand bottoms (Jensen 1995). Similar to the Bay Ghost Shrimp, they use specialized appendages to circulate water, which is filtered for plankton and detritus. Several burrow commensals frequently share their burrows, including the Burrow Pea Crab (*Scleroplax granulata*), the Northern Hooded Shrimp (*Betaeus harrimani*), and the Arrow Goby (Jensen 1995). Similar to Bay Ghost Shrimp, Blue Mud Shrimp are considered pests on oyster beds (Dumbauld et al. 1996).

Heart Cockle (*Clinocardium nuttallii*), a species that reaches its maximum abundance in Puget Sound and British Columbia, is frequently found in flats of "corn meal" sand protected from tidal action (Rickett et al. 1985). Similar to other bivalve molluscs, it filter feeds on particulates from which it retains food items and discards or passes indigestible material.

Bent-nose Macoma (*Macoma nasuta*), a species found in almost every mud flat between Kodiak (Alaska) and the southern tip of Baja California, can tolerate water so hypoxic that all other species will be killed and it can live in softer mud than any other species (Ricketts et al. 1985). Native Americans in California and perhaps further north, made extensive use of this species for food and their middens contain more shells of this species than any other.

Soft-shell Clam (*Mya arenaria*), a now well-established species accidentally introduced from the East Coast of North America in the 1800s, are incapable of maintaining themselves in a shifting substratum, having lost all power of digging, and hence require a completely protected habitat (Ricketts et al. 1985). They thrive in brackish water and can stand temperatures below freezing. In common with several other clams that can live in hypoxic estuary mud, Soft-shell Clams exhibit a striking ability for anaerobic respiration—the ability to live in a medium lacking free oxygen. During periods of low oxygen, the shell serves as an alkaline reserve to neutralize the lactic acid produced by anaerobic metabolism.

Native Littleneck Clam (*Protothaca staminea*) is a species that is found in packed mud or in gravel mixed with sand, but seems to prefer clayey gravel (Ricketts et al. 1985). In suitable localities, it occurs so densely that the valves often touch, such as the level gravel beaches of Hood Canal and Whollochet Bay in southern Puget Sound.

Butter Clam (*Saxidomus giganteus*) is the most abundant clam on suitable beaches from Alaska to Puget Sound (though it occurs as far south as Monterey [California]), and occurs on the portion of sandy mud flat influenced by tidal currents because of its pelagic larvae (Ricketts et al. 1985).

Manila Littleneck Clam (*Tapes japonica*), a species probably introduced by accident in conjunction with the Pacific Oyster (*Crassostrea gigas*), is now abundant in Puget Sound, where is has become commercially important (Ricketts et al. 1985). It occurs buried just below the surface in sand, gravel and mud, just above the low tide line (Telnack and Phipps 2008). Ricketts et al. (1985) characterized it as from rocky shores in the low intertidal. The most desirable habitat for this recreationally important bivalve and the Native Littleneck Clams is gravel substrates near locations where flow velocity increases slightly due to constrictions in local topography, e.g., bridge supports (C. Speck, pers. comm.).

Gaper Clam (*Tresus capax*) and the related Northern Gaper Clam (*Tresus nuttallii*) co-occur in protected mud substrates in Puget Sound (Ricketts et al. 1985). Predators include bottom-feeding rays (as the tips of their siphons are often found in their stomachs) and the Moon Snail (*Polinices lewisii*).

Moon Snail (*Polinices lewisii*) adults live in intertidal and shallow-subtidal zones of fine sediment (often sand and muddy sand) bays and estuaries along the Pacific Coast of North America (Page and Pedersen 1998), where they deposit eggs in large distinctively collar-shaped masses reinforced by sand grains in mid-intertidal areas (Thorson 1935) and attain densities up to 0.85 individuals/m^2 (Bernard 1967). Moon Snails develop as pelagic, phytoplankton-feeding larva that transform to drill and ingest small bivalve molluscs and adult ostracods as juveniles (Page and Pederson 1998) and become sediment-burrowing, shell-drilling predators of marine bivalves and snails as adults (Kabat 1990).

Responses to Options: The Managed Lake Option will not differ greatly from the Status Quo Option in terms of supporting primarily freshwater-adapted invertebrate groups, namely Caddisflies, Crane Flies, Freshwater Oligochaetes, Leeches, *Typhlocypris* Ostracods, and most Chironomid Midges and Fingernail Clams (Table 16). Because response to freshwater conditions is species-specific, some members of the latter two groups may not respond as positively to the two lake options. The response of Isopods cannot be gauged because freshwater, brackish, and marine species may be involved. We expect that those species in the aforementioned freshwater groups that require somewhat higher oxygen levels may show an improved response under the Managed Lake Option. We cannot specify the species that may respond in this manner since species-specific data are lacking for most of these groups.

Both estuarine options are likely to improve habitat for the brackish and marine species, namely the Polychaete Worms, the Green Shore Crab, and all the shrimp and clam species discussed except for most Fingernail Clams (Table 17). Additionally, planktonic larvae of the shrimp and crab species, including several species not discussed (and that would probably not use the estuary as adults), could use at least portion of the restored estuary as a nursery. Some of this may result in an incremental benefit to shrimp, and perhaps crab, production in the Sound Puget Sound Region. We do not anticipate substantial differences between the Estuary and Dual Basin Options, but management of the saltwater Reflection Pool in the Dual Basin option has the potential to either somewhat favor or disfavor selected brackish or marine species. Lack of understanding of the management approach disallows distinguishing these subtleties. Since the vast majority of habitat in the estuarine options is mudflats, we anticipate that that most benefit under the estuarine options would accrue for those species successful in mud or sandy mud habitats, namely the Green Shore Crab, the shrimps, and several of the clams except the Manila and Native Littlenecks.

3.1.2.2 Planktonic Invertebrates

Sampling of planktonic invertebrates has been exclusive to Capitol Lake; we could find no record of systematic sampling of plankton in Budd Inlet. The first studies of planktonic invertebrates in Capitol Lake were conducted in 1955, during studies designed to evaluate the trophic relationships of juvenile Chinook Salmon (Engstrom-Heg 1955). Samples were obtained at roughly weekly intervals from April to October, and identifications were made to genus or selected higher taxa. Zooplankters identified as seasonally occurring in high densities were cladocerans (water fleas[8] in the genera *Daphnia* and *Bosmina*), copepods in the genus *Diaptomus*, and rotifers in the genus *Asplanchna*. A striking feature of this early work was the relatively high densities of copepods.

[8] Technically, the common name water fleas is reserved for the cladoceran species of the genus *Daphnia* and its close relatives, but generically, the term water fleas is applied to all cladocerans.

Table 16. Anticipated responses of freshwater benthic invertebrates to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Taxon (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Caddisflies	Trichoptera (order)	0	0	L	--	L	--	L
Crane Flies	Tipuloideae (superfamily)	0	0	L	--	L	--	L
Chironomid Midges	Chironomidae (family)	0	0*	H	--	L	--	L
Fingernail Clams	Sphaeriidae (family)	0	0	L	--	L	--	L
Freshwater Amphipods	*Hyalella spp.*	0	0	L	--	L	--	L
Freshwater Oligochaetes	Oligochaeta (subclass)	0	0	L	--	L	--	L
Freshwater Isopods	Isopoda (order)	0	0	L	--	L	--	L
Freshwater Leeches	Hirudinea (subclass)	0	0	L	--	L	--	L
Freshwater Snails	*Physa/Physella spp.*	0	0	L	--	L	--	L
Nematodes	Nematoda (phylum)	0	0	L	--	L	--	L
Ostracods	*Typhlocypris spp.*	0	0	L	--	L	--	L
Water Mites	Hydracarina (suborder)	0	0	L	--	L	--	L

Table 17. Anticipated responses of marine benthic[1] invertebrates to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Taxon (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Amphipods	*Corophium spp.*	0	-*	H	++*	H	++	L
Marine Isopods	Isopoda (order)	0	0	L	++*	H	++	L
Marine Nematodes	Nematoda (order)	0	0	L	++*	H	++	L
Polychaete Worm	Ampharetidae (family)	0	0	L	++*	H	++	L
Polychaete Worm	*Nereis spp.*	0	0	L	++*	H	++	L
Green Shore Crab	*Hemigrapsus oregonensis*	0	0	L	++*	H	++	L
Humpy Shrimp	*Pandalus goniurus*	0	0	L	++*	H	++	L
Bay Ghost Shrimp	*Neotrypaea californiensis*	0	0	L	++*	H	++	L
Blue Mud Shrimp	*Upogebia pugettensis*	0	0	L	++*	H	++	L
Heart Cockle	*Clinocardium nuttallii*	0	0	L	+*	H	+	L
Bent-nose Macoma	*Macoma nasuta*	0	0	L	+*	H	+	L
Soft-shell Clam (E)	*Mya arenaria*	0	0	L	+*	H	+	L
Native Littleneck Clam	*Protothaca staminea*	0	0	L	+*	H	+	L
Butter Clam	*Saxidomus giganteus*	0	0	L	+*	H	+	L
Manilla Littleneck Clam (E)	*Tapes japonica*	0	0	L	+*	H	+	L
Gaper Clam	*Tresus capax*	0	0	L	+*	H	+	L
Northern Gaper Clam	*Tresus nuttallii*	0	0	L	+*	H	+	L
Moon Snail	*Polynices lewisii*	0	0	L	+*	H	+	L

[1] Adults of most of these species are benthic, but the larval stage of many are planktonic.

Over the interval 28 June-22 November 1974[9], Orsborn et al. (1975) sampled zooplankton on five dates in the North and Middle Basins of Capitol Lake. Though cladocerans, copepods, and rotifers were again the zooplankter groups present, rotifers and cladocerans were dominant and copepods were few. In the Middle Basin, *Asplanchna* and *Bosmina* were again dominant elements, but the rotifers genus *Polyarthra* was also a dominant. Further, *Asplanchna* and *Bosmina* were dominant in June, *Polyarthra* was dominant in July, *Asplanchna* was dominant in August, and zooplankters were generally rare in October-November. Samples from the North Basin were similar in that *Bosmina* dominated in June, *Polyarthra* was one of the dominants in July, *Asplanchna* dominated in August, and October and November samples had relatively few zooplankters. North Basin samples differed from Middle Basin samples in that the rotifer genus *Synchaeta* and the cladoceran genus *Daphnia* were also dominant elements in the July sample, and rotifers in the genus *Brachionus* were fairly common in the October sample. Similarity in the dominant genera between 1955 and 1974 is high, but lack of species-level identification, among other things, prevents distinguish the true degree of difference between these samples.

Based on sampling conducted in the North and Middle Basins in March to October 1977, CH2M Hill (1978) reported low zooplankton densities in March with progressive increases in April and May. In April, the dominant zooplankter was the rotifer *Keratella cochlearis*, whereas the rotifer *Brachionus calycifloras* and the cladoceran *Bosmina longirostris* became dominant in May. Zooplankton densities were then drastically reduced during a May drawdown, but reached high levels by 21 June, with *B. calycifloras* and the rotifer *Polyartha vulgaris* representing the dominant zooplanters. Zooplankton densities stayed high in July, with the rotifer *Conochilus unicornis*, and the cladocerans *Bosmina longirostris* and *Daphnia pulex* being dominants, and in late July, the rotifer *Trichocera cylindrica* also became dominant. A second drawdown occurred in late July, again causing the zooplankton population to plummet. CH2M Hill (1978) also reported a shift in zooplankton species in *Bosmina* from *B. coregoni* in 1955 to *B. longirostris* in 1977, which was thought to suggest a trend toward poorer water quality in 1977. However, the 1955 data on which they based this comparison is unclear, since available 1955 data of Engstrom-Heg (1955) only provided genus-level identifications.

Cladocerans, copepods, and rotifers also dominated the most recent plankton sample available (17 October 2003; Herrera 2004). However, though cladocerans dominated in the 1970s samples, they appear to be minor elements in 2003. *Chydorus sphaericus* was the dominant cladoceran in the 2003 sample, representing ~80 percent of sampled individuals (Herrera 2004). *Chydorus sphaericus*, a common widespread cladoceran that typically uses littoral or benthic habitats (Greve et al. 2000), frequently becomes pelagic in eutrophic systems (Vijverberg and Boersma 1997), like Capitol Lake. *Chydorus sphaericus* in the 2003 sample represents a pelagic collection as the beginning of the sample tow encompassed the entire water column 1 m above the bottom (R. Zisette, pers. comm.).

Among copepods, one species of the genus *Diaptomus* dominant in some of the 1970s samples, *D. oregonensis*, was present in the 2003 sample, but few cyclopoid copepods were

[9] Specific sampling dates were 28 June, 25 July, 28 August, 16 October, and 22 November 1974.

recorded (Herrera 2004). Copepod nauplii (larval copepods) and ergasilid copepods were the most often recorded in 2003.

Among rotifers dominant in the 1970s, only members of the genus *Polyarthra*, *P. major* and *P. vulgaris,* were recorded during the 2003 sample. Dominant rotifers in the 2003 sample were *Keratella cochlearis* and *Polyarthra major*; *Keratella* was not a dominant rotifer in the 1970s. Both *K. cochlearis* and *P. major* are well known to be favored under eutrophic conditions (Gannon and Stemberger 1978, Sládeček 1983, Christoffersen et al. 1993).

Responses to Options: We expect differences in the species composition of planktonic invertebrate between the Managed Lake Option and the Status Quo Option, but basically a freshwater zooplankton is anticipated in both cases (Table 17). Differences between the Managed Lake Option and the Status Quo Option in zooplankton are expected to reflect somewhat less eutrophic conditions associated with the Managed Lake Option.

The conversion of Capitol Lake to an estuary under both estuarine options would change the freshwater plankton assemblage to mostly a euryhaline[10] plankton assemblage (Table 17), but the Dual Basin Option may harbor a denser plankton assemblage because the stability of the Reflection Pool may allow the development of plankton to a greater degree than the constant tidal exchange of the estuary, but whether production over time is as great may be questionable. This ambiguity is because one of the features of a functioning estuary is tidal exchange, and provides a presumably constant renewal of nutrients that can encourage phytoplankton, and as consequence, zooplankton to a potential greater degree that the nutrient cycling pattern in the physically more static Reflection Pool. The management approach to the Reflection Pool and its type of linkage to the estuary is expected to influence precisely what sort of plankton assemblage it develops. Restoration of tidal flushing is also anticipated to increase both plankton transport that may enhance planktivores (e.g., bivalve mollusks) and their associated links in the West Bay food web and increase nutrient transport that may promote plankton growth.

3.1.3 Exotic Species

Among the fauna previously discussed are nine exotic species that were accidentally or intentionally introduced. Seven of these exotic species (American Bullfrog, Common Carp, Brown Bullhead, Smallmouth Bass, Largemouth Bass, Yellow Perch, and Nutria), are regarded as species that threaten the native fauna or its habitats and disfavored under the estuarine options. Small- and Largemouth Bass are managed elsewhere as warmwater fishery species, but not in Capitol Lake, where they represent probable escapees from Black Lake. Both estuarine options favor the remaining two exotic species (Soft-shelled Clam and Manila Littleneck Clam), both of which are used as food and not known to negatively affect native fauna.

3.1.4 Next Step: Species-Specific Models

To address the uncertainty associated with species responses, especially those with particular policy relevance, we offer the following advice. Given the scope of the work presented here (i.e., across a broad species array), we did not conduct a formal vulnerability

[10] Euryhaline organisms tolerate a broad range of salinity conditions.

Table 18. Anticipated responses of freshwater planktonic invertebrates to management options for Capitol Lake. All options are evaluated relative to the status quo (current conditions), which was designated zero (0). Responses can be positive (+ or ++) or negative (- or --) relative to the status quo and are meant to reflect a change in habitat quality and/or quantity. Higher degrees of positive (++) or negative (--) responses were meant to help distinguish differences between the Dual Basin and Estuary Options. Our uncertainty was scored at two levels, low (L) indicating a high degree of confidence, and high (H) indicating a low degree of confidence. Asterisked responses with high uncertainties reflect our inability to predict change in habitat quality and/or quantity (as opposed to uncertainty associated with a lack of knowledge about species ecology).

Taxon (Standard English Name)	**Scientific name**	**Status Quo**	**Managed Lake**		**Dual Basin**		**Estuary**	
			Response	Uncertainty	Response	Uncertainty	Response	Uncertainty
Cladoceran	*Bosmina* spp.	0	+*	H	--	L	--	L
Cladoceran	*Ceriodaphnia* spp.	0	+*	H	--	L	--	L
Cladoceran	*Chydorus sphaericus*	0	+*	H	--	L	--	L
Cladoceran	*Daphnia* spp.	0	+*	H	--	L	--	L
Copepod	*Diaptomus* spp.	0	+*	H	--	L	--	L
Rotifer	*Keratella cochlearis*	0	-*	H	--	L	--	L
Rotifer	*Polyarthra major*	0	-*	H	--	L	--	L
Rotifer	*Polyarthra vulgaris*	0	+*	H	--	L	--	L

analysis on any species or species group. A formal vulnerability analysis would include a process whereby a group of species experts quantify their opinion as to the response of particular species. In a few cases where we may have additional data from other areas or from other closely related species, experts may be able to craft population-based models that could be used to predict species responses in a more quantitative way.

4 Special Designation Species

Among the fauna previously discussed are a species with special designations at federal or state levels (Table 19). In contrasting options, we can exclude Bald Eagle and Barrow's Goldeneye since those two species are not expected to respond differently among any of the proposed options.

In the federal listing category, although Chinook Salmon are found or use the Deschutes River and originate from a listed stock in the White River, NOAA does not consider the Deschutes River population part of the listed stock (A. Wilson, pers. comm.). Similarly, the Steelhead population in the Deschutes is not considered part of listed stock despite the fact that some uncertainty exists regarding the existence of a native Steelhead run in Percival Creek. Hence, no difference between options exists for federally listed species (Table 19).

In the state listing category, the lake options (Status Quo and Managed Lake) would have more special designation species on the basis of favoring two Candidate species, the Purple Martin and Vaux's Swift.

In the state Priority Habitat and Species (PHS) listing category, the estuarine options would favor 10 species, whereas the lake options would favor four species, and among the latter four are the two basses, which are exotic taxa that probably represent escapees from Black Lake via the Black Lake ditch. WDFW manages bass for a recreational fishery in Black Lake, but not in Capitol Lake.

In the economic category, the estuarine options would favor seven species, whereas the lake options would favor none.

We also expect in each of the aforementioned cases, that the species favored in the estuary option would be slightly more favored under the Estuary Option than the Dual Basin Option based on quality of habitat over the available area alone, though other factors may enhance this difference. Similarly, we would expect that species favored under the lake options would be slightly more favored under the Managed Lake versus the Status Quo Option.

In sum, state listed species are favored under lake options, while estuarine options favor more PHS and economically important species.

Table 19. Species with Special Designations for this Assessment. Federal and state listing status can be coded as: E = Endangered, T = Threatened, C = Candidate, Sc = Species of Concern (federal only), and S = Sensitive (state only). PHS refers to the Washington Department of Fish and Wildlife list where 1 = State-listed or Candidate species, 2 = Vulnerable aggregations, 3 = Species of recreational, commercial, and/or tribal importance that are vulnerable.

Standard English Name	Scientific name	Federal	State	PHS	Economic Importance
Chinook, Puget Sound	*Oncorhynchus tshawytscha*	---[1]	---	2, 3	+
Chum Salmon[2]	*Oncorhynchus keta*	---	---	2, 3	+
Coho Salmon[2]	*Oncorhynchus kisutch*	---	---	2, 3	+
Steelhead, Puget Sound	*Oncorhynchus mykiss*	---[3]	---	3	+
Largemouth Bass	*Micropterus salmoides*	---	---	3	
Smallmouth Bass	*Micropterus dolomieu*	---	---	3	
Bald Eagle	*Haliaeetus leucocephalus*	Sc	T	1	
Barrow’s Goldeneye	*Bucephala islandica*	---	---	3	
Bufflehead	*Bucephala albeola*	---	---	3	
Common Goldeneye	*Bucephala clangula*	---	---	3	
Hooded Merganser	*Lophodytes cucullatus*	---	---	3	
Purple Martin	*Progne subis*	---	C	1	
Vaux’s Swift	*Chaetura vauxi*	---	C	1	
Humpy Shrimp	*Pandalus goniurus*	---	---	2, 3	+
Butter Clam	*Saxidomus giganteus*	---	---	2, 3	+
Native Littleneck Clam	*Protothaca staminea*	---	---	2, 3	+

[1]Chinook in the Deschutes River/Budd Inlet system are transplants from listed White River stock.
[2]Chum populations on Hood Canal and the Lower Columbia, Coho populations on the Lower Columbia and southwest Washington, and Sockeye populations on the Snake River and Ozette Lake have federal or state listings, but populations of these species in the Deschutes River/Budd Inlet system are not listed.
[3]A small native run of Steelhead may exist in Percival Creek, both the existence and the origin of this run is uncertain: if a native run exists, it would represent part of the South Puget Sound Threatened listed stock.

5 Ecosystems Present and their Functions and Processes

Collectively, the four management options encompass two fundamental ecosystem types: an estuarine wetland and a freshwater lake. Hence, we focus our explanation of functions and processes on these two types.

5.1 The Open Freshwater Lake Ecosystem and its Significance

Capitol Lake’s currently functions as an open-water[11] freshwater lake. At our latitude and elevation, freshwater lakes usually display dimictic circulation, i.e., turnover (exchange of surface and deeper water) that occurs twice seasonally driven by temperature-based differences in the density of water (Wetzel 2001). In winter when temperatures are below

[11] As used here, open water, means emergent vegetation free, not necessarily free of submergent or floating vegetation.

4°C (39.2°F), the densest water (at 4°C) is at the lake bottom with progressively colder water nearer the surface. As air temperatures warm with the approach of spring, surface waters warm to 4°C, increasing in density, and sink, displacing less dense water beneath. Displacement moves typically nutrient-richer bottom water to the surface, which result first in phytoplankton and then zooplankton blooms. As temperatures continue to warm, surface water become progressively warmer than the denser, cooler bottom water, promoting stratification, where water in surface versus bottom layers now at very different temperatures (and densities) that tend to resist mixing. Stratification typically increases in strength during summer warming unless a mixing agent (e.g., wind) limits or disrupts it. In the fall, decreasing temperatures return surface waters to 4°C, and turnover reoccurs; progressive cooling then returns the water column to the aforementioned winter pattern.

Capitol Lake has some characteristics of a dimictic lake, i.e., stratification during summer low flows and some degree of seasonal turnover. Certain bathymetric and hydrodynamic features of Capitol Lake tend to increase spatial variability of these mixing patterns, which in turn can increase variation in primary production. These features are:

1) Areas of Capitol Lake outside the Deschutes River channel are variably shallow, and over a meter (3.3 feet) shallower than when first constructed. The shallower the lake, the greater the vulnerability to mixing, and the more stratification and turnover is limited (Wetzel 2001). Greater mixing increases overall primary production because nutrient-richer bottom water is more frequently mixed with less nutrient-rich surface water, and production will tend to be less seasonal than where dimictic circulation is uniform.

2) Water in Capitol Lake is replaced relatively frequently, averaging about 20 days (George et al. 2006). Frequency of water replacement is largely a function of discharge from the Deschutes River, and to a lesser degree, Percival Creek. Input from the Deschutes River and Percival Creek help mix lake waters and limit stratification and turnover. Reduced discharge, characteristic of summer low flow, results in longer water replacement intervals, and an increased likelihood that some stratification will occur.

   Continuous flow from the Deschutes River also represents a steady entrainment of nutrients into Capitol Lake, which increases overall system productivity.

3) Flood-control drawdowns can also contribute to vertical mixing.

The collective effect of these features is that Capitol Lake's modified dimictic circulation encourages eutrophication, a pattern that may be exacerbated by increasing nutrient inputs expected from the Deschutes River (Roberts et al. 2004). Eutrophication of Capitol Lake is a seasonally repeated, long-stranding dynamic that contributes to fecal coliform (Prescott 1981, Singleton 1982, Singleton and Bailey 1983) and phosphate pollution (Singleton and Bailey 1983, Roberts et al. 2004), both of which frequently exceed the Washington Department of Ecology (WDOE) water quality standards. Moreover, locally shallow water makes the lake more sensitive to solar heating, and Capitol Lake is among water bodies listed by WDOE as being temperature-limited. Warmer temperatures and phosphate pollution also promote aquatic weed growth, and in Capitol Lake, until recently, a larger proportion of this growth was dominated by the aquatic exotic invasive, Eurasian Milfoil (*Myriophyllum spicatum*; Roberts et al. 2004). A Triclopyr treatment in 2004 set Eurasian

Milfoil back significantly (TCPHSS 2004); and selected additional hotspot removal efforts have been implemented. Though Eurasian Milfoil has increased somewhat from the 2004 post-treatment levels, Eurasian Milfoil been brought under some level of control. Eurasian Milfoil levels in 2008 were roughly one-quarter of that in 2007, which may reflect annual variation in flow. Notwithstanding control on Eurasian Milfoil, other floating aquatics appear to have replaced it and generally seem on the increase (K. Hamel, pers. comm.). High summer water temperatures that sometimes exceed 26°C (K. Keown, pers. comm.), and oxygen depletion resulting from biological demand for oxygen exceeding its replenishment (Roberts et al. 2004) can be lethal to aquatic organisms, especially cold-adapted fish like salmonids, without sufficiently oxygenated cold-water refuges. These patterns may be exacerbated by the normal seasonal dieoffs of high densities of Three-spined Sticklebacks, which may facilitate periodic kills of other fish species in Capitol Lake during warm weather (K. Keown, L. Hallock, pers. comm.).

The Status Quo Capitol Lake is a very productive system that may approach the high levels typical of an estuary. However, this productivity in combination with sometimes elevated fecal coliform counts, phosphate pollution, Eurasian milfoil development, and oxygen depletion reduces the quality of the lake for a suite of native organisms. On the other hand, the productivity likely enhances Capitol Lake as a producer of flying insects with aquatic larval stages (Herrera 2004). This insect production appears to be an important foraging base, for several species of bats and birds (i.e., Vaux Swifts [*Chaetura vauxi*] and various species of swallows). In particular, the maternal roost of over 3,000 Yuma Myotis (*Myotis yumanensis*) bats from Woodard Bay and at least one substantial roost (500+ individuals) from another nearby location may depend on Capitol Lake while rearing young (Falxa 2007; G. Falxa, pers. comm.). Foraging by Yuma Myotis appears to be focused on gleaning the surface of stillwater bodies large and productive enough to produce a high volume of emergent insects where limited motion disrupts that surface (von Frenckell and Barclay 1987, Falxa 2007; G. Falxa, pers. comm.). Systematic foraging over saltwater by Yuma Myotis is not known and would not be expected given that foraging is flying insect-based (Falxa 2007). Vaux Swifts, also entirely dependent on flying insects, are known to preferentially forage over freshwater aquatic habitats (Bull and Beckwith 1993). At least two other bat species (e.g., Little Brown Bat [*Myotis lucifugus*], Big Brown Big [*Eptesicus fuscus*]) and several species of swallows are known to forage for insects emerging from or flying over Capitol Lake, but how dependent these species are on flying insect production derived from this aquatic-habitat is unclear.

5.2 The Estuarine Ecosystem and its Significance

Estuaries are unusually productive ecosystems (Correll 1978), with their primary production typically 2-10 fold greater than other aquatic or terrestrial ecosystems at the same latitude (Whitaker and Likens 1975). Production in a variety of estuaries has been estimated to average 1,500 grams per meter square per year (g/m^2/year; dry matter) as compared to only 125 g/m^2/year for open ocean, 360 g/m^2/year for oceanic continental shelves, 400 g/m^2/year for lakes and streams, and 650 g/m^2/year for cultivated land (Whitaker and Likens 1975). Estuaries are not only highly productive in the food web or biological energy flow sense (Correll 1978), they are also productive by virtue of their critical role as spawning and nursery grounds for many species of marine or anadromous fish (Visintainer et al. 2006, Simenstad et al. 2007) and invertebrates, and as feeding and resting areas for many species of water birds (Milne and Dunnet 1972).

Budd Inlet (including Capitol Lake) is a 6.8-mile (10.9-kilometer) long estuary averaging 1.15 miles (1.85 kilometers) wide and 27 feet (8 meters) deep (Haring and Konovsky 1999). As with all estuaries, tides and freshwater inflows are the primary drivers of circulation and mixing[12], which continuously alter water levels and salinity (Correll 1978). The interface where fresh- and saltwater mix, often termed a ‘salt wedge’, is dynamic, with dense saltwater usually moving beneath less dense freshwater. In an unconstrained state, i.e., Budd Inlet before construction of the 5th-Avenue Dam and creation of a shipping channel[13], the salt wedge was extremely mobile. In particular, Budd Inlet having a combination of a shallow gradient and mean tidal range greater than any other estuary in Puget Sound[14] (Haring and Konovsky 1999) allowed movement of the salt wedge over a long distance. Though not precisely known, the salt wedge travel distance probably extended at least as high as the upper Middle Basin (based on the uppermost extent of the salinity prism during saltwater refills of Capitol Lake and dam removal modeling; George et al. 2006) to a lower point well seaward of the south end of the dredged Port turning basin (i.e., well over 3 kilometers [~2 miles]). Mixing at the salt wedge interface creates a variably sized zone of turbulence where water is brackish to varying degrees.

This brackish water zone of turbulence promotes high biological activity through mixing of nutrients and oxygen, provides cover and food, and is thought to be a primary process driving the high productivity of estuaries relative to other ecosystems (Correll 1978, Lotez et al. 2006). Mixing nutrients and oxygen stimulates phytoplankton and secondarily zooplankton growth to the extent that plankton can become sunlight rather than nutrient-limited due to turbulence-induced turbidity (Cole and Cloern 1987). Phytoplankton are typically the most important estuarine primary producers in terms of absolute amounts of production (Correll 1978); surface-attached unicellular algae, kelps, and submerged plants (e.g., eelgrass) can only exist in very shallow water in most estuaries, since turbidity limits light penetration to a few meters. Turbulence also stirs up fine substrates and benthic microorganisms. Hence, the turbulent boundary can attract many small fish (juvenile of many species [e.g., salmon and many marine species] and adult forage fishes [e.g., herring, sand lance, and smelt]) that prey on concentrated planktonic or mobilized benthic organisms (Puget Sound Action Team 2007). The turbid water also provides some refuge for these fishes to hide from predators as they feed. Abundant small fishes often attract numerous predators (e.g., larger salmon, dogfish, seabirds) that tend to concentrate them into tight schools to facilitate feeding on them (Puget Sound Action Team 2007). Hence, in an unconstrained estuary, large schools of small fish will frequently track the turbulent zone up and down the estuary channel.

[12] Wind and to a lesser degree, direct precipitation contribute secondarily to circulation and mixing.

[13] A channel and turning basin were dredged to 33 feet (~10 meters) below MSL for ship access to the Port of Olympia, and along the pier in the turning basin, depth actually reaches 43 feet (~13 meters) below MSL. A narrower channel has also been dredged into East Bay for access by recreational and small commercial vessels to 16 feet (4.9) below MSL.

[14] Budd Inlet has the greatest mean tidal range among estuaries in Puget Sound at 14.4 feet (4.4 meters), which reflects its most remote position in the Sound from open ocean (Aura Nova et al. 1998).

The aforementioned description characterizes partially mixed estuaries, which contrast with well-mixed estuaries, where water density is vertically more uniform and the salinity gradient is constantly increasing from the head of the estuary to the marine environment (George et al. 2006). However, such mixing is not necessarily estuary-specific, and based on simulations under a free-flowing Budd Inlet, can change depending on the river flow, point in the tidal cycle, and location. For example, based on simulations near high tide, the Middle Basin is typically partially mixed (some stratification), while stratification seems to break down in the North Basin (George et al. 2006). The area of partial mixing (stratification) appears to increase with the volume of freshwater inflow (George et al. 2006), but high uncertainty exists in predicting the degree of mixing or the position of the mixing/non-mixing interface.

Mixing and turbulence in an unconstrained estuary also functions to help disperse nutrients and toxins, and provide greater opportunity to break toxins down, regardless of their origin. In contrast to other estuaries in Puget Sound, Budd Inlet is a relatively contaminated with aromatic and chlorinated hydrocarbons, both in context of its sediments and bottom-dwelling fishes (Stehr et al. 1998).

Given this basic illustration of estuarine ecosystem function, current and recent historic operation of the Capitol Lake alters the estuarine water dynamic in three significant ways:

1) As the 5th-Avenue Dam forming Capitol Lake truncates roughly the southern fifth (based on linear distance) of Budd Inlet, mobility of the salt wedge is truncated daily except for very limited exchange via the dam's siphon. With incoming tides, the salt wedge will exhibit only limited vertical movement up the face of the dam for several hours, effectively making it stationary during this interval. A stationary salt wedge may exacerbate an existing predator trap (the area below the fish ladder at the dam), defined as an area where predators can concentrate to easily ambush prey. Several marine mammals, seabirds, and predatory fish have been observed to concentrate below the 5th-Avenue Dam fish ladder when staging associated with salmonid migration through the 5th-Avenue Dam fish ladder occurs (R. Beach, pers. comm., S. Jeffries, pers. comm.).
2) Turbulent exchange between fresh water and salt water is restricted to only those times when freshwater discharge from Capitol Lake occurs. Turbulent exchange is most reduced during summer when it occurs for as little as 2 hours per day. The implications for reduction in turbulent exchange include:
    a) Reduction in refuge cover that could increase prey vulnerability to predators.
    b) Prey species may remain in dispersed refuges when turbulent exchange is not occurring and thus, may be limited in their ability to utilize available food resources.
    c) Reduced or interrupted mixing of nutrients and oxygen may reduce marine primary productivity in the West Bay area of South Budd Inlet.
    d) Suspension of benthic food organisms drawn into the water column via turbulent exchange is more limited.
3) Daily reduction in turbulent exchange may limit oxygen exchange to benthic areas of south Budd Inlet. Studies conducted during summer 1997 identified anoxic

(anoxic = no oxygen) or near anoxic conditions near the seafloor of south Budd Inlet (Ebbesmeyer et al 1998, Davis et at 1998). Another paper in this cluster of studies stated:

"It is noteworthy that among the deep stations, the amount of oxygen depletion was greatest at the head of the inlet [i.e., South Budd] *and decreased towards the mouth, presumably resulting from progressively greater influence of mixing with well-oxygenated south Puget Sound Waters (Uhlenhopp and Deveol 1998)" .*

Though these studies were not intended to assess the effects of estuary restoration and represent but a snapshot in time, the conditions described by these studies can be detrimental to marine life, and, if allowed to worsen, may lead to fish kills as has been recently observed in Hood Canal (Devois et al. 2007).

All the aforementioned effects may also worsen in summer when other factors (temperature, aquatic weeds) affect water quality issues (Davis et al. 1998).

5.3 Relative Importance of Ecosystem Types

Our assessment suggests that different species or species groups benefit from the different management options considered here. Notwithstanding the complexities of trying to predict species-specific responses, species-based information represents one piece that may help inform policymakers about the tradeoffs among the management options for Capitol Lake. However, even though individual species are often the focus of conservation efforts, the realization is growing that other elements of biodiversity including ecosystem structures, functions and processes should also be considered in conservation efforts, even if these elements of biodiversity lack the same legal standing as species under the Endangered Species Act. We have included a brief discussion of changes that would occur to ecosystems and associated processes and functions among alternatives management options. We provide this discussion for three reasons:

1) Ecosystem processes create and maintain habitat on which species rely. Hence, considering species without considering the habitat and processes on which they depend is shortsighted and doomed to failure. Reestablishing important processes addresses unknown but important interactions among species, and among species and their physical habitat.
2) Specific habitat or ecosystem types represent unique sets of physical and biological conditions that support unique assemblages of plants and animals. Ecosystems are increasingly and explicitly considered elements of biodiversity worthy of conservation, that is, ecosystem rarity can be viewed as an analogous to species rarity.
3) Restoring the composition of ecosystems type to an historic range of natural variability is well-accepted coarse-filter approach to conservation (Schwartz 1999, Thompson and DeGraaf 2001). This approach addresses the uncertainty associated with the effects of human management on ecosystems, which are poorly understood, especially across the entire suite of species.

Thus, another way of providing policymakers with information on which to base Capitol Lake management decision is to understand tradeoffs related to changes in abundance (or amounts) of different ecosystem types.

Based on estimates of absolute area, the current combined area of freshwater lakes in Washington State is over 60 times the combined area in estuaries (Table 20). This figure likely underestimates the true difference between these two ecosystem types because the area of freshwater lakes excludes reservoirs with a maximum storage volume of less than 10 acre-feet (such small reservoirs are unregulated by the Washington Department of Ecology and hence unquantified; B. Zeigler, pers. comm.).

A contrast also exists in the change between historic and current area for each ecosystem type. Notably, the area of estuaries has declined over 80%, whereas the area of freshwater lakes has increased over 370% (Table 20), largely due to the increase in reservoirs associated with hydroelectric projects. These assessments support the notion that estuaries are the more imperiled of these two ecosystem types in Washington State, and consistent with the general concept that estuaries are at risk (PSAT 2007).

Table 20. Comparison of historic and current areas for estuary and freshwater lake ecosystem types in Washington State. Historic values are estimates that approximate conditions prior to Euro-immigration; Current represents data collected in the interval post-1990. Units are acres (ac) and hectares (ha).

Ecosystem	Units	Historic	Current	Change (%)	Source
Estuarine	ac	50,162	11,589	-77	PSAT (2007)
	ha	20,301	4,690		
Riverine Tidal	ac	27,428	2,273	-92	PSAT (2007)
	ha	11,100	920		
Estuaries (Total)	ac	77,590	13,862	-82	PSAT (2007)
	ha	31,401	5,610		
Freshwater Lake	ac	194,368	722,894	+372	WDOE (1994), Butkus (2004)
	ha	77,660	292,555		

6 *The Consequences of Sea Level Rise*

We were asked to evaluate to the effects of a potential rise in sea level of 3 feet (0.91 meter) under each management option. Most of the Capitol Lake shoreline within a meter of the water surface at the currently managed full pool (i.e., +6.4 MSL) is relatively steep. Along the east margin of the Middle and South Basins, and along the west margin of Percival Cove are hillslopes that rise to 75-150 feet (23-46 meters) above MSL. Most of the remaining lake shoreline is defined by roadbeds and recreational hiking trails built on rock substrate and perched more than 3 feet (0.91 meter) above the lake surface. The east margin of the North Basin is concrete bulkhead capped by a sidewalk.

Under both estuarine options, we do not anticipate significant expansion of estuary surface area because of the preponderance of steep banks, but we do expect the influence of marine conditions including the travel of the salt wedge to extend further up the estuary. The salt marsh fringe, mud flats and sand flats will aggrade with sea level rise. As the South Basin has been filled with sediments to a greater extent than the Middle and North Basins, we anticipate that a salt marsh fringe would slowly extend into the South Basin. We further expect that continuing shallowing of the South Basin will ultimately expand salt marsh across much of the area of this basin, but that process may take many decades. The rise in sea level will continue the geological evolution that has occurred since the last ice age, but at an accelerated rate, in part contributed by the increased deposition associated with the greater precipitation, one of the predictions linked to climate change in the Pacific Northwest. We do not anticipate changes in species composition triggered by sea level rise, rather a progressive broadening of the distribution of marine species into the estuary. Lastly, under the Dual Basin Option, whether the Reflection Pool can be maintained as a freshwater body depends on its connection to the estuary, but we anticipate that progressive saltwater instrusion will make this increasingly difficult regardless of an isolating dike with increasing sea level rise.

Under the two lake options, we assume that summer lake levels will be managed at the current full pool target for as long as possible. Our best guess is that cyclic discharge of lake water through the 5th-Avenue Dam will likely occur at lower level of the ebb tide than currently occurs. At some point, the current mechanical controls at the 5th-Avenue Dam will no longer be effective at preventing saltwater intrusion into the lake. Again we do not anticipate large changes in species utilization triggered by sea level rise, rather a broadening of marine species distribution as saltwater intrusion into the lake occurs.

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9 *Appendix I – Excluded Species*

This appendix lists species, which were excluded from the evaluation of responses to the management options for Capitol Lake and, and justification for not including them in this assessment: see also species assessment section.

Species (Standard English Name)	**Scientific name**	**Reason for exclusion**	**Documentation**
Barn Swallow	*Hirundo rustica*	1	S. Pearson, pers. comm
Cliff Swallow	*Petrochelidon pyrrhonota*	1	S. Pearson, pers. comm
Common Nighhawk	*Chordeiles minor*	2	S. Pearson, pers. comm
Rufous Hummingbird	*Selasphorus rufus*	3	Sibley (2001)
Hutton's Vireo	*Vireo huttoni*	3	Sibley (2001)
Red-eyed Vireo	*Vireo olivaceus*	3	Sibley (2001)
Solitary Vireo	*Vireo solitarius*	3	Sibley (2001)
Western Warbling Vireo	*Vireo swainsonii*	3	Sibley (2001)
Audubon's Warbler	*Dendroica auduboni*	3	Sibley (2001)
Black-throated Gray Warbler	*Dendroica nigrescens*	3	Sibley (2001)
Yellow Warbler	*Dendroica petechia*	3	Sibley (2001)
Yellowthroat	*Geothlypis trichas*	4	Black Hills Audubon
Orange-crowned Warbler	*Vermivora celata*	3	Sibley (2001)
Wilson's Warbler	*Wilsonia pusilla*	3	Sibley (2001)
Brown-headed Cowbird	*Molothrus ater*	3	Sibley (2001)
Western Tanager	*Piranga ludoviciana*	3	Sibley (2001)
Evening Grosbeak	*Coccothraustes vespertinus*	3	Sibley (2001)
Black-headed Grosbeak	*Pheucticus melanocephalus*	3	Sibley (2001)
Purple Finch	*Carpodacus purpureus*	3	Sibley (2001)
House Finch	*Carpodacus mexicanus*	3	Sibley (2001)
Pine Siskin	*Carduelis pinus*	3	Sibley (2001)
Savannah Sparrow	*Passerculus sandwichensis*	3	Sibley (2001)
White-crowned Sparrow	*Zonotrichia leucophrys*	3	Sibley (2001)
House Sparrow (E)	*Passer domesticus*	3	Sibley (2001)
California Quail	*Callipepla californica*	3	Sibley (2001)
Swainson's Thrush	*Catharus ustulatus*	3	Sibley (2001)
American Robin	*Turdus migratorius*	3	Sibley (2001)
Varied Thrush	*Zoothera naevia*	3	Sibley (2001)
Golden-crowned Kinglet	*Regulus satrapa*	3	Sibley (2001)
Ruby-crowned Kinglet	*Regulus calendula*	3	Sibley (2001)
Cedar Waxwing	*Bombycilla cedrorum*	3	Sibley (2001)
European Starling (E)	*Sturnus vulgaris*	3	Sibley (2001)
Steller's Jay	*Cyanocitta stelleri*	3	Sibley (2001)

Reasons for exclusion categories: 1 - Limited use, greater use off Capitol Lake; 2 - Habitat use not Capitol Lake area-specific, 3 - Non-aquatic habitat use focus; and 4 - Limited use of South Basin.

Species (Standard English Name)	**Scientific name**	**Reason for exclusion**	**Documentation**
Common Crow	*Corvus brachyrhynchos*	1	S. Pearson, pers. comm
Chestnut-back Chickadee	*Poecile rufescens*	2	Sibley (2001)
White-breasted Nuthatch	*Sitta carolinensis*	2	Sibley (2001)
Red-breasted Nuthatch	*Sitta canadensis*	2	Sibley (2001)
Brown Creeper	*Certhia americana*	2	Sibley (2001)
House Wren	*Troglodytes aedon*	2	Sibley (2001)
Winter Wren	*Troglodytes troglodytes*	2	Sibley (2001)
Bewick's Wren	*Thryomanes bewickii*	2	Sibley (2001)
Long-billed Marsh Wren	*Cistothorus palustris*	3	Black Hills Audubon
Spotted Towhee	*Pipilo maculatus*	2	Sibley (2001)
Dark-eyed Junco	*Junco hyemalis*	2	Sibley (2001)
Song Sparrow	*Melospiza melodia*	2	Sibley (2001)
Northern Shrike	*Lanius excubitor*	2	Sibley (2001)
Golden-crowned Sparrow	*Zonotrichia atricapilla*	2	Sibley (2001)
Fox Sparrow	*Passerella iliaca*	2	Sibley (2001)
Ring-necked Pheasant	*Phasianus colchicus*	2	Sibley (2001)
Black-capped Chickadee	*Poecile atricapillus*	2	Sibley (2001)
Common Bushtit	*Psaltriparus minimus*	2	Sibley (2001)
American Goldfinch	*Carduelis tristis*	2	Sibley (2001)
Green-winged Teal	*Anas carolinensis*	4	S. Pearson, pers. comm
Greater Scaup	*Aythya marila*	4	S. Pearson, pers. comm
Canvasback	*Aythya valisineria*	5	Entranco (1997)
White-winged Scoter	*Melanitta deglandi*	4	S. Pearson, pers. comm
Brandt’s Cormorant	*Phalacrocorax penicillatus*	4	S. Pearson, pers. comm
Pelagic Cormorant	*Phalacrocorax pelagicus*	4	S. Pearson, pers. comm
Red-necked Grebe	*Podiceps grisegena*	6	S. Pearson, pers. comm
Red-throated Loon	*Gavia stellata*	4	S. Pearson, pers. comm
Pacific Loon	*Gavia pacifica*	6	S. Pearson, pers. comm
American Bittern	*Botaurus lentiginosus*	3	Black Hills Audubon
Common Snipe	*Gallinago gallinago*	3	Black Hills Audubon
Red-winged Blackbird	*Agelaius phoeniceus*	3	Black Hills Audubon
Brewer's Blackbird	*Euphagus cyanocephalus*	3	Black Hills Audubon
Band-tailed Pigeon	*Patagioenas fasciata*	5	Entranco (1997)
Sooty Grouse	*Dendragapus fuliginosus*	5	Entranco (1997)
Ruffed Grouse	*Bonasa umbellus*	5	Entranco (1997)
Northern Saw-whet Owl	*Aegolius acadicus*	5	Entranco (1997)
Western Screech Owl	*Megascops kennicottii*	7	Black Hills Audubon
Great Horned Owl	*Bubo virginianus*	7	Black Hills Audubon

Reasons for exclusion categories: 1 - Habitat use not Capitol Lake area-specific; 2 - Non-aquatic habitat use focus, 3 - Limited use of South Basin; 4 - Upper Budd Inlet use, unlikely to move, 5 - Unusual for Capitol Lake area, 6 - Infrequent use of area., and 7 - Limited use, greater use off Capitol Lake.

Species (Standard English Name)	**Scientific name**	**Reason for exclusion**	**Documentation**
Turkey Vulture	*Cathartes aura*	1	S. Pearson, pers. comm
American Dipper	*Cinclus mexicanus*	2	Entranco (1997)
Northern Flicker	*Colaptes auratus*	2	Entranco (1997)
Pileated Woodpecker	*Dryocopus pileatus*	3	Sibley (2001)
Yellow-bellied Sapsucker	*Sphyrapicus varius*	3	Sibley (2001)
Hairy Woodpecker	*Picoides villosus*	3	Sibley (2001)
Downy Woodpecker	*Picoides pubescens*	3	Sibley (2001)
Townsend's Big-eared Bat	*Corynorhinus townsendii*	13	G. Falxa, pers. comm.
Hoary Bat	*Lasiurus cinereus*	1	G. Falxa, pers. comm.
California Myotis	*Myotis californicus*	1	G. Falxa, pers. comm.
Sea Otter	*Enhydra lutris*	4	S. Jeffries, pers. comm.
Steller Sea Lion	*Eumetopias jubatus*	5	S. Jeffries, pers. comm.
Pink Salmon	*Oncorhynchus gorbuscha*	6	Haring and Konovsky (1999)
Sockeye Salmon	*Oncorhynchus nerka*	6	Haring and Konovsky (1999)
Coastrange Sculpin	*Cottus aleuticus*	7	Wydoski and Whitney (2003)
Reticulate Sculpin	*Cottus perplexus*	8	Wydoski and Whitney (2003)
Olympic Mudminnow	*Novumbra hubbsi*	9	M. Hallock, pers. comm.
Pacific Herring	*Clupea pallasii*	10.	PSAT (2007), WDFW (2008a)
Northern Anchovy	*Engraulis mordax*	11	PSAT (2007), WDFW (2008b)
Signal Crayfish	*Pacifastacus lenuisculus*	12	Entranco (1997)
Floater (Freshwater Mussel)	*Anodonta* sp.	13	M. Hallock, pers. comm
Graceful Decorator Crab	*Oregonia gracilis*	14	Ricketts et al. (1985)
Kelp Crab	*Pugettia producta*	15	Ricketts et al. (1985)
Granular Hermit Crab	*Pagurus granosimanus*	16	Ricketts et al. (1985)
Red Rock Crab	*Cancer productus*	17	Ricketts et al. (1985)
Dungeness Crab	*Pugettia producta*	18	Fernandez et al. (1993)
Spot Prawns	*Pandalus platyceros*	19	Butler (1980), Jensen (1995)
Dock Shrimp	*Pandalus danae*	19	Butler (1980), Jensen (1995)
Coonstripe Shrimp	*Pandalus hypsinotus*	20	Butler (1980), Jensen (1995)
Alaska Shrimp	*Pandalus eous*	21	Butler (1980), Jensen (1995)
Ocean Pink Shrimp	*Pandalus jordani*	22	Butler (1980)
Shield Limpet	*Lottia pelta*	23	Telnack and Phipps (2008)
Plate Limpet	*Notoacmea scutum*	24	Ricketts et al. (1985)
Olympia Oyster	*Ostrea lurida*	25	Hopkins (1935)
Pacific Oyster	*Crassostrea gigas*	25	SIT (2006)

Reasons for exclusion categories: 1 - Limited use, greater use off Capitol Lake, 2 - Unusual for Capitol Lake area, 3 - Non-aquatic habitat use focus; 4 - No recent confirmed sightings in Budd Inlet, 5 - Occasional irregular visitors to Budd Inlet, 6 - No persistent, regular use., 7 - Preference for at least moderate current, 8 - Coastal streams, not in brackish water, 9 - Capitol Lake not preferred habitat, 10 - Upper Budd Inlet forager, eelgrass oviposit, 11 - Sporadic, deeper nearshore, 12 - Infrequent observations, too little data, 13 - Single anecdotal observation, 14 - Habitat limited, occasional on wharf pilings, 15 - Habitat limited, seaweed stand associated, 16 - Habitat limited, high rocky intertidal, 17 - Habitat limited, rocky habitat, 18 - Habitat limited, rocky shores – low intertidal, 19 - - Habitat limited, needs refuge over substrate, 20 - Habitat limited, subtidal , depths > 5 meters, 21 - Habitat limited, subtidal, depths > 16 meters, 22 - Infrequent in Puget Sound, 23 - Habitat limited, rocky intertidal, docks, 24 - Habitat limited, large rocky intertidal, and 25 - Habitat limited, hard surfaces to establish.

Species (Standard English Name)	**Scientific name**	**Reason for exclusion**	**Documentation**
Bay Mussel	*Mytilus trossulus*	1	Ricketts et al. (1985)
Checkered Periwinkle	*Littorina scutulata*	1	Voltolina and Sacchi (1990)

Reasons for exclusion categories: 1 - Habitat limited, rocky intertidal, docks.

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