

Prepared in cooperation with the Wisconsin Department of Natural Resources

Assessment of Skin and Liver Neoplasms in White Sucker (*Catostomus commersonii*) Collected at the Sheboygan River Area of Concern, Wisconsin, in 2017



Open-File Report 2019-1014

Cover. U.S. Geological Survey biologists processing fish collected in the Sheboygan River, Wisconsin, and images of sampled fish with skin tumors, lesions, and nodules. Photographs by V.S. Blazer, U.S. Geological Survey.

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**U.S. Department of the Interior
U.S. Geological Survey**

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U.S. Geological Survey
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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
micrometer (μm)	0.00003937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Volume		
milliliter (mL)	0.03382	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	1.308	cubic yard (yd^3)
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

AOC	area of concern
BUI	beneficial use impairment
LSC	Leetown Science Center
PCB	polychlorinated biphenyl
PAH	polynuclear aromatic hydrocarbon
WDNR	Wisconsin Department of Natural Resources
WS	white sucker

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Abstract

Two hundred adult white sucker (*Catostomus commersonii*), age 3 years and older, were collected from the lower Sheboygan River Area of Concern in 2017, during the spring spawning run. Fish were euthanized, weighed, and measured, and any visible abnormalities were documented. Pieces of raised skin lesions as well as five to eight pieces of liver were removed and preserved for histopathological analyses. Skin and liver neoplasm prevalence was determined for assessment of the Fish Tumors or Other Deformities Beneficial Use Impairment. Although 45.5 percent of the suckers had raised skin lesions, the prevalence of skin neoplasms, either papilloma or squamous cell carcinoma, was 29.5 percent. This observation was similar to the prevalence (32.6 percent) of skin neoplasms in 2012; however, the percentage of squamous cell carcinoma was higher in 2017 (9.5 percent) than in 2012 (2.1 percent). The prevalence of liver neoplasms in 2017 (8.5 percent) was similar to that in 2012 (8.3 percent).

Introduction

In 1985, the lower 22.5-kilometer reach of the Sheboygan River and Harbor in east-central Wisconsin (fig. 1) was designated an Area of Concern (AOC) as a result of water-quality and habitat problems associated with the historical discharge of contaminants. The Sheboygan River AOC encompasses the lower Sheboygan River downstream from the Sheboygan Falls Dam, including the entire harbor and nearshore water of Lake Michigan. Nine of the 14 beneficial use impairments (BUIs) of waterways were identified, including the “fish tumors or other deformities” impairment. Contaminants of concern, including suspended solids, fecal coliform bacteria, phosphorus, nitrogen, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and heavy metals, were considered the

primary contributors. The elevated concentrations of nutrients, solids, and toxic compounds entering the river caused a series of problems, including nuisance algal blooms, fish consumption advisories, and contaminated sediments. The contaminant discharges were also suspected of contributing to the degradation of wildlife, fish, and benthos and plankton populations, and the reduction in fish and wildlife habitat (U.S. Environmental Protection Agency, 2018). Contaminated sediment is considered a major contributor of contaminant compounds and contributes directly or indirectly to seven of the BUIs at AOCs within the Great Lakes Basin (Burzynski, 2000).

Unfortunately, historical data to assess the fish tumor BUI within the Sheboygan AOC are limited. Fish health assessments were conducted by the Wisconsin Department of Natural Resources (WDNR) on white sucker (WS) captured in the AOC in 1994, but the overall sample size was small. Only 16 liver and 4 each of spleen, kidney, and gill samples were collected from the lower Sheboygan River and an upstream reference site. The research concluded that WS residing in the lower Sheboygan River were exposed to and absorbed substantial amounts of PCBs and PAHs, and exhibited biochemical, histological, and hematological alterations, indicative of impaired fish condition (Schrack and others, 1997). In 2012, a more comprehensive (193 adult WS) survey was completed. Microscopic analyses of raised skin lesions and liver tissue collected from these fish indicated 32.6 percent of the WS had skin neoplasms, whereas 8.3 percent had liver neoplasms. This prevalence was greater than the 5 percent indicated in the 2008 Delisting Targets for the Sheboygan River Area of Concern: Final Report (Environmental Consulting & Technology, Inc., 2008). It was also greater than the liver tumor prevalence of WS collected within the Kewaunee River (3.5 percent), a non-AOC reference site (Blazer and others, 2017). Consequently, monitoring of the tumor prevalence was continued in 2017. This report documents the findings of the tumor survey conducted in 2017 and compares them with the findings from 2012.

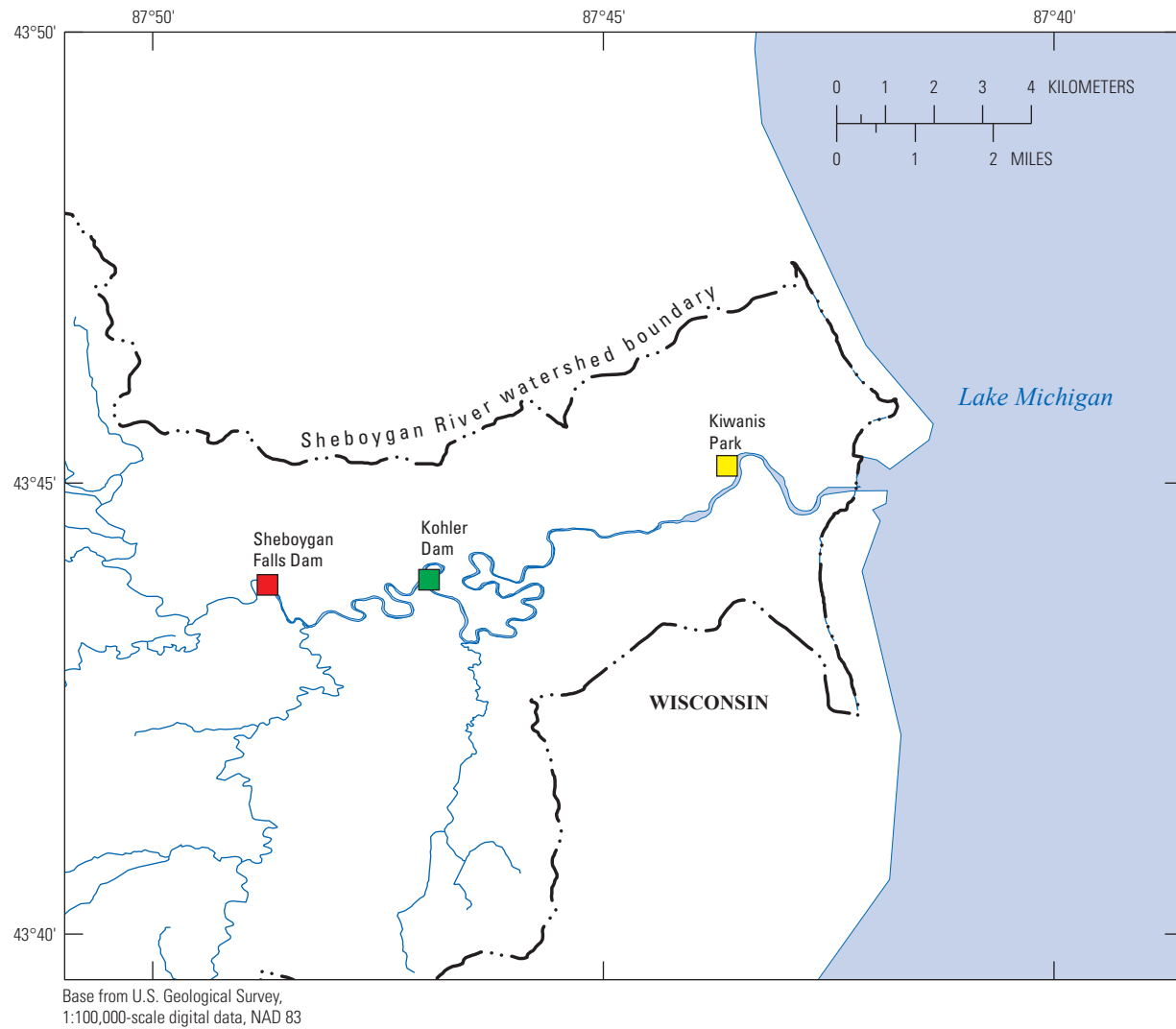


Figure 1. Lower Sheboygan River, Wisconsin. Fish were collected in the vicinity of Kiwanis Park.

Methods

Field Methods

White sucker (WS) age 3 years and older were targeted to focus on sexually mature individuals (Becker, 1983) that were easily accessible during the spring spawning run. Fish were collected by Wisconsin Department of Natural Resources (WDNR) personnel using boat electroshocking in the vicinity of Kiwanis Park, Sheboygan, Wisconsin (fig. 1) and were processed as they were collected over a 2-day period from March 30 to 31, 2017. Therefore, the samples are considered to be a random sample of the Sheboygan WS population.

Fish were euthanized with a lethal aqueous dose of buffered Tricaine-S (Syndel USA, Ferndale, Washington; 300 milligrams per liter) immediately prior to necropsy. Necropsies were performed by personnel from the U.S. Geological Survey Leetown Science Center (LSC) and West Virginia University (Morgantown) in accordance with the LSC laboratory animal care and use policy. White sucker were weighed, measured, and examined for any grossly visible abnormalities. Pieces of liver (5 to 7 discrete areas throughout the organ) as well as any skin lesions were placed into Z-fix solution (Anatech Ltd., Battle Creek, Michigan) for preservation. External abnormalities including red and eroded lesions; melanistic spots on body surfaces; and raised, pale to reddened lesions in the oral cavity and on the fins and body surfaces were recorded. Prevalence was calculated as the number of fish with each abnormality divided by total number of fish multiplied by 100 percent. Otoliths were removed for age determination.

Laboratory Methods

Preserved tissues were routinely processed, embedded into paraffin, sectioned at 5 micrometers (μm) and stained with hematoxylin and eosin (Luna, 1992). A variety of microscopic pathological changes, including inflammatory, proliferative, preneoplastic, and neoplastic changes in the skin and liver, were documented following the diagnostic criteria developed for brown bullhead and other fish species (Boorman and others, 1997; Wolf and Wolfe, 2005; Blazer and others, 2006; Blazer and others, 2007). The microscopic appearance of the observed lesions in WS were described previously by Blazer and others (2017). All pathology slides were read by two of the coauthors (V.S. Blazer and H.L. Walsh), and consensus was reached on all diagnoses.

Lapillus otoliths were prepared for aging using a modification of the multiple-stage process described by Koch and Quist (2007). First, the caps of plastic 2.0-milliliter flat-top microcentrifuge tubes (Fisher Scientific, Pittsburgh, Pennsylvania) were filled with modeling clay and their tapered ends removed to create a cylinder. Single lapilli were placed into the clay such that the “thumb” of the otoliths was embedded into the clay. The vial was filled using the Epoxicure brand

of resin and hardener (Buehler Inc., Lake Bluff, Illinois) and allowed to harden. The plastic case was removed and the otolith was sectioned at 7.6-millimeter thickness using an Isomet low-speed saw (Buehler Inc.). Sections were read under transmitted light by two individuals and consensus age was reached by using a light microscope.

Statistical Analyses

Data were compared by using GraphPad version 5 (GraphPad Software, Inc., La Jolla, California). Comparison of prevalence among years was made by using Fisher’s exact test. An α -level of 0.05 was used to indicate significance in all tests.

Biometric Data, Gross Abnormalities, and Microscopic Observations

Biometric Data

In 2017, a total of 77 females, 120 males, and 3 unidentified white sucker (WS) were collected. Fish ranged in age from 3 to 18 years (table 1, at end of report). Otoliths were not collected for three fish. The mean age was 8.6 ± 2.9 (mean \pm standard deviation) years in 2017.

In 2012, 193 WS were collected—112 females and 81 males—and ranged in age from 3 to 28 years (table 2, at end of report). The mean age of the WS collected in 2012 was 10.2 ± 4.4 years.

The age of WS collected in 2012 was significantly ($p=0.0004$) greater than the age of those collected in 2017. More fish collected in 2012 were 10 years old or older (fig. 2).

External Lesions and Prevalence

Grossly observed abnormalities included three types of raised skin and lip lesions: small, raised, discrete grayish-white lesions involving a single scale to larger, nodular, raised white areas (fig. 3A and 3B); slightly raised, translucent, plaque-like lesions (fig. 3C and 3D); and the larger, multi-lobed, papillomatous, pale to reddish lesions of lips and body surface (fig. 3E and 3F).

In 2017, 45.5 percent of the WS had some type of raised lesion and 11 percent had more than one type. The large raised growths on lips and body surface were the most commonly observed. The prevalence of raised skin and lip lesions in 2017 (45.5 percent) was not significantly higher than the 38.3-percent prevalence noted in 2012 (table 3). The prevalence of both discrete white spots was higher in 2017, whereas the prevalence of mucoid lesions was not quite significantly different ($p=0.0771$) between collection years. The prevalence of raised papillomatous growths was also not different between years.

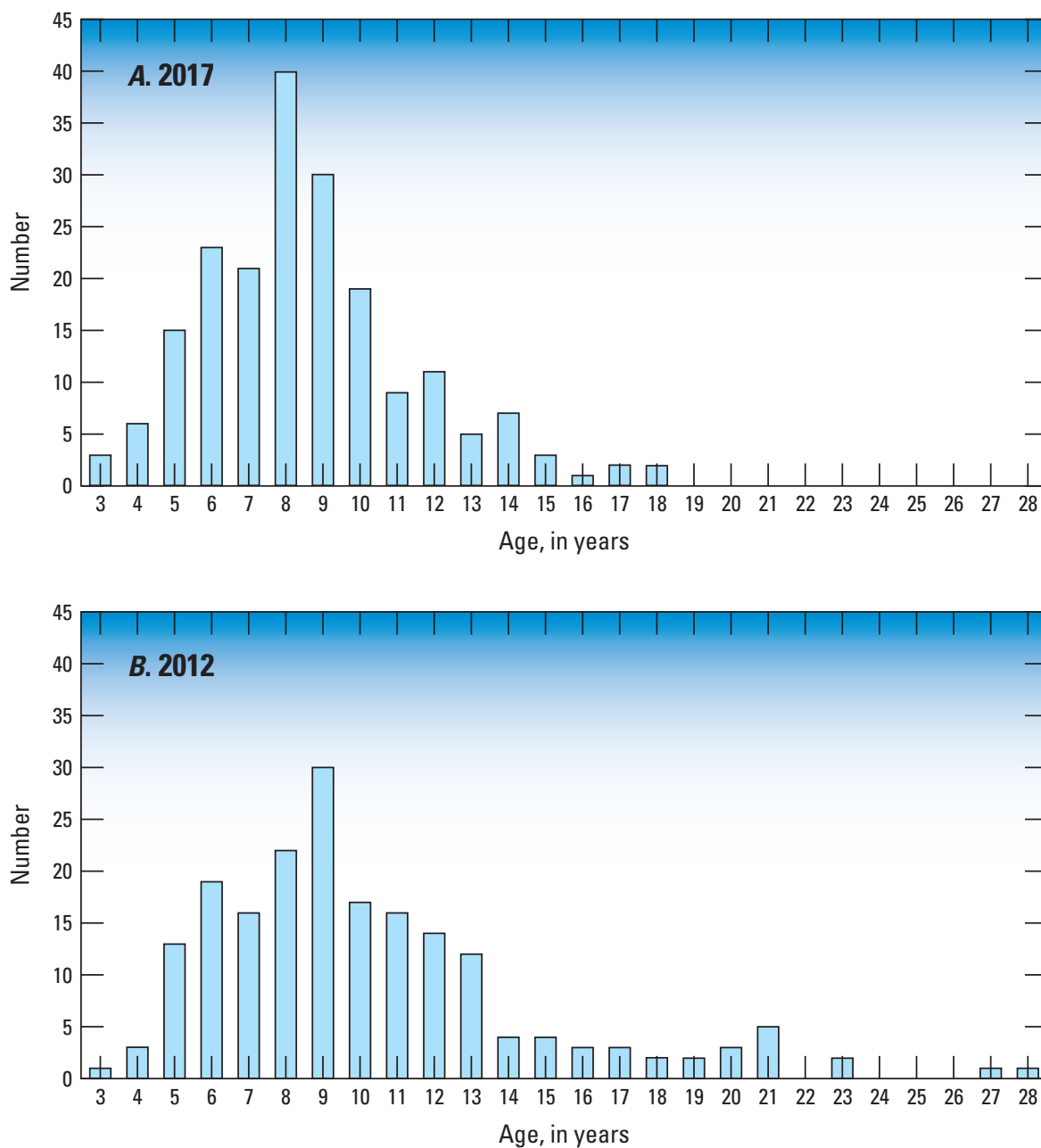


Figure 2. Age distribution of white sucker collected in the Sheboygan River, Wisconsin: *A*, age of the 200 white sucker collected in spring 2017; *B*, age of the 193 white sucker collected in spring 2012.

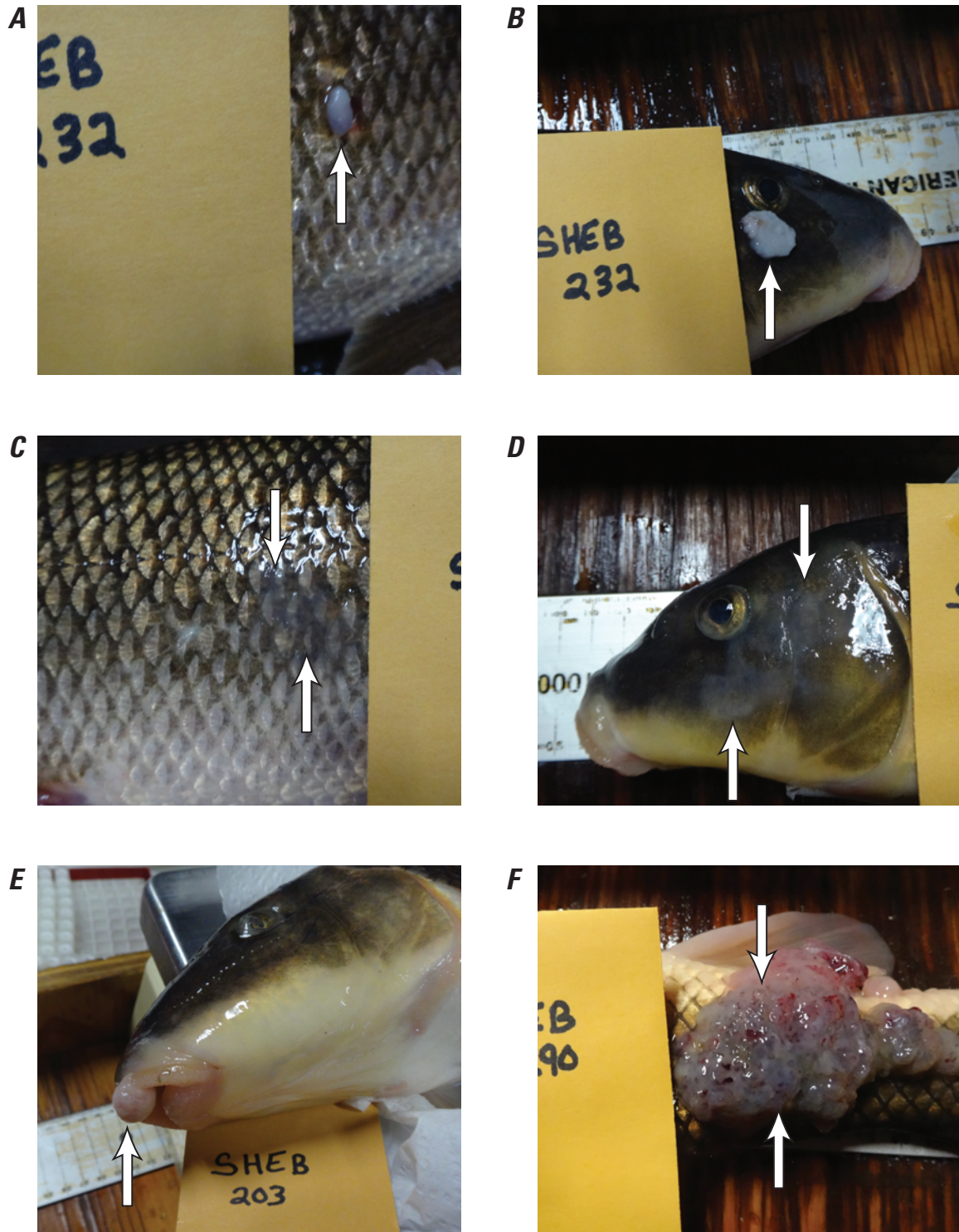


Figure 3. Raised skin lesions observed on white sucker collected in the Sheboygan River, Wisconsin, in 2017: *A*, Slightly raised white lesion covering a scale on the body surface; *B*, raised white lesion on the opercle; *C*, slightly raised mucoid lesion on the body surface; *D*, large, slightly raised mucoid lesion on the opercle; *E*, raised, papillomatous lesion on the lip; and *F*, large, raised lesion on the body surface. Photographs by V.S. Blazer, U.S. Geological Survey.

Table 3. Distribution of skin and liver lesions of white sucker collected in the Sheboygan River Area of Concern, Wisconsin, in 2017 and 2012.

[*n*, sample size (number of fish); different superscripts indicate a statistical difference between collection years]

Lesion type	Percentage of fish collected	
	Year 2017 (<i>n</i> = 200)	Year 2012 (<i>n</i> = 193)
Grossly observable skin lesions		
White spots on body	16.0 ^a	3.6 ^b
Mucoid plaques on fin/body	11.5 ^a	6.2 ^a
Raised papillomatous growths on lip/body	28.5 ^a	33.2 ^a
<i>Percentage of fish with raised skin lesions</i>	45.5 ^a	38.3 ^a
Microscopically verified skin neoplasms		
Papilloma	20.0 ^a	30.5 ^b
Squamous cell carcinoma	9.5 ^a	2.1 ^b
<i>Percentage of fish with skin neoplasms</i>	29.5 ^a	32.6 ^a
Microscopically verified liver neoplasms		
Hepatic cell	4.5 ^a	2.1 ^a
Bile duct	4.5 ^a	6.2 ^a
<i>Percentage of fish with liver neoplasms</i>	8.5 ^a	8.3 ^a

Skin Tumor Prevalence

Pieces of the raised skin lesions were examined microscopically to diagnose the pathological response. Two types of neoplasms, papilloma (a benign neoplasm) and squamous cell carcinoma (an invasive, malignant neoplasm), were observed. The microscopic appearance of these lesions was described previously (Blazer and others, 2017). The percentage of WS with any skin neoplasm was 29.5 percent in 2017, which was not statistically different from that observed in 2012 (32.6 percent). However, the percentage of suckers with malignant squamous cell carcinoma was greater in 2017 (table 1). Skin neoplasms were observed in WS aged 4 to 18 years in 2017 and 5 to 21 years in 2012. Mean age of suckers with skin neoplasms was lower ($p=0.0229$) in 2017 (9.3 ± 3.0) than in 2012 (11.2 ± 4.4).

Liver Tumor Prevalence

Both hepatic cell (adenoma and carcinoma) and bile duct (cholangioma and cholangiocarcinoma) tumors were observed. The microscopic appearance of these lesions was described previously (Blazer and others, 2017). The percentage of WS with any type of liver neoplasm in 2017 (8.5) was similar to

that in 2012 (8.3). The percentage of suckers with hepatic cell neoplasms or bile duct neoplasms was not significantly different between collection years (table 1). Both hepatic cell and bile duct neoplasms were observed in one fish in 2017.

Assessment of Skin and Liver Neoplasms

The initial study (data presented in table 2) of white sucker (WS) in the Sheboygan River Area of Concern (AOC) was completed in 2012 to provide a baseline for the fish tumor BUI. The prevalence of liver neoplasms was 8.3 percent (greater than the 5-percent delisting threshold) and 32.6 percent of the WS had skin neoplasms (Blazer and others, 2017). In 2012–13, approximately 305,822 cubic meters of sediment contaminated with PCBs and PAHs was removed from the river between Kiwanis Park and Lake Michigan. Two habitat restoration projects were also completed. Most of the WS collected in 2017 (data presented in table 3) would have been present in the river prior to and during the completion of the dredging in 2013 (4 years or older). Previous studies of brown bullhead at the Black River AOC, in the Lake Erie watershed, demonstrated a high prevalence of liver neoplasms associated with a coking plant and PAHs in sediment. Closing of the plant resulted in decreased PAH concentrations in sediment and a decreased prevalence of liver neoplasms. Dredging of the contaminated sediments led to an increased liver neoplasm prevalence when bullhead were surveyed 2 to 3 years after dredging. It was hypothesized by the authors that dredging caused exposure to buried PAHs. Subsequent monitoring indicated that younger bullhead not present prior to dredging had a reduced prevalence of liver neoplasms (Baumann and Harshbarger, 1998). It is possible a similar response is occurring in the WS from the Sheboygan AOC. Because the dredging was completed in 2013, almost all of the fish collected in 2017 were old enough to have been exposed to resuspended contaminants. Subsequent sampling will be required to determine whether removal of this sediment has reduced the tumor prevalence.

Liver neoplasms in fish have been associated with exposure to PAHs (reviewed by Rafferty and others, 2009), although other factors may be important. Hepatitis virus is a major risk factor for liver cancer in humans (Perz and others, 2006). A hepatitis B virus was discovered during hepatic transcriptome development of WS throughout the Great Lakes watershed (Hahn and others, 2015). There is currently no evidence that this virus is linked to the WS liver neoplasms. Human cholangiocarcinoma is associated with an opisthorchid trematode in parts of the world where raw fish is commonly eaten. The trematode induces biliary fibrosis and inflammation and eventually cancer (Sripa and others, 2011). Biliary hyperplasia, fibrosis, and inflammation, often associated with plasmodia of a myxozoan parasite, were also noted.

The risk factors associated with skin neoplasms are less well understood than those for liver neoplasms, although increased prevalence of papilloma and other skin neoplasms at sites with industrial contaminants and sewage effluent have been documented (Hayes and others, 1990; Korkea-aho and others, 2008). Associations between WS papilloma prevalence and exposure to persistent chemicals such as PCBs and organochlorines have been reported (Premdas and others, 1995). Experimental exposures to androgens and estrogens were shown to increase the growth of papilloma (Premdas and others, 2001; Kortet and others, 2003). Viruses have been associated with epidermal hyperplasia and mucoid lesions in walleye (*Sander vitreus*) similarly to those documented here in WS (Yamamoto and others, 1985). Further research is needed to understand the interactions among infectious agents, the proliferative responses they induce, and chemical contaminants in the initiation and progression of skin and liver neoplasms of WS.

References Cited

- Baumann, P.C., and Harshbarger, J.C., 1998, Long term trends in liver neoplasm epizootics of brown bullhead in the Black River, Ohio: Environmental Monitoring and Assessment, v. 53, p.213–223. [Also available at <https://doi.org/10.1023/A:1005967631275>.]
- Becker, G.C., 1983, Fishes of Wisconsin: Madison, Wisconsin, University of Wisconsin Press, 1,052 p.
- Blazer, V.S., Fournie, J.W., Wolf, J.C., and Wolfe, M.J., 2006, Diagnostic criteria for proliferative hepatic lesions in brown bullhead: Diseases of Aquatic Organisms, v. 72, p.19–30. [Also available at <https://pubs.er.usgs.gov/publication/70028252>.]
- Blazer, V.S., Fournie, J.W., Wolf, J.C., and Wolfe, M.J., 2007, Manual for the microscopic diagnosis of proliferative liver and skin lesions in brown bullhead (*Ameiurus nebulosus*): Erie, Pennsylvania, Pennsylvania Sea Grant, 34 p., accessed February 20, 2018, at <http://seagrant.psu.edu/sites/default/files/Histo%20manual.pdf>.
- Blazer, V.S., Walsh, H.L., Braham, R.P., Hahn, C.M., and McIntyre, P.B., 2017, Tumours in white suckers from Lake Michigan tributaries—Pathology and prevalence: Journal of Fish Diseases, v. 40, p. 377–393. [Also available at <https://doi.org/10.1111/jfd.12520>.]
- Boorman, G.A., Botts, S., Bunton, T.E., Fournie, J.W., Harshbarger, J.C., Hawkins, W.E., Hinton, D.E., Jokinen, M.P., Okihira, M.S., and Wolfe, M.J., 1997, Diagnostic criteria for degenerative, inflammatory, proliferative nonneoplastic and neoplastic liver lesions in medaka (*Oryzias latipes*)—Consensus of a national toxicology program pathology working group: Toxicologic Pathology, v. 25, p. 202–210.
- Burzynski, M., 2000, Sheboygan River food chain and sediment contaminant assessment: Final project report, U.S. Environmental Protection Agency Grant #GL-995681, accessed October 4, 2018, at <http://www.epa.gov/glnpo/sediment/FoodChain/index.html>.
- Environmental Technology & Consulting, Inc., 2008, Delisting targets for the Sheboygan River Area of Concern—Final report: accessed August 12, 2018, at <https://dnr.wi.gov/topic/greatlakes/documents/SheboyganRiverFinalReport2008.pdf>.
- Hahn, C.M., Iwanowicz, L.R., Cornman, R.S., Conway, C.M., Winton, J.R., and Blazer, V.S., 2015, Characterization of a novel Hepadnavirus in white sucker (*Catostomus commersonii*) from the Great Lakes region of the USA: Journal of Virology, v.89, p. 11801–11811. [Also available at <https://doi.org/10.1128/JVI.01278-15>.]
- Hayes, M., Smith, I.R., Rushmore, T.H., Crane, T.L., Thorn, C., Kocal, T.E., and Ferguson, H.W., 1990, Pathogenesis of skin and liver neoplasms in white suckers from industrially polluted areas in Lake Ontario: Science of the Total Environment, v. 94, p.105–123.
- Koch, J.D., and Quist, M.C., 2007, A technique for preparing fin rays and spines for age and growth analysis: North American Journal of Fisheries Management, v. 27, p. 782–784. [Also available at <https://doi.org/10.1577/M06-224.1>.]
- Korkea-aho, T.L., Vehniäinen, E.R., Kukkonen, J.V.K., and Taskinen, J., 2008, The effects of treated effluents on the intensity of papillomatosis and HSP70 expression in roach: Ecotoxicology and Environmental Safety, v. 70, p. 462–468. [Also available at <https://doi.org/10.1016/j.ecoenv.2008.03.004>.]
- Kortet, R., Vainikka, A., Rantala, M.J., Jokinen, I., and Taskinen, J., 2003, Sexual ornamentation, androgens and papillomatosis in male roach (*Rutilus rutilus*): Evolutionary Ecology Research, v. 5, p. 411–419.
- Luna, L.G., 1992, Histopathologic methods and color atlas of special stains and tissue artifacts: Gaithersburg, Maryland, American Histolabs, Inc., 767 p.
- Perz, J.J., Armstrong, G.L., Farrington, L.A., Hutin, Y.J.F., and Bell, B.P., 2006, The contributions of hepatitis B virus and hepatitis C virus infections to cirrhosis and primary liver cancer worldwide: Journal of Hepatology, v. 45, p. 529–538. [Also available at <https://doi.org/10.1016/j.jhep.2006.05.013>.]
- Premdas, P.D., Metcalfe, T.L., Bailey, M.E., and Metcalfe, C.D., 1995, The prevalence and histologic appearance of lip papillomas in white sucker (*Catostomus commersoni*) from two sites in central Ontario, Canada: Journal of the Great Lakes Research, v. 21, p. 207–218. [Also available at [https://doi.org/10.1016/S0380-1330\(95\)71032-2](https://doi.org/10.1016/S0380-1330(95)71032-2).]

- Premdas, P.D., Metcalfe, T.L., and Brown, S., 2001, The effects of 17 β -oestradiol, testosterone and tamoxifen on the development of papillomata in *Catostomus commersoni*: Journal of Fish Biology, v. 59, p. 1056–1069. [Also available at <https://doi.org/10.1006/jfbi.2001.1717>.]
- Rafferty, S.D., Blazer, V.S., Pinkney, A.E., Grazio, J.L., Obert, E.C., and Boughton, L., 2009, A historical perspective on the “fish tumors or other deformities” beneficial use impairment at Great Lakes Areas of Concern: Journal of Great Lakes Research, v. 35, p. 496–506. [Also available at <https://doi.org/10.1016/j.jglr.2009.07.005>.]
- Schrank, C.S., Cormier, S.M., and Blazer, V.S., 1997, Contaminant exposure, biochemical, and histopathological biomarkers in white suckers from contaminated and reference sites in the Sheboygan River, Wisconsin: Journal of Great Lakes Research, v. 23, p. 119–130. [Also available at [https://doi.org/10.1016/S0380-1330\(97\)70890-6](https://doi.org/10.1016/S0380-1330(97)70890-6).]
- Sripa, B., Berthony, J.M., Sithithaworn, P., Kaewkes, S., Mairiang, E., Loukas, A., Mulvenna, J., Laha, T., Hotez, P.J., and Brindley, P.J., 2011, Opisthorchiasis and *Opisthorchis*-associated cholangiocarcinoma in Thailand and Laos: Acta Tropica, v. 120, p. S158–S168. [Also available at <https://doi.org/10.1016/j.actatropica.2010.07.006>.]
- U.S. Environmental Protection Agency, 2018, Great Lakes AOCs—About Sheboygan River AOC: accessed August 12, 2018, at <https://www.epa.gov/great-lakes-aocs/about-sheboygan-river-aoc>.
- Wolf, J.C., and Wolfe, M.J., 2005, A brief overview of non-neoplastic hepatic toxicity in fish: Toxicologic Pathology, v. 33, p. 75–85. [Also available at <https://doi.org/10.1080/01926230590890187>.]
- Yamamoto, T., Kelly, R.K., and Nielsen, O., 1985, Epidermal hyperplasia of walleye, *Stizostedion vitreum vitreum* (Mitchill), associated with retrovirus-like type-C particles—Prevalence, histologic and electron microscopic observations: Journal of Fish Diseases, v. 19, p. 425–436.

Table 1. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2017.

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma; ND, not determined]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
Sheb-201	3/30/2017	M	10	438	910	0	0	0	0	0	0
Sheb-202	3/30/2017	F	10	502	1,545	1	0	0	0	0	0
Sheb-203	3/30/2017	M	16	465	1,056	0	0	1	SCC	0	CC
Sheb-204	3/30/2017	F	9	431	970	0	0	0	0	1	0
Sheb-205	3/30/2017	M	7	472	1,234	0	0	0	0	0	0
Sheb-206	3/30/2017	F	9	463	1,344	0	0	1	papilloma	0	0
Sheb-207	3/30/2017	M	12	465	1,053	0	1	0	0	0	0
Sheb-208	3/30/2017	M	4	420	795	0	0	0	0	0	0
Sheb-209	3/30/2017	F	9	500	1,513	0	0	0	0	0	HCC
Sheb-210	3/30/2017	F	6	435	980	0	0	0	0	0	0
Sheb-211	3/30/2017	F	10	514	1,533	0	0	0	0	0	CO
Sheb-212	3/30/2017	M	9	448	1,004	0	0	1	papilloma	0	0
Sheb-213	3/30/2017	M	9	468	934	0	1	1	SCC	0	0
Sheb-214	3/30/2017	M	8	446	1,095	0	0	0	0	0	0
Sheb-215	3/30/2017	F	7	427	1,038	1	0	0	0	0	0
Sheb-216	3/30/2017	F	6	380	645	0	0	0	0	0	0
Sheb-217	3/30/2017	M	8	427	934	0	0	1	papilloma	0	0
Sheb-218	3/30/2017	M	8	434	905	0	0	0	0	0	0
Sheb-219	3/30/2017	F	6	423	839	0	0	0	0	0	0
Sheb-220	3/30/2017	ND	11	430	854	0	0	1	SCC	0	0
Sheb-221	3/30/2017	M	8	452	1,043	0	0	1	papilloma	0	0
Sheb-222	3/30/2017	F	10	485	1,184	0	0	1	papilloma	0	0
Sheb-223	3/30/2017	F	5	490	1,309	0	0	0	0	0	0
Sheb-224	3/30/2017	M	8	405	673	0	0	0	0	0	0
Sheb-225	3/30/2017	M	14	426	1,255	0	0	1	papilloma	0	0
Sheb-226	3/30/2017	M	10	425	776	0	0	0	0	0	0
Sheb-227	3/30/2017	F	10	487	1,270	0	0	0	0	0	0
Sheb-228	3/30/2017	M	9	457	977	0	1	0	0	1	0
Sheb-229	3/30/2017	M	6	416	819	0	0	1	papilloma	1	0
Sheb-230	3/30/2017	M	12	440	899	0	0	0	0	1	0
Sheb-231	3/30/2017	M	6	384	619	0	0	0	0	0	0
Sheb-232	3/30/2017	M	12	481	1,322	1	0	1	papilloma	0	0
Sheb-233	3/30/2017	M	9	440	984	0	0	0	0	0	0
Sheb-234	3/30/2017	F	6	440	824	0	0	0	0	0	0
Sheb-235	3/30/2017	F	12	503	1,525	1	0	0	0	0	0
Sheb-236	3/30/2017	M	11	447	976	0	1	1	papilloma	0	0
Sheb-237	3/30/2017	M	15	472	1,128	0	1	0	0	0	0
Sheb-238	3/30/2017	F	ND	501	1,591	0	1	0	0	0	0
Sheb-239	3/30/2017	M	9	462	1,058	0	0	0	0	0	0
Sheb-240	3/30/2017	M	9	442	886	0	0	0	0	0	0

10 **Assessment of Neoplasms in White Sucker Collected at the Sheboygan River Area of Concern, Wisconsin, in 2017**

Table 1. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2017.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma; ND, not determined]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
Sheb-241	3/30/2017	F	9	495	1,384	0	0	0	0	0	0
Sheb-242	3/30/2017	F	6	372	600	0	0	0	0	0	0
Sheb-243	3/30/2017	F	8	505	1,503	0	0	1	papilloma	0	0
Sheb-244	3/30/2017	M	14	481	1,112	0	0	0	0	0	0
Sheb-245	3/30/2017	M	14	453	1,080	0	0	1	papilloma	0	0
Sheb-246	3/30/2017	F	6	443	1,046	0	0	0	0	0	0
Sheb-247	3/30/2017	M	14	472	1,004	0	0	0	0	0	0
Sheb-248	3/30/2017	M	7	416	822	1	0	0	0	0	0
Sheb-249	3/30/2017	M	12	482	1,215	0	0	1	papilloma	0	0
Sheb-250	3/30/2017	M	8	433	923	0	0	1	papilloma	0	0
Sheb-251	3/30/2017	M	7	436	887	0	0	0	0	0	0
Sheb-252	3/30/2017	F	9	490	1,441	1	0	0	0	0	0
Sheb-253	3/30/2017	M	8	396	753	1	0	1	papilloma	0	0
Sheb-254	3/30/2017	M	17	489	1,090	1	1	1	SCC	0	0
Sheb-255	3/30/2017	M	12	482	1,107	1	0	0	0	0	0
Sheb-256	3/30/2017	M	11	464	1,182	0	0	0	0	0	0
Sheb-257	3/30/2017	M	8	452	1,017	1	0	1	papilloma	0	0
Sheb-258	3/30/2017	M	10	462	1,054	0	0	1	papilloma	0	0
Sheb-259	3/30/2017	M	5	440	879	0	0	0	0	0	0
Sheb-260	3/30/2017	F	8	476	1,126	0	0	0	0	0	0
Sheb-261	3/30/2017	M	9	433	863	1	1	0	0	0	0
Sheb-262	3/30/2017	M	9	494	1,373	0	0	0	0	0	0
Sheb-263	3/30/2017	F	6	451	970	0	0	0	0	0	0
Sheb-264	3/30/2017	M	13	459	1,094	0	0	1	papilloma	0	0
Sheb-265	3/30/2017	F	10	480	1,151	1	0	0	0	0	HCC
Sheb-266	3/30/2017	M	8	461	1,025	0	0	1	papilloma	0	0
Sheb-267	3/30/2017	M	3	408	748	0	0	0	0	0	0
Sheb-268	3/30/2017	M	3	409	732	0	0	0	0	0	0
Sheb-269	3/30/2017	M	5	410	752	0	0	0	0	0	0
Sheb-270	3/30/2017	M	6	464	1,080	0	0	0	0	0	0
Sheb-271	3/30/2017	F	5	490	1,311	1	0	1	papilloma	0	0
Sheb-272	3/30/2017	M	8	454	1,025	0	0	0	0	0	0
Sheb-273	3/30/2017	F	10	485	1,409	0	0	0	0	0	0
Sheb-274	3/30/2017	F	8	479	1,350	1	0	1	SCC	0	0
Sheb-275	3/30/2017	M	8	436	876	0	0	1	SCC	0	0
Sheb-276	3/30/2017	F	8	513	1,580	0	0	0	0	0	0
Sheb-277	3/30/2017	M	12	466	1,067	0	1	1	0	0	0
Sheb-278	3/30/2017	M	8	428	850	0	0	0	0	0	0
Sheb-279	3/30/2017	M	5	460	865	0	0	1	SCC	0	0
Sheb-280	3/30/2017	F	14	498	1,380	0	1	0	0	0	0

Table 1. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2017.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma; ND, not determined]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
Sheb-281	3/30/2017	M	8	429	843	0	0	0	0	0	0
Sheb-282	3/30/2017	M	8	464	1,156	0	0	0	0	0	0
Sheb-283	3/30/2017	M	5	452	1,103	0	0	0	0	0	0
Sheb-284	3/30/2017	M	6	373	527	0	1	0	0	0	0
Sheb-285	3/30/2017	M	7	446	924	1	1	0	0	0	0
Sheb-286	3/30/2017	F	11	510	1,570	1	0	0	papilloma	0	0
Sheb-287	3/30/2017	M	7	471	1,099	0	0	0	0	0	0
Sheb-288	3/30/2017	M	8	439	926	0	0	0	0	0	0
Sheb-289	3/30/2017	ND	17	491	1,273	0	0	0	0	0	0
Sheb-290	3/30/2017	F	9	520	1,464	0	1	1	SCC	0	HCC
Sheb-291	3/30/2017	M	12	484	1,076	0	0	0	0	0	CO
Sheb-292	3/30/2017	M	9	473	1,062	0	0	0	0	0	0
Sheb-293	3/30/2017	M	8	431	918	0	0	1	papilloma	0	CC
Sheb-294	3/30/2017	M	ND	424	851	1	0	0	0	0	0
Sheb-295	3/30/2017	F	14	561	2,131	1	0	0	0	0	0
Sheb-296	3/30/2017	F	8	438	983	1	0	0	0	0	0
Sheb-297	3/30/2017	M	8	456	1,046	0	0	0	0	0	0
Sheb-298	3/30/2017	F	6	448	974	0	0	0	0	0	HA
Sheb-299	3/30/2017	F	9	485	1,420	0	0	0	0	0	0
Sheb-300	3/30/2017	M	5	449	926	0	0	0	0	0	0
Sheb-301	3/31/2017	M	8	438	907	0	0	0	0	0	0
Sheb-302	3/31/2017	F	13	484	1,187	0	0	0	0	0	0
Sheb-303	3/31/2017	M	6	422	838	0	0	1	SCC	0	0
Sheb-304	3/31/2017	F	4	379	643	0	0	0	0	0	0
Sheb-305	3/31/2017	F	9	493	1,365	1	0	0	0	0	0
Sheb-306	3/31/2017	M	7	469	1,207	0	0	0	0	0	0
Sheb-307	3/31/2017	F	7	483	1,189	0	0	0	0	0	0
Sheb-308	3/31/2017	F	6	472	1,333	0	0	0	0	0	0
Sheb-309	3/31/2017	M	14	500	1,560	0	0	0	0	0	0
Sheb-310	3/31/2017	M	5	397	639	0	0	0	0	0	0
Sheb-311	3/31/2017	M	7	432	960	0	0	0	0	0	0
Sheb-312	3/31/2017	M	8	421	875	0	0	0	0	0	0
Sheb-313	3/31/2017	M	7	477	1,095	0	0	1	SCC	0	0
Sheb-314	3/31/2017	F	8	526	1,620	0	0	0	0	0	HA
Sheb-315	3/31/2017	F	11	490	1,456	0	0	0	0	0	0
Sheb-316	3/31/2017	M	4	441	833	0	0	1	papilloma	0	0
Sheb-317	3/31/2017	F	5	450	1,068	0	0	1	SCC	0	0
Sheb-318	3/31/2017	M	5	426	785	0	0	0	0	0	0
Sheb-319	3/31/2017	F	4	374	585	0	0	0	0	0	0
Sheb-320	3/31/2017	M	10	482	1,205	0	1	0	0	0	CC

12 Assessment of Neoplasms in White Sucker Collected at the Sheboygan River Area of Concern, Wisconsin, in 2017

Table 1. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2017.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma; ND, not determined]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
Sheb-321	3/31/2017	M	4	425	900	1	0	0	SCC	0	0
Sheb-322	3/31/2017	M	12	491	1,144	0	0	1	0	0	CC, HCC
Sheb-323	3/31/2017	M	6	476	1,138	0	0	1	SCC	0	0
Sheb-324	3/31/2017	F	18	554	1,511	0	0	1	papilloma	0	0
Sheb-325	3/31/2017	F	9	441	1,038	1	0	1	papilloma	0	0
Sheb-326	3/31/2017	F	9	531	1,660	0	0	1	SCC	0	HA
Sheb-327	3/31/2017	F	9	490	1,141	0	1	1	SCC	0	0
Sheb-328	3/31/2017	F	8	471	1,340	0	0	0	0	0	0
Sheb-329	3/31/2017	M	9	478	1,118	1	0	0	0	0	0
Sheb-330	3/31/2017	M	6	422	822	0	0	0	0	0	0
Sheb-331	3/31/2017	M	3	414	762	0	0	0	0	0	CC
Sheb-332	3/31/2017	M	9	482	1,253	0	0	1	papilloma	0	0
Sheb-333	3/31/2017	F	6	484	1,456	0	0	0	0	0	0
Sheb-334	3/31/2017	M	7	470	1,090	0	0	0	0	0	0
Sheb-335	3/31/2017	F	8	439	1,035	0	0	0	0	0	0
Sheb-336	3/31/2017	M	7	425	854	0	0	1	papilloma	0	0
Sheb-337	3/31/2017	M	10	456	1,059	0	0	0	0	0	0
Sheb-338	3/31/2017	M	7	432	890	0	0	0	0	0	0
Sheb-339	3/31/2017	F	9	524	1,665	0	0	1	SCC	0	HA
Sheb-340	3/31/2017	M	12	446	956	1	0	1	papilloma	0	0
Sheb-341	3/31/2017	F	5	430	943	0	1	0	0	0	0
Sheb-342	3/31/2017	F	9	509	1,446	0	1	1	SCC	0	0
Sheb-343	3/31/2017	M	11	443	972	0	0	0	0	0	0
Sheb-344	3/31/2017	F	7	447	1,210	0	0	0	0	0	0
Sheb-345	3/31/2017	F	7	449	1,124	0	0	0	0	0	HCC
Sheb-346	3/31/2017	M	9	447	1,022	0	0	1	papilloma	0	0
Sheb-347	3/31/2017	F	15	561	1,872	0	1	1	SCC	0	0
Sheb-348	3/31/2017	F	8	443	898	0	0	0	0	0	0
Sheb-349	3/31/2017	M	18	464	1,051	0	0	0	0	0	CC
Sheb-350	3/31/2017	M	5	409	695	1	0	0	0	0	0
Sheb-351	3/31/2017	M	10	467	1,093	0	0	0	0	0	0
Sheb-352	3/31/2017	F	10	501	1,684	0	0	0	0	1	0
Sheb-353	3/31/2017	M	10	462	1,112	0	0	0	0	0	0
Sheb-354	3/31/2017	M	8	422	921	1	0	0	SCC	0	0
Sheb-355	3/31/2017	M	ND	489	1,210	0	0	0	0	0	0
Sheb-356	3/31/2017	M	11	477	1,275	1	0	1	papilloma	0	0
Sheb-357	3/31/2017	F	11	339	402	1	0	0	0	0	0
Sheb-358	3/31/2017	M	9	336	860	0	0	0	0	0	0
Sheb-359	3/31/2017	F	13	514	1,365	0	0	0	0	0	0
Sheb-360	3/31/2017	M	4	416	830	0	0	0	0	0	0

Table 1. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2017.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma; ND, not determined]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
Sheb-361	3/31/2017	M	10	458	889	0	0	0	0	0	0
Sheb-362	3/31/2017	M	8	438	806	0	1	0	0	0	0
Sheb-363	3/31/2017	M	5	412	706	0	0	0	0	0	0
Sheb-364	3/31/2017	F	10	479	1,299	0	0	0	0	0	0
Sheb-365	3/31/2017	M	8	450	983	1	0	1	papilloma	0	0
Sheb-366	3/31/2017	M	6	426	786	0	0	0	0	0	0
Sheb-367	3/31/2017	F	13	527	1,848	0	0	0	0	0	0
Sheb-368	3/31/2017	M	8	478	1,128	0	0	1	papilloma	0	0
Sheb-369	3/31/2017	F	8	433	896	0	0	0	0	0	0
Sheb-370	3/31/2017	M	8	432	920	0	0	0	0	0	0
Sheb-371	3/31/2017	M	15	481	1,065	1	0	0	0	0	CC
Sheb-372	3/31/2017	M	7	441	997	0	0	0	0	0	0
Sheb-373	3/31/2017	M	10	472	1,157	1	1	1	papilloma	0	0
Sheb-374	3/31/2017	F	5	478	1,245	0	0	0	0	0	0
Sheb-375	3/31/2017	M	8	430	875	0	0	1	papilloma	0	0
Sheb-376	3/31/2017	F	9	494	1,392	0	0	0	0	0	0
Sheb-377	3/31/2017	M	8	418	829	0	0	1	papilloma	0	0
Sheb-378	3/31/2017	M	8	449	935	0	0	0	0	0	0
Sheb-379	3/31/2017	F	7	439	996	0	0	0	0	0	0
Sheb-380	3/31/2017	M	10	479	1,040	0	0	0	0	0	0
Sheb-381	3/31/2017	M	6	440	1,010	0	0	0	0	0	0
Sheb-382	3/31/2017	F	5	456	1,107	0	0	0	0	0	0
Sheb-383	3/31/2017	M	11	481	1,087	0	0	0	0	0	0
Sheb-384	3/31/2017	F	6	481	1,381	1	0	0	0	0	0
Sheb-385	3/31/2017	M	6	456	1,012	0	0	0	0	0	0
Sheb-386	3/31/2017	F	12	492	1,549	0	0	1	papilloma	0	0
Sheb-387	3/31/2017	F	6	481	1,290	0	0	0	0	0	0
Sheb-388	3/31/2017	F	9	518	1,491	0	0	0	0	0	0
Sheb-389	3/31/2017	M	9	469	1,044	0	0	1	papilloma	0	0
Sheb-390	3/31/2017	M	10	472	1,153	0	0	0	0	0	0
Sheb-391	3/31/2017	F	7	466	1,248	0	1	1	papilloma	0	0
Sheb-392	3/31/2017	M	13	470	1,045	0	0	1	papilloma	0	0
Sheb-393	3/31/2017	F	7	502	1,477	0	0	0	0	0	0
Sheb-394	3/31/2017	F	7	479	1,237	0	0	0	0	0	0
Sheb-395	3/31/2017	M	8	454	1,036	0	0	0	0	0	0
Sheb-396	3/31/2017	M	8	450	1,062	0	0	0	0	0	0
Sheb-397	3/31/2017	F	7	486	1,326	0	0	1	papilloma	0	0
Sheb-398	3/31/2017	F	9	471	1,390	0	1	0	0	0	0
Sheb-399	3/31/2017	F	6	481	1,134	0	0	0	0	0	0
Sheb-400	3/31/2017	ND	8	431	993	0	1	1	papilloma	0	0

14 **Assessment of Neoplasms in White Sucker Collected at the Sheboygan River Area of Concern, Wisconsin, in 2017**

Table 2. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2012.

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
GL12-1	3/31/2012	M	13	458	957	0	1	0	0	0	CO
GL12-2	3/31/2012	F	15	548	1,995	0	0	1	papilloma	0	HA
GL12-3	3/31/2012	M	15	460	1,038	0	0	0	0	1	0
GL12-4	3/31/2012	M	19	472	1,067	0	0	1	0	0	0
GL12-5	3/31/2012	F	6	480	1,279	0	0	1	papilloma	0	0
GL12-6	3/31/2012	M	17	467	1,010	0	0	0	papilloma	0	0
GL12-7	3/31/2012	M	23	483	1,088	0	0	0	0	0	0
GL12-8	3/31/2012	F	9	411	881	0	0	0	0	0	0
GL12-9	3/31/2012	M	16	493	1,238	0	0	0	0	0	0
GL12-10	3/31/2012	M	9	460	848	0	0	0	0	0	0
GL12-11	3/31/2012	F	20	544	2,010	0	0	1	SCC	0	0
GL12-12	3/31/2012	F	28	560	1,990	0	0	1	0	0	CC
GL12-13	3/31/2012	F	21	560	1,562	0	0	0	0	0	0
GL12-14	3/31/2012	M	9	441	903	0	0	0	0	0	0
GL12-15	3/31/2012	M	13	476	1,059	0	0	0	0	1	0
GL12-16	3/31/2012	M	14	493	1,184	0	0	0	0	0	HCC
GL12-17	3/31/2012	M	8	375	501	0	0	0	0	0	0
GL12-18	3/31/2012	M	9	420	814	0	0	0	0	0	0
GL12-19	3/31/2012	F	9	419	798	0	0	0	0	0	0
GL12-20	3/31/2012	M	7	422	727	0	0	1	papilloma	0	0
GL12-21	3/31/2012	F	4	318	398	0	0	0	0	0	0
GL12-22	3/31/2012	M	8	435	823	0	0	0	0	0	0
GL12-23	3/31/2012	M	8	455	988	0	0	1	papilloma	0	0
GL12-24	3/31/2012	F	5	312	317	0	0	0	0	0	0
GL12-25	3/31/2012	F	17	575	1,781	0	0	1	papilloma	0	CC
GL12-26	3/31/2012	F	11	490	1,145	0	0	1	papilloma	0	CC
GL12-27	3/31/2012	M	4	253	178	0	0	0	0	0	0
GL12-28	3/31/2012	M	4	303	275	1	0	0	0	0	0
GL12-29	3/31/2012	M	12	482	1,061	0	0	0	0	0	0
GL12-30	3/31/2012	F	8	427	968	0	0	0	0	0	0
GL12-31	3/31/2012	M	6	455	936	0	0	0	0	0	0
GL12-32	3/31/2012	F	12	555	1,861	0	0	1	papilloma	0	0
GL12-33	3/31/2012	F	8	452	1,006	0	0	0	0	0	0
GL12-34	3/31/2012	F	19	571	1,998	0	0	1	papilloma	0	0
GL12-35	3/31/2012	F	7	450	970	0	0	1	papilloma	0	0
GL12-36	3/31/2012	M	8	460	1,005	0	0	1	papilloma	0	0
GL12-37	3/31/2012	M	8	435	890	0	0	0	0	0	CC
GL12-38	3/31/2012	M	8	410	658	1	0	0	papilloma	0	0
GL12-39	3/31/2012	F	21	571	2,025	0	0	1	papilloma	0	0
GL12-40	3/31/2012	M	5	435	848	0	0	1	papilloma	0	0

Table 2. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2012.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
GL12-41	3/31/2012	F	21	585	2,119	0	0	0	0	0	0
GL12-42	3/31/2012	F	13	527	1,441	0	0	0	0	0	0
GL12-43	3/31/2012	M	8	440	778	0	0	0	0	0	0
GL12-44	3/31/2012	F	8	487	1,034	0	0	1	papilloma	0	0
GL12-45	3/31/2012	M	12	448	801	0	1	1	SCC	0	0
GL12-46	3/31/2012	M	9	440	858	0	0	0	0	0	0
GL12-47	3/31/2012	M	9	410	604	0	0	0	0	0	0
GL12-48	3/31/2012	F	18	563	1,734	0	0	1	papilloma	0	0
GL12-49	3/31/2012	M	10	480	1,070	0	0	0	0	0	0
GL12-50	3/31/2012	M	6	416	711	0	0	0	0	0	0
GL12-51	3/31/2012	F	10	483	1,060	0	1	0	0	0	0
GL12-52	3/31/2012	F	6	373	547	0	0	0	0	0	0
GL12-53	3/31/2012	F	6	424	781	0	0	0	0	0	HA
GL12-54	3/31/2012	F	5	271	183	0	0	0	0	0	0
GL12-55	3/31/2012	F	9	433	880	0	0	0	0	0	0
GL12-56	3/31/2012	M	8	404	666	0	0	1	papilloma	0	0
GL12-57	3/31/2012	M	13	473	1,096	0	0	1	papilloma	0	0
GL12-58	3/31/2012	F	10	469	1,290	0	0	0	0	0	0
GL12-59	3/31/2012	F	14	531	1,435	0	0	0	0	0	0
GL12-60	3/31/2012	M	7	408	694	0	0	0	0	0	0
GL12-61	3/31/2012	M	7	446	795	0	0	1	0	0	0
GL12-62	3/31/2012	F	12	493	1,184	0	1	0	papilloma	0	0
GL12-63	3/31/2012	M	7	407	708	0	0	0	0	0	0
GL12-64	3/31/2012	M	6	422	811	1	0	0	0	0	0
GL12-65	3/31/2012	F	20	542	1,688	0	0	0	papilloma	0	0
GL12-66	3/31/2012	M	9	441	836	0	1	0	0	0	0
GL12-67	3/31/2012	M	9	446	777	0	1	1	papilloma	0	0
GL12-68	3/31/2012	M	10	432	787	0	0	1	papilloma	0	0
GL12-69	3/31/2012	F	10	529	1,306	0	0	1	papilloma	0	0
GL12-70	3/31/2012	M	8	443	820	0	1	1	papilloma	0	0
GL12-71	3/31/2012	M	6	375	613	0	0	0	0	0	0
GL12-72	3/31/2012	F	8	509	1,223	0	0	0	0	0	0
GL12-73	3/31/2012	F	9	508	1,256	0	0	0	papilloma	0	0
GL12-74	3/31/2012	F	6	452	893	0	0	1	papilloma	0	0
GL12-75	3/31/2012	F	11	501	1,272	1	0	0	0	1	CO
GL12-76	3/31/2012	F	6	383	588	0	0	0	0	0	0
GL12-77	3/31/2012	F	23	597	1,680	0	0	0	0	0	0
GL12-78	3/31/2012	M	8	466	1,040	0	0	0	0	0	0
GL12-79	3/31/2012	F	10	413	673	0	0	0	0	0	0
GL12-80	3/31/2012	F	10	504	1,175	0	0	1	0	0	0

Table 2. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2012.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
GL12-81	3/31/2012	F	7	431	899	0	0	0	0	0	0
GL12-82	3/31/2012	F	12	510	1,315	0	0	0	0	0	0
GL12-83	3/31/2012	F	18	555	1,678	0	0	1	papilloma	1	CC
GL12-84	3/31/2012	F	6	265	203	0	0	0	0	0	0
GL12-85	3/31/2012	M	14	445	944	0	0	1	papilloma	1	0
GL12-86	3/31/2012	F	6	455	1,060	0	0	0	0	0	0
GL12-87	3/31/2012	M	7	415	752	0	0	0	0	0	0
GL12-88	3/31/2012	M	11	455	941	0	0	0	0	0	0
GL12-89	3/31/2012	F	7	435	958	0	0	0	0	0	0
GL12-90	3/31/2012	M	9	414	693	0	0	0	0	0	0
GL12-91	3/31/2012	M	13	480	1,018	0	0	1	papilloma	0	0
GL12-92	3/31/2012	M	8	445	789	0	0	1	papilloma	0	0
GL12-93	3/31/2012	F	21	552	1,508	0	0	1	papilloma	0	CO
GL12-94	3/31/2012	F	5	312	372	0	0	0	0	0	0
GL12-95	3/31/2012	F	7	450	912	0	0	0	0	0	0
GL12-96	3/31/2012	M	5	378	544	0	0	0	0	0	0
GL12-97	3/31/2012	F	5	380	651	0	0	0	0	0	0
GL12-98	3/31/2012	F	6	428	742	0	0	0	0	0	0
GL12-99	3/31/2012	F	7	468	958	0	0	0	0	0	0
GL12-100	3/31/2012	F	5	462	1,048	0	0	1	0	0	0
GL12-101	3/31/2012	F	6	440	876	0	0	0	0	0	0
GL12-102	3/31/2012	M	6	378	656	0	0	0	0	0	0
GL12-103	3/31/2012	F	7	431	1,268	0	0	1	papilloma	0	0
GL12-104	3/31/2012	F	7	502	1,210	0	0	0	0	0	0
GL12-105	3/31/2012	M	6	295	267	0	0	0	0	0	0
GL12-106	3/31/2012	F	7	484	1,135	0	0	0	0	0	0
GL12-107	3/31/2012	F	9	490	1,079	0	0	0	0	0	0
GL12-108	3/31/2012	F	9	465	1,184	1	0	0	0	0	0
GL12-109	3/31/2012	M	5	255	169	0	0	0	0	0	0
GL12-110	3/31/2012	M	5	430	833	0	0	0	0	0	0
GL12-111	3/31/2012	F	14	525	1,732	0	1	1	papilloma	0	0
GL12-112	3/31/2012	M	13	455	1,068	0	0	0	0	0	0
GL12-113	3/31/2012	F	8	485	1,146	0	0	0	0	0	0
GL12-114	3/31/2012	M	13	502	1,159	0	0	0	0	0	0
GL12-115	3/31/2012	M	17	482	1,294	0	0	1	papilloma	0	0
GL12-116	3/31/2012	F	13	492	1,163	0	0	0	0	0	0
GL12-117	3/31/2012	F	10	495	1,377	0	0	1	0	0	0
GL12-118	3/31/2012	F	10	496	1,252	0	0	1	0	0	CC
GL12-119	3/31/2012	F	9	500	1,170	0	0	1	papilloma	0	0
GL12-120	3/31/2012	F	12	501	1,279	0	0	1	0	0	0

Table 2. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2012.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
GL12-121	3/31/2012	M	8	430	848	0	0	1	papilloma	0	0
GL12-122	3/31/2012	F	12	479	982	0	0	0	0	0	0
GL12-123	3/31/2012	M	10	447	889	0	0	1	papilloma	0	0
GL12-124	3/31/2012	M	12	449	915	0	0	0	0	0	0
GL12-125	3/31/2012	F	9	431	972	0	0	0	0	0	0
GL12-126	3/31/2012	F	9	477	1,026	0	0	0	0	0	0
GL12-127	3/31/2012	M	11	448	819	0	0	1	SCC	0	0
GL12-128	3/31/2012	F	9	464	1,100	0	0	1	papilloma	0	0
GL12-129	3/31/2012	F	8	502	1,270	0	0	1	papilloma	0	HCC
GL12-130	3/31/2012	F	9	511	1,300	0	0	0	0	0	0
GL12-131	3/31/2012	M	12	471	953	0	1	1	SCC	0	0
GL12-132	3/31/2012	M	11	433	800	0	0	1	papilloma	0	0
GL12-133	3/31/2012	F	11	472	1,094	0	0	0	0	0	0
GL12-134	3/31/2012	F	6	260	1,104	0	0	0	0	0	0
GL12-135	3/31/2012	F	10	542	1,518	0	0	1	papilloma	0	0
GL12-136	3/31/2012	M	21	481	1,106	0	0	1	papilloma	0	0
GL12-137	3/31/2012	F	10	490	1,188	0	0	0	0	0	0
GL12-138	3/31/2012	F	10	420	745	0	0	1	papilloma	0	0
GL12-139	3/31/2012	F	16	522	1,454	0	0	0	0	0	0
GL12-140	3/31/2012	F	9	446	857	0	0	0	0	0	0
GL12-141	3/31/2012	F	12	524	1,312	0	0	0	0	0	0
GL12-142	3/31/2012	F	13	534	1,382	0	0	1	papilloma	1	0
GL12-143	3/31/2012	F	9	482	1,135	0	0	0	0	0	0
GL12-144	3/31/2012	M	16	460	1,004	0	0	0	0	1	0
GL12-145	3/31/2012	F	20	558	1,534	0	0	0	0	0	CO
GL12-146	3/31/2012	F	12	528	1,332	0	0	0	0	0	0
GL12-147	3/31/2012	F	11	525	1,274	0	0	0	0	0	0
GL12-148	3/31/2012	F	11	495	1,070	0	0	0	0	0	0
GL12-149	3/31/2012	M	12	445	882	0	0	0	0	0	0
GL12-150	3/31/2012	M	10	430	766	0	0	0	0	0	0
GL12-151	3/31/2012	M	13	452	895	0	1	0	papilloma	0	0
GL12-152	3/31/2012	M	12	492	1,233	0	0	0	0	1	0
GL12-153	3/31/2012	M	9	418	764	1	0	1	papilloma	0	0
GL12-154	3/31/2012	F	3	288	255	0	0	0	0	1	0
GL12-155	3/31/2012	M	5	432	847	0	0	1	papilloma	0	0
GL12-156	3/31/2012	F	7	393	577	0	0	0	0	0	0
GL12-157	3/31/2012	M	5	298	298	0	0	0	0	0	0
GL12-158	3/31/2012	F	9	485	1,340	0	0	0	0	0	CO
GL12-159	3/31/2012	F	7	453	1,096	0	0	1	papilloma	0	0
GL12-160	3/31/2012	F	11	525	1,631	0	0	1	papilloma	0	0

Table 2. Biometric data and visible and microscopic abnormalities, Sheboygan River, Wisconsin, March 2012.—Continued

[mm, millimeters; F, female; M, male; 1, present; 0, absent; CO, cholangioma; HA, hepatic cell adenoma; SCC, squamous cell carcinoma; CC, cholangiocarcinoma; HCC, hepatic cell carcinoma]

Fish identifier	Collection date	Sex	Age (years)	Length (mm)	Weight (grams)	Raised external lesions			Skin neoplasms	Altered foci	Liver neoplasms
						White	Mucoid	Papillomatous			
GL12-161	3/31/2012	F	10	522	1,923	0	0	0	0	0	0
GL12-162	3/31/2012	F	5	438	971	0	0	0	0	0	0
GL12-163	3/31/2012	F	15	530	1,274	0	0	1	papilloma	0	0
GL12-164	3/31/2012	M	8	462	1,076	0	0	1	papilloma	0	0
GL12-165	3/31/2012	M	11	442	998	0	0	0	0	0	0
GL12-166	3/31/2012	F	5	425	791	0	0	0	0	0	0
GL12-167	3/31/2012	F	13	550	1,438	0	0	0	0	0	0
GL12-168	3/31/2012	M	13	446	877	0	0	1	papilloma	0	0
GL12-169	3/31/2012	F	11	450	912	0	0	0	0	0	0
GL12-170	3/31/2012	F	11	513	1,409	0	0	0	0	0	0
GL12-171	3/31/2012	M	6	515	1,191	0	0	1	papilloma	0	0
GL12-172	3/31/2012	M	27	422	704	0	0	0	0	0	0
GL12-173	3/31/2012	F	9	450	961	0	0	0	0	0	0
GL12-174	3/31/2012	M	10	453	967	0	0	1	papilloma	0	0
GL12-175	3/31/2012	F	9	510	1,375	0	1	0	papilloma	0	0
GL12-176	3/31/2012	M	8	458	892	0	0	0	0	0	0
GL12-177	3/31/2012	F	10	435	854	0	0	1	0	0	0
GL12-178	3/31/2012	M	6	451	810	0	0	0	papilloma	0	0
GL12-179	3/31/2012	F	9	502	1,263	0	0	0	0	0	0
GL12-180	3/31/2012	F	8	541	1,515	0	1	1	papilloma	0	0
GL12-181	3/31/2012	F	9	471	931	0	0	0	0	0	0
GL12-182	3/31/2012	F	9	487	1,080	0	0	0	0	0	0
GL12-183	3/31/2012	F	9	480	1,107	0	0	0	0	0	0
GL12-184	3/31/2012	F	11	470	968	0	0	0	0	0	0
GL12-185	3/31/2012	M	6	432	759	0	0	0	0	0	0
GL12-186	3/31/2012	M	15	498	1,075	0	0	0	0	0	0
GL12-187	3/31/2012	F	12	522	1,369	0	0	0	0	0	0
GL12-188	3/31/2012	M	7	435	819	0	0	1	papilloma	1	0
GL12-189	3/31/2012	F	8	482	1,089	0	0	0	0	0	0
GL12-190	3/31/2012	F	11	480	1,091	0	0	0	0	0	0
GL12-191	3/31/2012	F	9	434	1,389	0	0	0	0	0	0
GL12-192	3/31/2012	F	11	475	1,157	1	0	1	papilloma	0	CC
GL12-193	3/31/2012	F	11	482	1,129	0	0	0	0	0	0

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