HEALTHIEST LAKE.

Figure	Caption	Page
1	Part of the tidal estuary as it existed north of the State Capitol in 1944.	3
2	Main features of Capitol Lake.	3
3	Capitol Lake at the pinnacle of its recreational availability. Mueller & Mueller, 1983.	3
4	Geometric means of coliform counts in Capitol Lake over the time span 2000-2014 compared with the state Part 1 water quality standard for banning contact recreation. Values calculated by the author from data in TCPHSS 2014. See Figure 4a in End Notes.	9
4a	Annual Mean Coliform Counts in Capitol Lake, 2000-2014. Source graph from TCPHSS 2014 with author's calculated values superimposed by eye (red markers). [Compare with Figure 4.]	38
5	Coliform measurements that exceeded 100 colonies/100 mL during the years 2000-2014 in Capitol Lake and 2004-2014 in Black Lake. Data were taken at the centers of the North and Middle Basins (Capitol Lake) and at the Kennydell Park swimming area (Black Lake). Sources: TCPHSS 2014 and TCEHD 2014.	10
6	Lakes monitored for phosphorus (and other water quality parameters) by the Thurston Co. Dept. of Public Health & Social Services.	11
7	Concentrations of total phosphorus in the surface waters of 10 lakes monitored by Thurston County. Values shown are the averages of the monthly measurements from May through October. (For some lakes, 2 basins are monitored.) Year 2011. Source: TCPHSS 2012.	11
8	Concentrations of total phosphorus in the bottom waters of 10 lakes monitored by Thurston County. Values for all except Capitol Lake are averages of the monthly measurements from May through October, 2011. Source: TCPHSS 2012. Capitol Lake bottom values are not given by TCPHSS. Source for Capitol Lake (2004 only) is TMDL 2012 Fig. 24 (Ecology 2012.)	12
9	Swimmers at Capitol Lake, about 1964. This near-shore swimming cove was filled when Heritage Park was constructed. Source: DES (2002).	13

10	Clarity of water in Capitol Lake (North Basin) as measured by lowering a Secchi Disk. Bars in the blue zone show water clear enough to meet swimming standards. Summer months, 2013. Source: TCPHSS 2014.	13
11	Clarity of water in Capitol Lake (North Basin) as measured by lowering a Secchi Disk. Averages for spring and summer months (May-October), 1999-2013. Bars in the blue zone show water clear enough to meet swimming standards. Source: TCPHSS 2014.	14
12	Depletion of dissolved oxygen in the bottom water of lakes by addition of nutrients (from fertilizer in this example) to the water. Blue shows water with high DO levels (~10 mg/L), black shows water depleted of all of its oxygen (0 mg/L).	15
13	Vertical profiles of water quality properties in Hicks Lake. Blue dots = dissolved oxygen, high at the surface but decreasing to zero at the bottom. Source: TCPHSS 2012.	16
14	Summer oxygen concentrations in deepest waters of Thurston County lakes. Compiled from vertical profiles for these lakes in TCPHSS 2012.	17
15	Algal toxin alert for Lake Lawrence. Olympian newspaper. May 29 2015.	18
16	Sign prohibiting boating, warning public against contact with Capitol Lake water and reminding visitors that the reason is the New Zealand Mud Snail. Posted at Heritage Park, Olympia.	20
17	Left. New Zealand Mud Snail; features used to identify this species. Right. NZMS (leftmost of six specimens) and five other fresh water snails of Washington with which it might be confused. Source: King County, 2013.	20
18	Yuma myotis bat in flight. Wing span about 10 inches. Source: Harvey et al 1999.	22
19	Mayfly (L) and mosquito (R) adults and immature stages (respectively adults left & immatures right). Mayfly immatures are long-lived bottom dwelling gill-breathing organisms; mosquito larvae are air-breathing planktonic short-lived forms. Mayfly adult & larval size ~ 1 inch long. Both adult forms are food for bats. Source: Borror & DeLong 1964.	22
20	Olympic mudminnow. Maximum size 3.5 inches. Source: Mongillo and Hallock, 1999.	20

21a	Shells of freshwater mussels (Anodonta sp, left) and clams (Corbicula fluminea) from North Basin, Capitol Lake. Photo by author, December 2013.	24
21b	Freshwater mussel shells (and others) on frozen mud of North Basin's, west shore, Capitol Lake. Photo taken during the drawdown of the Lake December 13 2013 by author.	24
22	Exposed lake bottom (Middle Basin) during the freezing weather drawdown of December 2013. Photo by author.	25
23	Change in species diversity as one moves from fresh water (salinity 0 o/oo, left) through an estuary to the ocean (salinity 35 o/oo, right). Source: Day and others, 1989.	26
24	Detail of an interpretive sign on Deschutes Parkway, posted by the Department of General Administration, showing swimmers in 1964.	27
25	Signs at Blue Slough (Chehalis River) warning boaters about New Zealand Mud Snails. November 4, 2014.	28
26	Drawdown of Capitol Lake. The caption explains that the Washington Department of Fish and Wildlife hoped to kill 10 to 20% of the New Zealand Mud Snails. The Olympian, Jan. 2, 2015.	28
27	Typical trash-strewn shorelines of Capitol Lake. Feb 19, 2015.	29
28	Removal of nutrient nitrogen from Deschutes River water by Capitol Lake. 1977. Source: CH2M-Hill 1978.	30
29	Output of an Ecology computer model that portrays Capitol Lake in significant violation of some dissolved oxygen water quality standard. Source: Ecology 2012.	32
30	Real-world Capitol Lake dissolved oxygen levels, 2014. Measured DO levels of Capitol Lake (blue lines), May – October 2014, Middle Basin. For reference, the water quality standard for the lower Deschutes River (red line, 8.0 mg/L) is shown. The labels and levels used for water quality categories are shown on the colored key. There is a grey zone below 4.0 mg/L where ecological problems may be anticipated. I have added a commonly used "risk level" (black line, 3.0 mg/L) and indicated that 1.0 mg/L is deadly if that low level persists. Sources: TCPHSS 2012-2014; Ahmed et al 2013; Vaquer-Sunyer and Duarte 2008.	33

4a Annual Mean Coliform Counts in Capitol Lake, 2000-2014. Source graph from TCPHSS 2014 with author's calculated values superimposed by eye (red markers). [This Figure is in the End Notes.]

HEALTHIEST LAKE.

LIST OF TABLES.

Table

Caption

Page

- 1 All lakes and two selected creeks in Thurston County with 303(d) listings 7 for violations of the Clean Water Act, with all reasons for each listing shown. ("Listing" = Category 5, requiring action.) Source: Ecology 303d Website (in references).
- 2 Comparison of Capitol Lake with other Thurston County Lakes. Reasons 19 for 303(d) listings are excess phosphorus in the water (P), polychlorinated biphenyls in "tissues" (presumably fish; PCB's), another organic chemical in "tissues" (TCDD's), and coliform bacteria. Shaded items show water quality problems. Not monitored by TCPHSS and not shown here, but also 303(d) listed for PCB's is Offutt Lake. Overall Water Quality Designations as in TCPHSS (2012). *Water quality designations were assigned by the Thurston County Public Health and Social Services (TCPHSS) Department.
- 3 Introduced species known to inhabit Capitol Lake. After Johannes, 2010b, 24 and author's personal observations. Johannes cites Hayes et al 2008.
- 4 Introduced species known to inhabit Budd Inlet. Author's personal 25 observations; Wrobel and Mills, 1998.
- Coliform counts from locations in Capitol Lake, 2006. Values are numbers of coliform bacteria per 100 mL of water. Source: TCHSS "later" (2013).

[This Table is in the End Notes.]

ACKNOWLEDGMENTS.

This Report could not have been written without the extensive help and encouragement of many people. THANKS to all of you for your support and insights during this long research and writing process!

Foremost among the leaders is John DeMeyer, a colleague who single-handedly researched a vast number of issues -- sedimentation, nutrient budgets, river flow data, coliform levels and the like – for at least 8 years, and who graciously shared all of his findings with me. Whenever I was stumped – John knew how to find the answer. Others who provided information and feedback are Jack Havens, Bob Holman, Jewel Goddard, Ginny Stern, Oscar Soule, Bob Wubbena, Allen Mills, Denis Curry, Gerardo Chin-Leo, Erik Thuesen, and Dan Cheney. I am particularly indebted to four scientific reviewers; my colleague Dr. Kaye V. Ladd (chemist) and three unnamed others with expertise in water pollution issues, limnology, and botany.

Most of all, my thanks and gratitude go to my wife Dee for her long, enduring patience and support while I was engaged with this project. THANKS, Dee!