St. Marys River Area of Concern

Fish Tumours or Other Deformities

Current Status of the Beneficial Use Impairment for the St. Marys River Area of Concern (Canadian section)

Prepared by:

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FINAL

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Executive Summary

The status of the beneficial use impairment *Fish Tumours or Other Deformities* is currently impaired in the St. Marys River Area of Concern; however, there are recent signs of improvement. The impaired designation has been in place since the Stage 1 and Stage 2 Remedial Action Plans (released in 1992 and 2002, respectively) reported the liver tumour rate from collected White Suckers to be 9.2%. In 2009, an assessment determined the tumour rate to be 10.6%, and a follow-up survey in 2015 concluded the rate had dropped to 6%.

Experts believe there is a state of "environmental degradation" when the prevalence of hepatic neoplasms (i.e., liver tumours) is greater than 5% (Great Lakes Commission, 2002).

Whereas external fish anomalies – deformities, fin erosion, lesions, and tumours (or "DELTs") – can be the result of physical or biological stress such as injury or viruses, liver tumours are associated with exposure to chemical contaminants (Baumann, 2014). Elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) in St. Marys River sediment has been identified as the likely cause of the fish tumour impairment (MOE, 2002). Historical point sources of PAHs to the St. Marys River include the steel mill on the Canadian side of the river, and the former manufactured gas plant on the U.S. side.

In the 1990s and 2000s, stricter environmental regulations, enhanced wastewater treatment, and remedial actions and cleanup initiatives contributed to reduced contaminants in water and sediment. Yet a 2009 survey concluded fish tumours were still elevated, with a reported 10.6% tumour rate. A possible explanation by Baumann (2013) is that dredging in the Algoma Boat Slip in 2006 could have exposed higher concentrations of PAHs that were otherwise covered, which might have contributed to a spike in fish tumours accounted for in the 2009 survey.

A follow-up assessment to the 2009 work was warranted, and fieldwork took place in August 2015. Results indicate that the tumour rate has dropped to 6%. While being a marked improvement, this lower rate does not meet the Remedial Action Plan's delisting criteria established for the beneficial use impairment for the Canadian side of the Area of Concern:

> *This beneficial use will no longer be impaired when a survey from within the Area of Concern of a locally abundant member of the sucker family, encompassing a diverse age range, indicates a liver tumour prevalence rate of less than 5%*.

The purpose of this report is to present and discuss the methods and results of the 2015 fish tumour assessment, and to compare to past study results. Proposed next steps are also identified. This is a draft report to be shared and discussed with community partners and the St. Marys River Binational Public Advisory Council. Feedback will be incorporated into a final report.

Introduction

St. Marys River was designated an Area of Concern (AOC) under the *1987 Protocol to the Canada-U.S. Great Lakes Water Quality Agreement.* Discharges of pollutants from local industry and municipal wastewater treatment plants were impairing water quality and ecosystem health, resulting in the identification of a number of beneficial use impairments (BUIs), including Fish Tumours or Other Deformities.

Released in 1992, the Stage 1 Remedial Action Plan (MOE et al, 1992) reported, "an abnormal incidence of liver neoplasms" (tumours) in White Suckers (*Catostomus commersoni*) collected along the Ontario shoreline, and a "relatively high incidence of liver tumours" found in Brown Bullheads (*Ictalurus nebulosus*) collected from Michigan waters in Munuscong Bay. Although a tumour prevalence rate was not reported at the time, Fish Tumours was designated a beneficial use impairment and further research was planned.

The Stage 2 Remedial Action Plan (MOE, 2002) report upheld the impaired status and provided more information to this BUI. The report noted a 1985-1990 survey that collected 185 White Suckers from the St. Marys River, and found 17 with liver tumours; equating to a 9.2% tumour rate (MOE, 2002). The Remedial Action Plan report also discussed the likely cause being exposure to chemical contaminants in the river sediment, namely polycyclic aromatic hydrocarbons (PAHs).

In 2009, a joint assessment by Environment and Climate Change Canada (ECCC) and Fisheries and Oceans Canada (unpublished) again found elevated tumour rates, with 15 out of 141 sampled White Suckers (10.6%) having liver tumours. These results were unexpected given the amount of time that had passed since the implementation of stricter environmental legislation, upgraded wastewater treatment, and remedial cleanup efforts that had taken place in the 1990s and 2000s. Reduced contaminants in water and sediment were expected to result in lower exposure to fish, and therefore lower tumour rates.

In 2013, a report on the probable causes of the fish tumours in St. Marys River (Baumann, 2013) supported the claim that PAHs in contaminated sediment is the likely cause of the fish tumour impairment; noting past sediment studies have shown particularly evaluated concentrations near the Algoma Boat Slip and downstream of Bellevue Marine Park[1]. Baumann hypothesized it is feasible that maintenance dredging in the Algoma Boat Slip in 2006 could have exposed higher concentrations of PAHs that were otherwise covered, and that this could be correlated to a spike in tumour rates accounted for three years later in the 2009 fish tumour survey.

[1] Note: The Algoma Boat Slip was dredged in 1995 and 2006, removing 11500 m3 and 2630 m3 of material, respectively. From late August to mid-September 2017, Algoma Steel again dredged the slip, and plans to complete the operation in 2018-2019. The plan is to remove all sediment (down to bedrock), if possible. The area downstream of Bellevue Marine Park around Topsail Island will be addressed under a contaminated sediment management strategy developed by Canada and Ontario.

Baumann recommended a repeat fish tumour survey in 2015 to obtain updated information and to see if the tumour rate had declined nearly a decade after the 2006 dredging event.

In August 2015, ECCC collected 100 White Suckers along the Ontario shoreline that included the two locations identified in the 2009 survey. Subsequent histological evaluations (liver tumour analyses) by the British Columbia Ministry of Agriculture and Experimental Pathology Laboratories Inc. revealed six had tumours; equating to a 6% tumour rate.

This is a marked improvement from the higher rates detected in the past, but it remains above the 5% threshold the Great Lakes Commission (2002) established as an indicator of environmental degradation, and it does not meet the Remedial Action Plan's delisting criteria[2] established for the beneficial use impairment on the Canadian side of the Area of Concern:

> *This beneficial use will no longer be impaired when a survey from within the Area of Concern of a locally abundant member of the sucker family, encompassing a diverse age range, indicates a liver tumour prevalence rate of less than 5%*.

The following sections outline the study methods and discusses the results for both the 2009 and 2015 fish tumour surveys.

[2] For the U.S. side of the St. Marys River AOC, the Fish Tumours BUI delisting criteria is (MDEQ, 2015):

- No reports of fish tumors or deformities due to chemical contaminants which have been verified through observation and analysis by the MDNR or MDEQ for a period of five years.

OR, in cases where any tumors have been reported:

- A comparison study of resident benthic fish (e.g., brown bullhead) of comparable age and at maturity (3 years), or of fish species which have historically been associated with this BUI, in the AOC and a non-impacted control site indicates that there is no statistically significant difference (with a 95% confidence interval) in the incidence of liver tumors or deformities.

Methodology – fieldwork

In 2009, fieldwork was carried out by ECCC's Aquatic Contaminants Research Division from October 4 to 22. Sample collections focused on the urbanized waterfront of Sault Ste. Marie, Ontario, particularly the Bellevue Marine Park-Topsail Island area and Partridge Point (downstream of the municipal wastewater discharge) midway along the Lake George Channel (Figure 1). In 2015, fieldwork was again carried out by the Aquatic Contaminants Research Division of ECCC (from August 18 to 23), with the focus on the same areas sampled in 2009.

The sampling areas were selected because they are downstream of the active steel mill, include known sediment depositional areas, and are in proximity to a large municipal wastewater treatment plant on the Canadian side of the river. The Bellevue Marine Park area is also across the river from the former U.S. manufactured gas plant, a historical source of coal tar and PAHs that has since been remediated through a dredging and capping cleanup completed in 2012.

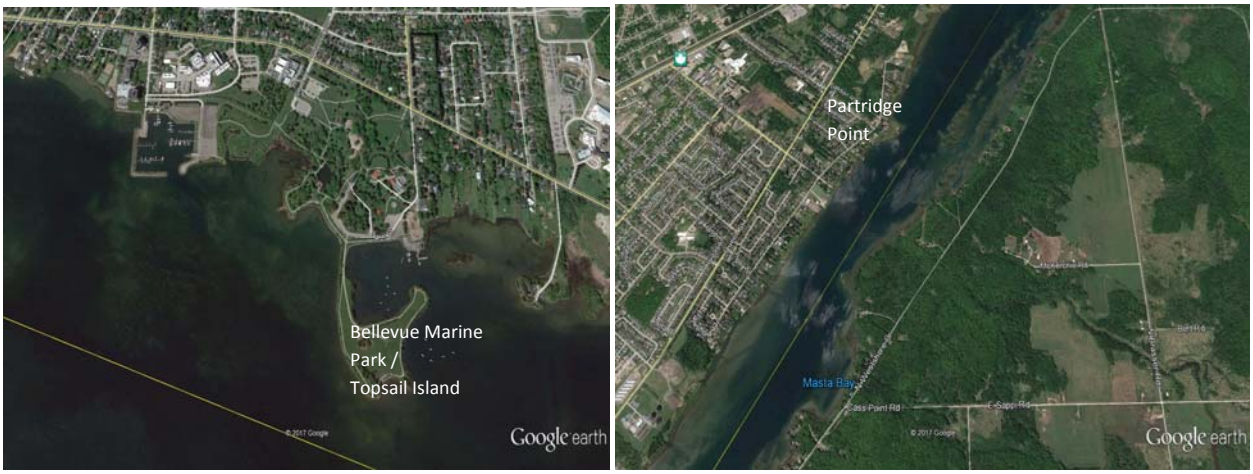

Figure 1: Sampling areas used in both the 2009 and 2015 fish tumour surveys.

For a high-confident assessment, a minimum sample size of 100 adult fish per survey is required (Baumann, 2010). This requirement was achieved in both surveys, with 141 White Suckers collected in 2009 (100 at Bellevue Marine Park and 41 around the municipal wastewater discharge near Partridge Point), and 100 collected in 2015 (split between the two areas).

In 2015, the White Suckers were caught by overnight gill net sets and electrofishing, and some captured in trap nets. Recognizing the need for the sample sets to reflect a diverse age range, the field team targeted a variety of sizes. Figure 2 is an illustrated example of typical sample length measurement.

Figure 2: Example of measuring fish length during sample collection.

Following capture, the fish were placed into a live well for transport to the shore. Fish were anaesthetized in a clove oil bath and then sacrificed using standard operating procedures (animal use protocol 0816 and 1312 respectively approved by ECCC's Animal Care Committee).

Their physical state was assessed using a visual examination of physical abnormalities (any external deformities or lesions were noted), and general measurements were taken, including gender, fork length (±0.1 cm), and body weight (± 0.1 g). The operculae – hard, bony flaps covering and protecting the gills – were collected for aging in the laboratory, and the subsequent results aged the fish from 3+ to 23 years old.

Appendix A and B provide the statistics on the age, gender, length, and body weight of all the fish collected in 2009 and 2015.

In addition, the livers were removed from each fish and separated into sections for histological evaluation, fixed in Davidson's Fixative, and later transferred and stored in 70% ethanol one to four weeks after collection.

Methodology – lab work

At the ECCC laboratory in Burlington, Ontario, the samples were further processed. Five liver sections from each fish were distributed on ten slides (two slides per sample). Figure 3 provides an illustrated example of the sections collected (McMaster 2016).

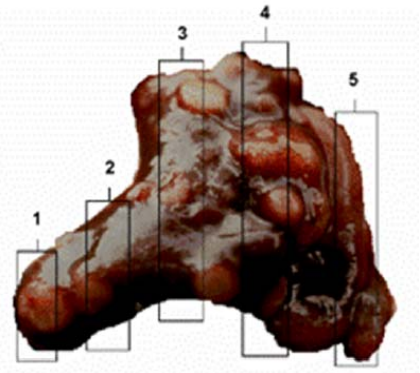

Figure 3: Sample histology slide (each liver has five samples taken from it)

Each slide contained three to five serial or step-sections from the same paraffin block. In both the 2009 and 2015 surveys, staff from ECCC's Aquatic Contaminants Research Division conducted a preliminary examination of slides to confirm good sections, staining and mounting.

The 2009 samples were assessed by the Department of Fisheries and Oceans' lab in Winnipeg, Manitoba (Brad Park), and the 2015 samples were sent to the British Columbia Ministry of Agriculture (Dr. Gary Marty). In both surveys, the histological evaluations (liver tumour analyses) followed the *Blazer Protocol* (Blazer et al., 2007), a process developed by experts with the U.S. Geological Survey and U.S. Environmental Protection Agency for the systematic identification of liver tumours in brown bullhead. The Blazer Protocol has become the standard approach for identifying fish tumours and determining tumour rates in the Canadian Great Lakes Areas of Concern, including Thunder Bay, Jackfish Bay, St. Clair River, St. Lawrence River, the Bay of Quinte, Hamilton Harbour, Toronto Harbour, and St. Marys River.

There are different kinds of liver abnormalities, including putatively pre-neoplastic lesions, foci of cellular alteration; neoplastic hepatocellular lesions; non-neoplastic biliary lesions; and neoplastic biliary lesions (McMaster, 2016). As outlined in Baumann (2010 and 2014), some of these liver abnormalities are not conclusively linked to environmental contaminants, and some may not progress into actual liver tumours (i.e., *pre*-neoplastic lesions may never become neoplastic lesions). For this reason, only neoplastic lesions are used for evaluating fish tumours in Canadian Areas of Concern.

Therefore, to ensure the analysis and diagnosis of liver samples can produce a high-degree of confidence that detected tumours are linked to chemical contaminants in the environment; the 2009 and 2015 surveys examined the following abnormalities:

- **Neoplastic Hepatocellular Lesions**: Hepatocellular Adenoma and Hepatocellular Carcinoma, which are cancers in the liver; and

- **Neoplastic Biliary Lesions**: Cholangioma and Cholangio carcinoma, which are cancers in the bile duct.

As outlined in Marty and Snyman (2017), staff at the British Columbia Ministry of Agriculture conducted a blind examination; meaning no information was known about the fish other than the species and the year the fish were collected.

For each liver sample, every section was systematically scanned using the 4× objective lens (low power), and then a single section was systematically scanned using the 10× objective lens (medium power). When needed, higher magnification (20× and 40×) was used (Figure 4).

For foci of cellular alteration and neoplasia, the number of foci per liver was recorded. For other lesions, findings were scored on a relative scale as none (0), mild/small amounts (1), moderate (2), or severe/abundant (3).

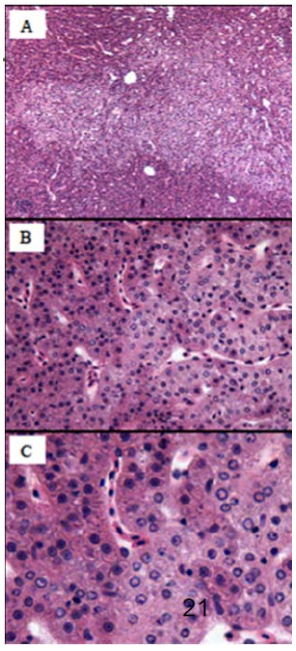

Figure 4: Same liver sample at increasing magnification

Fish Tumour Results

2009

Of the 141 White Suckers collected in 2009 from the Bellevue Marine Park-Topsail Island and Partridge Point areas, 15 were found to have liver tumours. This equates to a 10.6% tumour rate.

Among the 40 fish captured at the Partridge Point location close to the discharge of the East End Wastewater Treatment Plant, three were found with tumours including:

- Heptocellular Carcinoma and a Hepatocelluar Adenoma in the liver of one young male fish (6 years old);
- Hepatocelluar Carcinoma in the liver of an older female (17 years old); and
- Cholangioma in the liver of an older female fish (21 years old).

Of the 101 fish captured around the Bellevue Marine Park-Topsail Island area including the marina, all 12 that exhibited tumours were female:

- four with Cholangioma;
- seven with Cholangio carcinoma; and
- one with a Hepatocellular Carcinoma.

Generally, tumor prevalence in fish are positively correlated with age; older fish are exposed to environmental contaminants longer and a latent period exists between induction and tumour development (Baumann 2013). However, in the case of the 2009 collection, Baumann (2013) suggests the high tumour rate observed in the St. Marys River population (mean age 11 years old) was not influenced by age structure, but rather may have been due to contaminant exposure. This theory was supported by noting the St. Marys River sample set had a higher percentage of younger fish (ages 5-9), than compared to reference site populations in Mountain Bay (in north-central Lake Superior), which had a greater percentage of the population in older age groups (especially ages 18-24), but no observed liver tumours in the 2006-07 collection.

Batchewana Bay was also sampled as a reference location to compare results to the St. Marys River, with 100 White Suckers collected in 2009 (mean age = 10.4 years). Five of those reference fish had liver tumours (mean age = 10.6 years), equating to a 5% tumour rate. An elevated tumour rate had been recorded for Batchewana Bay in the past, when the 1985-90 survey found an 8.6% tumour rate (n = 230). Although theories have been proposed, the reason for why Batchewana Bay has elevated fish tumour rates is currently unknown. That area should not be impacted by the PAH-contaminant issue occurring in the St. Marys River AOC. Baumann (2013) recommended that Batchewana Bay should not be used in the future as a reference location; therefore, ECCC did not collect samples from there in 2015.

2015

In August 2015, a follow-up sampling survey was completed to reassess the 2009 results. One hundred White Suckers were collected from the Bellevue Marine Park and Partridge Point areas, and six were found to have liver tumours, equating to a 6% tumour rate.

The histological evaluation was completed by the British Columbia Ministry of Agriculture in January 2017. Marty and Snyman (2017) found four of the livers had some type of neoplasia:

- cholangiocarcinoma in the liver of one young male fish (5 years old);
- cholangiomas in the liver of two older female fish (7 and 8 years old); and
- hepatocellular adenoma in the liver of an older female fish (12 years old).

The Ministry's microscopic assessment also identified unusual results with the livers of five additional fish. As a result, and a second opinion was sought. Jeff Wolf (Experimental Pathology Laboratories, Virginia) was able to evaluate three of the five livers (the other two were insufficient for testing) and found that two of the three livers had a putative rodlet cell tumour not previously observed in fish. The two fish were 10 year old females. Wolf (2017) believes the tumours were possibly the result of some agent (e.g., chemical or viral) that directly or indirectly induced neoplastic transformation.

The combination of assessments from Marty and Snyman (2017) and Wolf (2017) resulted in a total of six fish out of 100 collected in the 2015 survey to have a liver tumour, equating to a 6% tumour rate. The average age of these 100 fish (average 7.3 years old) were younger than those collected in 2009 (average 11 years old). The average age of the six fish with liver tumors was 8.7 years.

Conclusion

Following a robust approach used to evaluate the *Fish Tumours or Other Deformities* beneficial use impairment in Canadian Great Lakes Areas of Concern, two intensive fish tumour surveys have been completed in the St. Marys River in 2009 and 2015.

The 2015 incidence rate of tumours was lower (6%), compared to the 2009 assessment (10.6%) and 1985-1990 baseline assessments (9.2%).

While a marked improvement, the 6% tumour rate remains above the 5% threshold the Great Lakes Commission (2002) established as an indicator of environmental degradation, and it does not meet the Remedial Action Plan's delisting criteria established for the Canadian side of the Area of Concern:

> *This beneficial use will no longer be impaired when a survey from within the Area of Concern of a locally abundant member of the sucker family, encompassing a diverse age range, indicates a liver tumour prevalence rate of less than 5%*.

As such, the status of the *Fish Tumours or Other Deformities* beneficial use impairment remains impaired for the Canadian side of the St. Marys River AOC.

Next Steps

Given that there is a correlation between fish tumours in the St. Marys River and elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) in the river sediment, Environment and Climate Change Canada and the Ontario Ministry of the Environment and Climate Change will further the development of a multi-agency contaminated sediment management strategy for the Canadian side of the AOC. The focus of the management strategy will be in the depositional area east of Bellevue Marine Park near Topsail Island. The process will involve community consultation, which will begin in 2018.

The agencies will also continue to track the dredging activities within the Algoma Boat Slip that had commenced in August 2017, which will remove contaminated sediment. A post-dredge assessment in 2018 will seek to answer questions such as: how much material was successfully removed, how much remains, and what are the current concentrations of contaminants including PAHs.

Plans for another fish tumour survey will be discussed as part of the multi-agency contaminated sediment management strategy for the Canadian side of the AOC. It is anticipated a follow-up survey will not occur until at least 2021, which will continue the 6-year interval between studies.

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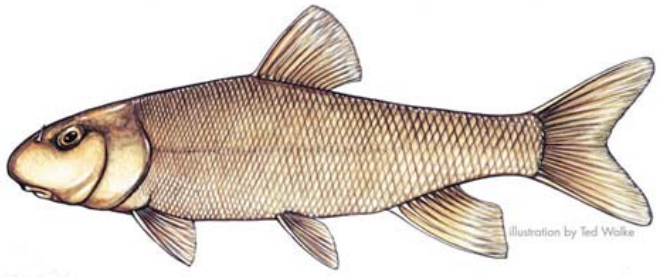

Appendix A: White Suckers collected in 2009
Statistics on age, gender, fork length and total body weight

All Fish (141)
median length: 43.9 cm
median weight: 1193.7 g
median age: 11.11 years

Females (89)
median length: 45.0 cm
median weight: 1293.6 g
median age: 11.8 years

Males (52)
median length: 41.2 cm
median weight: 999.8 g
median age: 9.7 years

Notes:
C – Cholangioma
CC – Cholangio Carcinoma
HC – Hepatocelluar Carcinoma
HA – Hepatocelluar Adenoma

Location	Fish ID#	Length (cm)	Weight (g)	Gender	Age (years)	Tumour
Bellevue Marina	65	49.4	1569.1	F	12	
Bellevue Marina	67	44.5	1229.3	F	9	
Bellevue Marina	71	50.1	1466.8	F	13	
Bellevue Marina	72	45.5	1257.8	F	15	C
Bellevue Marina	73	50.9	1804.0	F	19	CC
Bellevue Marina	74	41.8	1027.2	F	7	
Bellevue Marina	75	42.1	1046.9	F	8	CC
Bellevue Marina	76	46.1	1262.6	F	9	
Bellevue Marina	77	48.8	1455.6	F	16	
Bellevue Marina	80	43.5	1245.2	F	7	
Bellevue Marina	81	44.2	1113.7	F	11	
Bellevue Marina	82	44.6	1449.3	F	9	
Bellevue Marina	83	47.7	1401.5	F	10	
Bellevue Marina	85	44.1	1343.1	F	9	
Bellevue Marina	86	45.2	1338.7	F	8	
Bellevue Marina	87	44.9	1197.7	F	13	
Bellevue Marina	215	40.0	889.9	F	8	
Bellevue Marina	216	45.5	1436.7	F	10	

Bellevue Marina	220	40.7	1060.7	F	7	
Bellevue Marina	221	41.0	1091.3	F	6	
Bellevue Marina	222	46.5	1457.9	F	12	
Bellevue Marina	223	49.0	1685.2	F	14	
Bellevue Marina	66	46.0	887.3	IF	12	
Bellevue Marina	167	48.9	1031.2	IF	18	C
Bellevue Marina	64	41.6	1010.9	M	8	
Bellevue Marina	68	40.7	901.5	M	8	
Bellevue Marina	69	47.0	1313.5	M	17	
Bellevue Marina	70	40.7	923.9	M	6	
Bellevue Marina	78	44.6	1442.8	M	12	
Bellevue Marina	79	42.2	1032.6	M	15	
Bellevue Marina	84	43.3	1065.2	M	10	
Bellevue Marina	88	38.9	757.4	M	7	
Bellevue Marina	214	40.5	986.3	M	7	
Bellevue Marina	217	39.6	979.5	M	7	
Bellevue Marina	218	41.5	1063.5	M		
Bellevue Marina	219	40.1	1062.9	M	7	
Bellevue Marina	224	42.9	1189.0	M	9	
Bellevue Marina	225	40.1	930.7	M	7	
Bellevue Marina	226	39.9	827.6	M	7	
Bellevue Marina	227	41.3	1068.7	M	8	
Bellevue Marina	228	43.8	1130.1	M	16	
Bellevue Marina	272	36.5	670.3	M	5	
Bellevue Marina	273	42.8	977.1	M	7	
Bellevue Marina	274	41.5	957.0	M	7	
Bellevue Marina	T01	47.7	1672.4	M	14	
Bellevue Marina	T5	40.6	1506.5	F	16	C

Bellevue Marina	T6	N/A	N/A	F	17	
Bellevue Marina	T7	40.4	2002.0	F	9	
Bellevue Marina	T8	43.2	1272.1	F	8	
Bellevue Marina	T9	37.0	778.2	IF	6	
Bellevue Marina	T10	44.5	1469.4	F	8	
Bellevue Marina	T11	46.6	1419.2	F	13	
Bellevue Marina	T12	47.6	1723.2	F	20	
Bellevue Marina	T13	49.5	1801.9	F	16	
Bellevue Marina	T14	42.9	1108.1	F	8	
Bellevue Marina	T15	48.0	1619.3	F	12	
Bellevue Marina	T16	47.0	1210.8	F	15	
Bellevue Marina	T17	40.4	893.9	F	6	HC
Bellevue Marina	T18	49.5	1550.2	F	14	CC
Bellevue Marina	T19	48.4	1373.1	F	23	CC
Bellevue Marina	T20	40.6	905.4	F	7	
Bellevue Marina	T21	47.0	1450.6	F	11	
Bellevue Marina	T22	43.0	1247.0	F	8	
Bellevue Marina	T23	49.5	1644.0	F	17	
Bellevue Marina	T24	46.9	1234.3	F	9	CC
Bellevue Marina	T27	41.5	998.1	F	7	
Bellevue Marina	T28	48.0	1576.3	F	15	
Bellevue Marina	T29	45.0	1230.3	F	10	
Bellevue Marina	T30	42.4	1152.2	F	9	
Bellevue Marina	T31	43.0	1064.9	F	7	
Bellevue Marina	T32	47.0	1445.5	F	16	C
Bellevue Marina	T33	46.0	1495.3	F	11	
Bellevue Marina	T34	44.0	1093.1	F	10	
Bellevue Marina	T35	46.3	1319.5	F	13	

Bellevue Marina	T36	42.0	1112.0	M	10	
Bellevue Marina	T37	41.0	962.9	F	8	
Bellevue Marina	T38	41.0	1105.2	F	7	
Bellevue Marina	T39	43.5	1227.3	M	8	
Bellevue Marina	T40	47.5	1423.4	F	16	CC
Bellevue Marina	T41	43.5	1252.5	M	12	
Bellevue Marina	T42	42.4	1075.5	M	12	
Bellevue Marina	T43	43.5	1113.3	M	15	
Bellevue Marina	T44	39.7	953.0	M	6	
Bellevue Marina	T45	46.1	1359.4	F	15	
Bellevue Marina	T46	43.7	1209.1	M	10	
Bellevue Marina	T47	44.0	1125.9	F	11	
Bellevue Marina	T48	42.1	1109.9	F	10	
Bellevue Marina	T49	39.9	993.2	F	7	
Bellevue Marina	T50	47.8	1646.4	F	18	
Bellevue Marina	T51	46.4	1543.2	F	12	
Bellevue Marina	T52	44.4	1233.4	M	15	
Bellevue Marina	T53	46.7	1367.2	F	16	
Bellevue Marina	T54	45.3	1368.5	F	11	CC
Bellevue Marina	T55	48.0	1685.7	F	8	
Bellevue Marina	T56	42.2	1043.3	F	9	
Bellevue Marina	T57	44.4	1381.4	F	9	
Bellevue Marina	T58	42.9	1202.8	M	7	
Bellevue Marina	T59	43.0	1245.7	F	11	
Bellevue Marina	T60	43.7	1104.2	F	12	
Bellevue Marina	T122	37.8	691.8	M	6	
Bellevue Marina	T123	36.0	611.3	IF	6	
Partridge Point	378	46.6	1345.6	F	14	

Partridge Point	379	49.6	1649.0	F	21	C
Partridge Point	381	45.9	1268.6	F	13	
Partridge Point	383	47.1	1278.0	F	15	
Partridge Point	385	44.6	1265.7	F	19	
Partridge Point	386	46.5	1335.7	F	10	
Partridge Point	387	50.7	1734.3	F	17	
Partridge Point	388	50.0	1431.5	F	19	
Partridge Point	389	47.6	1417.6	F	18	
Partridge Point	390	37.6	715.4	F	6	
Partridge Point	391	47.7	1492.3	F	17	HC
Partridge Point	396	42.2	1121.9	F	7	
Partridge Point	397	47.0	1467.4	F	11	
Partridge Point	399	48.4	1426.1	F	17	
Partridge Point	401	44.4	1034.2	F	10	
Partridge Point	404	47.5	1451.5	F	17	
Partridge Point	406	38.3	794.5	F	7	
Partridge Point	407	45.6	1329.4	F	15	
Partridge Point	410	46.8	1426.8	F	12	
Partridge Point	418	37.6	736.0	F	6	
Partridge Point	377	45.3	1177.3	M	15	
Partridge Point	380	41.0	916.2	M	12	
Partridge Point	382	43.9	1063.7	M	10	
Partridge Point	392	41.5	1071.6	M	13	
Partridge Point	393	33.5	534.8	M	5	
Partridge Point	394	44.1	1065.5	IM	13	
Partridge Point	395	43.1	986.7	M	11	
Partridge Point	398	44.3	1059.4	M	19	

Partridge Point	400	44.9	1190.4	M	15	
Partridge Point	402	38.9	811.0	M	8	
Partridge Point	403	34.8	596.8	M	5	
Partridge Point	405	34.2	596.9	M	5	
Partridge Point	408	42.2	997.8	M	13	
Partridge Point	409	36.2	664.9	M	6	HA,HC
Partridge Point	411	41.4	985.3	M	8	
Partridge Point	412	42.6	1243.0	M	9	
Partridge Point	413	39.1	867.2	M	7	
Partridge Point	414	36.0	700.0	M	6	
Partridge Point	415	41.0	873.2	M	11	
Partridge Point	416	41.8	996.8	M	14	
Partridge Point	417	34.4	559.7	M	5	

Appendix B: White Suckers collected in 2015
Statistics on age, gender, fork length and total body weight

All Fish (100)
median length: 44.7 cm
median weight: 1290.0 g
median age: 7.3 years

Females (57)
median length: 46.2 cm
median weight: 1406.9 g
median age: 7.9 years

Males (43)
median length: 42.7 cm
median weight: 1135.0 g
median age: 6.5 years

Notes:
C – Cholangioma
CC – Cholangio Carcinoma
HC – Hepatocelluar Carcinoma
HA – Hepatocelluar Adenoma
R – Putative Rodlet

Location	Fish ID #	Length (cm)	Weight (g)	Gender	Age (years)	Tumour
	500	47.4	1498.6	F	8	
	501	48.1	1422.3	F	8	
	502	46.3	1186.9	F	7	
	505	47.7	1457.1	F	8	
	506	49.6	1692.1	F	10	
	507	48.2	1763.8	F	9	
	508	49.6	1681.5	F	9	
	510	48.5	1463.9	F	8	
	511	42.6	1273.2	F	4	
	512	40.5	1183.2	F	7	
	515	47.2	1484.8	F	8	
	516	47.3	1514.9	F	8	
	517	43.5	1234.1	F	5	
	520	48	1646.9	F	9	
	521	48.2	1556	F	9	
	524	51.4	1707.2	F	12	
	526	43.3	1229.4	F	6	

	527	44.4	1226	F	5	
	528	48.2	1230.9	F	9	
	529	45.9	1538.3	F	8	
	530	43.8	1171.4	F	8	
	532	43.5	1163.8	F	6	
	533	43.5	1218.3	F	6	
	536	39.9	1021.5	F	5	
	537	49.1	1758.8	F	10	R
	539	43.9	1101.6	F	7	
	540	47	1260.3	F	8	
	541	44.9	1533.4	F	7	
	542	50.3	1608.3	F	10	
	543	44.9	1705.6	F	7	
	544	37.6	1284.6	F	3	
	545	44.2	868	F	8	
	547	41.3	1551.5	F	6	
	550	48.1	1322.6	F	8	
	551	48.1	1575.1	F	9	
	553	48.2	1715.3	F	8	
	556	43.1	1162.1	F	7	
	557	46.7	1479.1	F	8	
	559	46.5	1218	F	7	
	560	45.1	1372.1	F	9	
	561	45.1	1208.4	F	7	
	563	50	1556.2	F	12	HC
	565	49.9	1393	F	11	
	569	48.2	1608.2	F	7	
	579	46.9	1509.8	F	10	R

	580	47.7	1442.3	F	9	
	584	46.9	1641.5	F	9	
	585	45.4	1252.3	F	8	C
	588	44	1184.1	F	7	
	589	48	1478.2	F	9	
	590	45.9	1506.1	F	10	
	591	49.2	1476.8	F	10	
	592	45	1334	F	7	
	593	45.3	1330.5	F	8	
	597	44.5	1275	F	7	C
	598	44.7	1211.3	F	6	
	599	50.6	1705.2	F	9	
	503	44.9	1116.5	M	8	
	504	42.5	1093.7	M	6	
	509	46.5	1388.6	M	8	
	513	41.5	1121.2	M	5	
	514	43.3	1109.2	M	6	
	518	42.3	1167.4	M	5	
	519	39.2	872	M	5	
	522	42.9	1278.1	M	8	
	523	47.3	1507.8	M	8	
	525	43.7	1255.1	M	7	
	531	42.9	1191	M	6	
	534	42.8	1128.7	M	6	
	535	39.5	912.3	M	5	
	538	31.6	1037.2	M	6	
	546	47.7	1375.3	M	8	
	548	44.1	1058.2	M	7	

	549	44.3	1325.3	M	6	
	552	46.7	1485.7	M	9	
	554	43.5	1196.6	M	6	
	555	43.1	1095.7	M	8	
	558	40.3	1064.4	M	6	
	562	41.9	1061.9	M	6	
	564	40.8	1010.1	M	6	
	566	44.1	1224.2	M	10	
	567	42.7	1071.6	M	7	
	568	46.6	1335.2	M	7	
	570	41.7	1028.7	M	7	
	571	41	1057.1	M	7	
	572	44.1	1107.8	M	8	
	573	43	1018.8	M	6	
	574	40.4	937.5	M	5	
	575	42.2	1013.5	M	5	CC
	576	45	1379.9	M	7	
	577	43.8	1203.5	M	6	
	578	40.9	963.3	M	6	
	581	43.9	1152.5	M	7	
	582	37.7	730.3	M	6	
	583	42.9	1096.8	M	3	
	586	42.9	1203.8	M	7	
	587	41.1	947.1	M	7	
	594	42.4	1112.4	M	7	
	595	43.3	1306.4	M	6	
	596	41.1	1061.5	M	5	