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RISK ASSESSMENT OF WATER QUALITY IN OKANAGAN LAKE, BRITISH COLUMBIA, TO ZEBRA/QUAGGA MUSSEL INFESTATIONS

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Date: September 27, 2010

INTRODUCTION

The recent invasion of the quagga and/or zebra mussel beyond the 100th Meridian has been described by Mackie and Claudi (2010). They examined the distribution of dreissenids and their rates of invasion beyond the 100th Meridian since the discovery of the quagga mussel in 2007 in California (e.g. Murray Reservoir, Colorado River Aqueduct, Lower Otay Lake, Lake Miramar, Lake Skinner, Copper Basin Resevoir), Nevada (e.g. Lake Mead, Colorado River), and Arizona (e.g. Lake Pleasant, Central Arizona Project canal). The species appeared in Colorado in 2008 in Pueblo Reservoir, Tarryall Reservoir, Granby Reservoir and Julesburg Reservoir.

Mackie and Claudi (2010) describe the devastation of native unionids, especially species at risk, by dreissenids in numerous watersheds in North America. The rapid dispersal of dreissenids beyond the 100th Meridian is causing concern of its invasion into BC watersheds, especially those that support populations of mussel species at risk, such as the Rocky Mountain Ridged Mussel (RMRM), *Gonidea angulata*, which is presently listed by COSEWIC as special concern. Since the RMRM is common throughout most of Okanagan Lake, there is concern that if the water quality of the lake will support massive infestations of zebra and/or quagga mussels, the dreissenids may kill existing populations of the RMRM.

Mackie and Claudi (2010) describe methods for predicting the level of infestation by dreissenids based on water quality. The most common parameters used (and listed in order of their predictive value from most reliable to less reliable) are: 1, calcium content; 2, alkalinity; 3, pH; 4, total hardness; 5, nutrient (total phosphorous, total nitrogen) levels; 6, chlorophyll *a* levels; 7, Secchi depth; 8, dissolved oxygen content; 9, conductivity (and/or salinity, total dissolved solids); 10, mean annual temperature. Although mean annual values of each of the parameters can be used, temporal (e.g. seasonal) and spatial (e.g. depth, horizontal) variations lend more certainty to the predictions of mussel survival and potential densities. However, means and ranges of these water quality parameters can be very useful for a rapid assessment of infestation potential.

METHODOLOGY

Mackie and Claudi (2010) utilized a suite of “chalk variables”, “trophic variables”, and “physical variables” for their risk assessments. Of the chalk variables (i.e. calcium, alkalinity, pH, total hardness), the calcium level is by far the most used and most reliable. The alkalinity informs us of the availability of the calcium. The total hardness consists of temporary hardness (i.e. amount of calcium (and magnesium) in carbonate form and is similar to alkalinity values) and permanent hardness (i.e. amount of calcium (and magnesium) in non-carbonate form that is largely unavailable to mussels). The pH governs the form of carbonates, pH values below 8.2 having all the calcium in bicarbonate form and values above 8.2 having the calcium in monocarbonate form. Removal of carbon dioxide (e.g. by photosynthesis of plants and algae) results in precipitation of calcium carbonate, making it unavailable to mussels. Hence, while calcium is the key variable, knowledge of the values of the other chalk variables are also important in predicting densities of dreissenids.

The trophic variables include nurients (e.g. total phosphorous and nitrogen), chlorophyll *a* levels, Secchi depth, and dissolved oxygen content and all are related. The higher the values of the nutrient variables, the greater the biomasses of algae and hence of chlorophyll *a*, and dissolved oxygen (at the surface), and the lower the Secchi depth values (i.e. water is more turbid). Since mussels feed on algae, the values of the trophic indicators are also important criteria for predicting dreissenid densities. Total phosphorous should be used when phosphorous is limiting and total nitrogen when nitrogen is limiting.

Conductivity and mean annual surface water temperature are the only physical criteria used but mostly as a last resort, especially if the amount of information for the chalk and trophic criteria are meager or lacking. Nevertheless, they do add support to any predictions on mussel infestation intensities.

Table 1 was derived from the values reported by numerous researchers (see Mackie and Claudi 2010 for list) and gives the ranges of values for each of the parameters and the potential level of risk of infestation by zebra mussels for each parameter. The key parameter is calcium content and its availability. Calcium levels exceeding 30 mg/L are needed to support massive infestations. Its availability becomes a question only at high pHs. pH levels exceeding 9.5 are lethal to dreissenids, with the lethal threshold starting at pH 9.0. Optimal pH levels are between pH 8.0 and 9.0. The total alkalinity provides a measure of the availability of calcium to dreissenids. Only calcium in bicarbonate and carbonate forms are believed to be the major sources of calcium for shell formation; calcium as sulphate or chloride (called permanent hardness) is largely unavailable to mussels. Temperature is a useful criterion only during the summer months; hence, means and ranges of summer temperatures are more useful than annual means and ranges. Similarly, summer means and ranges for nutrients (P and N), and chlorophyll *a* are more useful than annual means and ranges.

Table 1. Criteria used in determining levels of infestation by zebra mussels in the temperate zone of North America

Parameter	No infestation	Little	Moderate	High
Calcium mg/L	<10	<16	16-24	≥24
Alkalinity mg $CaCO_3$/L	<35	35-45	45-89	>90
Total Hardness mg $CaCO_3$/L	<40	40-44	45-90	≥90
pH	<7.2	7.2-7.5	7.5-8.0 or 8.7-9.0	8.0-8.6
Mean Summer Temperature ^{o}C	<18	18-20 or >28	20-22 or 25-28	22-24
Dissolved Oxygen mg/L (% saturation)	<6 (25%)	6-7 (25-50%)	7-8 (50-75%)	≥8 (>75%)
Conductivity µS/cm	<30	<30-37	37-84	≥85
Salinity mg/L (ppt)	>10	8-10 (<0.01)	5-10 (0.005-0.01)	<5 (<0.005)
Secchi depth m	<0.1	0.1-0.2 or >2.5	0.2-0.4	0.4-2.5
Chlorophyll a µ/L	<2.5 or >25	2.0-2.5 or 20-25	8-20	2.5-8
Total phosphorous µg/L	<5 or >35	5-10 or 30-35	15-30	10-15
Total Nitrogen µg/L	<200	200-250	250-300	300-500

RESULTS

Table 2 gives the means and ranges of values for each risk parameter. The values were provided by Vic Jensen (pers. comm.) through Sue Pollard as extracted from the Environmental Monitoring System Historical Statistics Report, Report ID, EMSR0300. It should be noted that the mean summer temperature is estimated. The % dissolved oxygen values are determined from solubility tables based on the temperature values. The maximum value for chlorophyll *a* concentration seems exceedingly high (i.e. in the “pea soup” range) and the summer mean value is unknown and is of little use here in the risk assessment for Okanagan Lake. Similarly, the mean summer phosphorous values are unknown and of little value in the risk assessment for Okanagan Lake. The risk potential highlighted in red indicates a high risk for massive infestations; the risk potential for moderate infestations is shown in green (none apply here) and for little to no infestations is shown in yellow. See text for further explanations.

Table 2. Okanagan Lake surface water quality data, with parameters listed alphabetically. The risk potential for supporting a zebra mussel population is derived from Table 1.

Variable	Range	Mean Value	Risk potential
Alkalinity, total mg $CaCO_3$/L	108-116	111.2	**High**
Calcium mg/L	30.7-34.1	32.1	**High**
Chlorophyll *a* µg/L (mean summer value estimated)	0.0-1400	?	**?**
Conductivity, µS/cm, but see text below	0.3-300	185.7	**High**
Dissolved oxygen, % saturation, but see text below	138-141?	134?	**High?**
Dissolved oxygen, mg/L	8.6-13.2	10.6	**High**
pH	7.3-8.5	7.98	**Little to high**
Temperature, (mean summer ^{o}C estimated)	1.7-23.0	18?	**High**
Total phosphorous µg/L	2-100	?	**?**
Overall likelihood of water quality supporting a zebra mussel infestation			**High/intense**

DISCUSSION AND CONCLUSIONS

Based on Table 2, the assessment indicates a “high” potential for infestations of dreissenids in 5 out of 6 parameters, especially calcium and alkalinity levels that are high throughout the year. The pH drops to 7.3 throughout the year but if this minimum value occurs during periods when dreissenids are not growing or reproducing (e.g. fall or winter) then the parameter is of less value than the mean, which indicates a high risk for massive infestations. The average % dissolved oxygen content is high in the surface waters and will support massive infestations throughout the year. However, since the sources of dissolved oxygen are from the atmosphere and primary production, supersaturation as indicated by the values exceeding 100% in Table 2, are usually the result of excessive algae productivity. The maximum chlorophyll *a* and total phosphorous levels meets the criteria for highly eutrophic waters and if blooms of filamentous algae form, they will mitigate against dreissenid infestations. The ranges in values of these parameters range from oligotrophic to highly eutrophic waters, which is unusual and it may be that these values were based on samples from different parts of the lake. ***In conclusion, based on the analyses of the risk potential parameters, there is a high risk of dreissenids***

not only surviving in some parts of Okanagan Lake, but a high potential for massive infestations.

LITERATURE CITED

Mackie, G. L. and R. Claudi. 2010. Monitoring and control of macrofouling mollusks in fresh water systems. CRC Press, Boca Raton, FL. 508 pp.

ACKNOWLEDGEMENTS

My thanks to Vic Jensen, Senior Impact Assessment Biologist, Environmental Protection Program and Sue Pollard, Aquatic Species At Risk Specialist, Ecosystem Branch, Aquatic Ecosystems Science Section, both with the Ministry of Environment, Government of British Columbia, for providing water quality data for Okanagan Lake.