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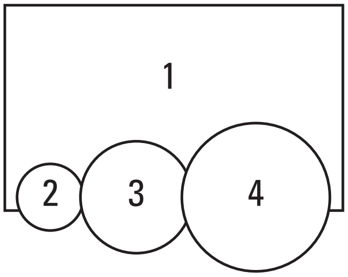
U.S. Environmental Protection Agency and the New York State
Department of Environmental Conservation

Toxicity of Bed Sediments from the Niagara River Area of Concern and Tributaries, New York, to *Chironomus dilutus* and *Hyalella azteca*, 2014–15

Data Series 1016

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



Cover. (1) Looking north on the Lackawanna Canal towards Buffalo, New York. Photograph by Brian Duffy. (2) Scientist of the New York State Department of Environmental Conservation processes a sediment sample. Photograph by Brian Duffy. (3) Scientist of the U.S. Geological Survey processes a sediment sample. Photograph by Brian Duffy. (4) Scientist of the New York State Department of Environmental Conservation empties the contents of a petite Ponar grab into a bucket. Photograph by Barry Baldigo.

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U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
liter (L)	61.02	cubic inch (in^3)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

Datum

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

Toxicity of Bed Sediments from the Niagara River Area of Concern and Tributaries, New York, to *Chironomus dilutus* and *Hyalella azteca*, 2014–15

By Scott D. George, Barry P. Baldigo, and Brian T. Duffy[1]

Abstract

The Niagara River was designated as an Area of Concern in 1987 on both the United States and Canadian sides of the international boundary line because past industrial discharges and hazardous waste sites had caused extensive degradation of aquatic habitats. The degradation of the "benthos", or the benthic macroinvertebrate community, was identified as one of seven beneficial use impairments caused by contaminated bed sediments. The U.S. Geological Survey and the New York State Department of Environmental Conservation, in cooperation with the U.S. Environmental Protection Agency, conducted a study in 2014 and 2015 to gather more extensive data on (a) the toxicity of bed sediments and (b) the status of macroinvertebrate communities on the main stem and tributaries of the Niagara River. This report addresses the first component of that study (toxicity of bed sediments), and summarizes results from laboratory toxicity tests that compare the survival and growth of two macroinvertebrate species between bed sediments from study sites and laboratory controls. Sediment toxicity was negligible at most sites, however poor performance of one or both test species in bed sediments from several tributary sites suggests that the quality of sediments may be adversely affecting benthic macroinvertebrate communities in some tributaries to the Niagara River.

Introduction

In 1972, the governments of Canada and the United States committed to restoring the physical, chemical, and biological integrity of the Laurentian Great Lakes under the Great Lakes Water Quality Agreement (Great Lakes Water Quality Agreement, 2012). Through this framework, 43 Areas of Concern (AOCs) were subsequently identified in the Great Lakes Basin. Areas of Concern are defined as geographic areas impacted by environmental degradation resulting from human activities at the local level, and exhibit impairment to 1 or more of 14 possible beneficial uses relating to chemical, physical, or biological integrity. For each AOC, a remedial action plan is developed by a local remedial action committee to guide restoration efforts and the evaluation of recovery. Beneficial use impairments (BUIs) are then reevaluated over time, or following remedial efforts, to determine if they are still applicable to an AOC or if the BUIs may be removed and the entire AOC delisted.

The Niagara River forms the boundary between the United States and Canada (fig. 1) and was designated as a binational AOC in 1987 because past industrial discharges and hazardous waste sites had caused extensive degradation of aquatic habitats. Within the United States (eastern) portion of the AOC (which is the focus of this report), seven BUIs have been identified, including the degradation of the "benthos", or the benthic macroinvertebrate community. Past assessments of macroinvertebrate community structure and sediment toxicity, which indicated that macroinvertebrate communities were adversely affected by contaminated bed sediments, provided the rationale for this BUI (New York State Department of Environmental Conservation, 1994, 2012). Contaminants such as polychlorinated biphenyls (PCBs) and hexachlorocyclohexane are believed to be among the primary causes of impairment to this assemblage (New York State Department of Environmental Conservation, 1994, 2012). However, the extent of the contaminated sediments is not limited to the original boundaries of the AOC (fig. 1) as many tributaries to the Niagara River are now known or suspected to contain sediments that exceed the probable effect thresholds for various contaminants and contribute contaminant loads to the main stem (New York State Department of Environmental Conservation, 1994; Niagara River Secretariat, 2007; New York State Department of Environmental Conservation, 2012, 2013).

The U.S. Geological Survey (USGS) and the New York State Department of Environmental Conservation (NYSDEC), in cooperation with the U.S. Environmental Protection Agency, conducted the current study during 2014 and 2015 to

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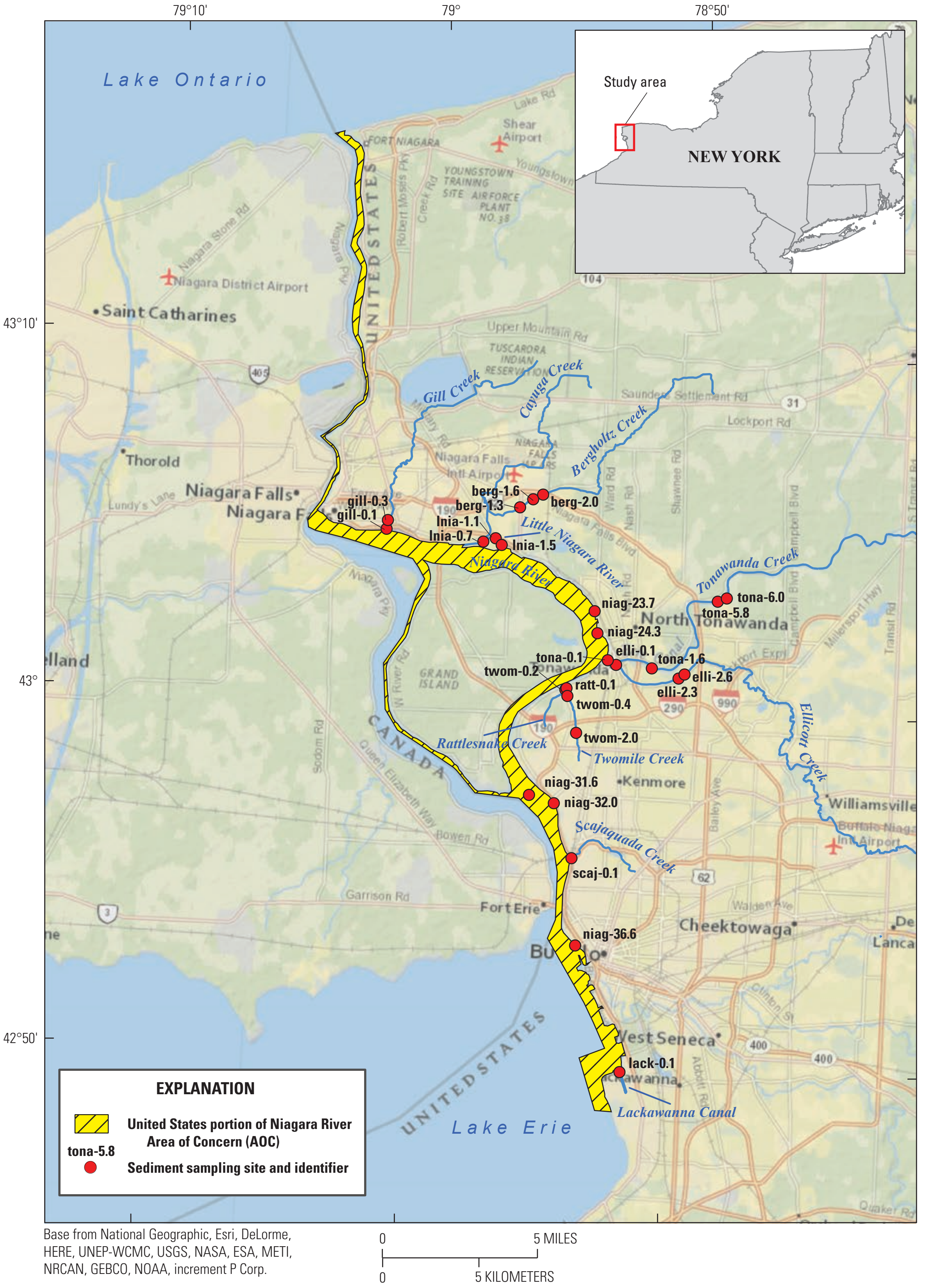
[1] New York State Department of Environmental Conservation.



Base from National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Figure 1. Sampling sites on the main stem and tributaries of the Niagara River, New York, where bed sediments were collected in 2014–15. The numbers following site identifiers indicate river miles upstream from the mouth.

gather more extensive data on the toxicity of bed sediments and the status of macroinvertebrate communities on the main stem and tributaries of the Niagara River. This information is necessary to (a) assess the current status of the benthos BUI, (b) determine the extent of sediment toxicity in tributaries not included in the original AOC in order to identify source areas that may be contributing toxic sediments to the Niagara River, and (c) produce baseline data that can be used to evaluate the success of future remediation efforts. To this end, sediments were collected for (a) laboratory toxicity tests in which the survival and growth of two macroinvertebrate species were compared between sediments from study sites and laboratory controls and (b) assessment of macroinvertebrate community integrity. This report addresses the first component of that study, and its purpose is to disseminate those results so that they can inform natural resource managers and policy makers, and guide future research and remedial efforts. The second component of the study (macroinvertabrate community integrity) will be presented in a subsequent report.

Methods

Bed sediments were collected from depositional areas using either a petite Ponar (0.03 square meter) dredge or a stainless-steel sediment scoop (for nonwadeable and wadeable streams, respectively) at 8 sites in 2014 and 18 sites in 2015 (table 1). At each site, 4 to 5 grabs or scoops were composited into a bucket, mixed, and a 4-liter (L) subsample was stored in a polyethylene container. Samples were kept on ice and shipped to Great Lakes Environmental Center, Inc., where sediment toxicity testing was conducted to quantify toxicity to the dipteran, *Chironomus dilutus*, and the amphipod, *Hyalella azteca*, during 10-day survival and growth bioassays following EPA test methods 100.2 and 100.1, respectively (U.S. Environmental Protection Agency, 2000). *Chironomus dilutus* and *H. azteca* are used as indicator species because they each inhabit broad geographic ranges, burrow in sediments, and have known sensitivities to common nutrients and toxins (U.S. Environmental Protection Agency, 2000; American Society for Testing and Materials, 2010). In short, exposures for each species were run using eight replicates from each sample. Each replicate was composed of 100 milliliters (mL) of sediment and 175 mL of overlying water into which 10 test organisms were added. At the conclusion of the 10-day exposure, the percentage of organisms surviving (hereafter survival), average ash-free dry weight of the surviving organisms (hereafter growth), and ash-free dry weight of the surviving organisms divided by the starting number of organisms (hereafter biomass) were assessed for each replicate. The quality of the data generated by the toxicity tests was assured by (a) testing two laboratory control sediment samples (one in 2014 and one in 2015) to verify that test conditions and organism responses generally met test acceptability criteria, (b) collecting and testing duplicate sediment samples from three sites to determine the precision of test endpoints, and (c) daily monitoring of temperature and dissolved oxygen in overlying water (U.S. Environmental Protection Agency, 2000). See “Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates” for a thorough summary of the test conditions and procedures used in the EPA test methods 100.2 and 100.1 (U.S. Environmental Protection Agency, 2000).

Toxicity results from sediment samples collected in 2014 and 2015 were analyzed separately to determine if test endpoints differed significantly ($P \leq 0.05$) between sites and their respective year laboratory control (that is, 2014 samples were compared to the 2014 lab control and 2015 samples were compared to the 2015 lab control). Due to the heteroscedastic nature (unequal variance) of some endpoints between sites, Welch’s one-way analysis of variance (ANOVA) and the Games-Howell multiple comparisons procedure were used to determine if the mean value of each endpoint differed between individual sites and their respective laboratory controls. This approach is appropriate for comparing groups when the data are heteroscedastic and do not meet the assumption of equal variance. The data for each endpoint are available in George and others (2016) and are presented in table 2 as the means of the eight replicates from each site. The data are also shown in figures 2 and 3 as interval plots of the mean of the laboratory replicates plus or minus one standard error with asterisks to indicate which sites differ significantly from their laboratory control.

Results

Quality-assurance procedures were conducted to ensure that test organisms and overlying water quality met minimum test acceptability criteria and did not inadvertently affect the test results. The survival and growth of *C. dilutus* exceeded the minimum test acceptability criteria of 70 percent and 0.48 milligram (mg) (U.S. Environmental Protection Agency, 2000), respectively, in the 2014 and 2015 laboratory controls (table 2). Similarly, the survival and growth of *H. azteca* exceeded the minimum test acceptability criteria of 80 percent and exhibiting measurable growth (U.S. Environmental Protection Agency, 2000), respectively, in both laboratory controls. The overlying water-quality measurements were also within the acceptable limits for each test method with the exception of a few brief decreases in dissolved oxygen in two replicates from site twom-2.0 during *C. dilutus* and *H. azteca* tests. Such transitory deviations generally do not affect the quality of test data (U.S. Environmental Protection Agency, 2000). Results from the three sets of duplicate sediment samples indicated that the relative percent difference between test endpoints in duplicates was generally less than 20 percent and averaged 16.4 percent for survival of *C. dilutus*, 4.4 percent for growth of *C. dilutus*, 11.9 percent for biomass of *C. dilutus*, 5.6 percent for survival of *H. azteca*, 10.9 percent

Table 1. Stream name, site identifier (ID), U.S. Geological Survey station ID, date sampled, and locations for sediment samples collected from the main stem and tributaries of the Niagara River, New York.

[USGS, U.S. Geological Survey. Latitude/longitude, datum is NAD 83 (North American Datum of 1983). The numbers following site IDs indicate approximate river miles upstream from the mouth and “D” indicates sites where duplicate sediment samples were collected to determine the precision of test endpoints.]

Stream name	Site ID	USGS ID	Date sampled	Latitude (decimal degrees)	Longitude (decimal degrees)
Bergholtz Creek	berg-1.3	430530078562901	9/8/2015	43.09175	-78.94142
Bergholtz Creek	berg-1.6D	430544078560001	9/8/2015	43.09579	-78.93336
Bergholtz Creek	berg-2.0	430553078553701	9/8/2015	43.09820	-78.92712
Ellicott Creek	elli-0.1	430113078523201	9/8/2014	43.02035	-78.87576
Ellicott Creek	elli-2.3	430055078500801	9/9/2015	43.01528	-78.83568
Ellicott Creek	elli-2.6	0421939005	9/9/2015	43.01737	-78.83199
Gill Creek	gill-0.1	430443079013201	9/8/2014	43.07877	-79.02575
Gill Creek	gill-0.3	430458079013001	9/8/2015	43.08292	-79.02516
Lackawanna Canal	lack-0.1	424949078514201	9/9/2014	42.83050	-78.86170
Little Niagara River	lnia-0.7	430429078574901	9/8/2014	43.07496	-78.96380
Little Niagara River	lnia-1.1	430436078572101	9/8/2014	43.07681	-78.95602
Little Niagara River	lnia-1.5D	430425078570701	9/8/2015	43.07380	-78.95202
Niagara River	niag-23.7	430241078532701	9/8/2015	43.04494	-78.89095
Niagara River	niag-24.3	430204078531801	9/8/2015	43.03471	-78.88852
Niagara River	niag-31.6	425728078553801	9/9/2015	42.95784	-78.92725
Niagara River	niag-32.0	425716078544001	9/9/2015	42.95449	-78.91123
Niagara River	niag-36.6	425319078533601	9/9/2015	42.88865	-78.89355
Rattlesnake Creek	ratt-0.1	430028078542601	9/9/2015	43.00780	-78.90731
Scajaquada Creek	scaj-0.1D	0421621505	9/9/2014	42.92926	-78.89839
Tonawanda Creek	tona-0.1	430120078525201	9/8/2014	43.02237	-78.88113
Tonawanda Creek	tona-1.6	430110078511001	9/25/2014	43.01949	-78.85289
Tonawanda Creek	tona-5.8	430307078484601	9/9/2015	43.05198	-78.81288
Tonawanda Creek	tona-6.0	430313078482601	9/9/2015	43.05368	-78.80727
Two Mile Creek	twom-0.2	430030078542301	9/9/2015	43.00838	-78.90653
Two Mile Creek	twom-0.4	04216270	9/9/2015	43.00484	-78.90575
Two Mile Creek	twom-2.0	425915078535601	9/9/2015	42.98776	-78.89913

for growth of *H. azteca*, and 17.6 percent for biomass of *H. azteca*. Overall, the quality assurance data indicated that test acceptability criteria were met and therefore the test results can be considered valid assessments of sediment toxicity.

Survival of *C. dilutus* at test sites from both years ranged from 6.3 percent in sediments from site twom-0.4 to 98.8 percent at lnia-1.5 and tona-5.8 (table 2). Results from sites scaj-0.1, tona-1.6, twom-0.2, twom-0.4, and twom-2.0 differed significantly from their respective laboratory controls (fig. 2). Growth of *C. dilutus* ranged from 0.736 mg in sediments from site twom-0.2 to 1.575 mg at gill-0.1 (table 2). Results from sites lack-0.1, tona-0.1, berg-1.3, and lnia-1.5 differed significantly from their respective laboratory controls (fig. 2). It is noteworthy that growth of *C. dilutus* at all 2015 test sites except for twom-0.2 exceeded that of the 2015 laboratory control, which exhibited notably lower growth than the comparable 2014 laboratory control. The unusually large variability in growth of *C. dilutus* at sites twom-0.4 and twom-2.0 (fig. 2) likely reflects the fact that most test organisms did not survive the 10-day exposures to sediments from these sites and the resulting reduction in intraspecific competition may have caused high growth rates for a few individuals. Biomass of *C. dilutus* ranged from 0.094 mg in sediments from twom-0.4 to 1.512 mg at gill-0.1 (table 2). Results from sites lack-0.1, scaj-0.1, tona-0.1, tona-1.6, berg-1.3, lnia-1.5, twom-0.2, twom-0.4, and twom-2.0 differed significantly from their respective laboratory controls (fig. 2).

Survival of *H. azteca* at test sites from both years ranged from 35.0 percent in sediments from site scaj-0.1 to 98.8 percent at berg-2.0 and niag-36.6 (table 2), and only the

Table 2. Results of 10-day *Chironomus dilutus* and *Hyalella azteca* toxicity tests of sediments from the main stem and tributaries of the Niagara River, New York.

[ID, identifier; Site identifiers ending in "D" are duplicate samples collected to determine the precision of test endpoints and were not used in statistical comparisons with laboratory controls. Bolded text indicates endpoint values that are significantly less than the corresponding control.]

Site ID	Number of lab replicates	Mean survival of *C. dilutus* (percent)	Mean growth of *C. dilutus* (milligrams)	Mean biomass of *C. dilutus* (milligrams)	Mean survival of *H. azteca* (percent)	Mean growth of *H. azteca* (milligrams)	Mean biomass of *H. azteca* (milligrams)
2014							
Lab Control 2014	8	98.8	1.403	1.388	95.0	0.104	0.100
elli-0.1	8	93.8	1.333	1.244	90.0	**0.064**	**0.058**
gill-0.1	8	96.3	1.575	1.512	91.3	0.080	0.073
lack-0.1	8	90.0	**1.102**	**0.995**	80.0	**0.062**	**0.050**
lnia-0.7	8	83.8	1.438	1.195	93.8	**0.065**	**0.061**
lnia-1.1	8	93.8	1.315	1.235	91.3	**0.072**	**0.065**
scaj-0.1	8	**35.0**	1.049	**0.365**	**35.0**	**0.062**	**0.021**
scaj-0.1D	8	43.8	0.941	0.398	38.8	0.069	0.027
tona-0.1	8	86.3	**0.903**	**0.760**	68.8	0.079	**0.052**
tona-1.6	8	**91.3**	1.103	**1.009**	93.8	**0.078**	0.073
2015							
Lab Control 2015	8	92.5	0.838	0.766	98.8	0.123	0.122
berg-1.3	8	88.8	1.261	1.114	96.3	0.156	0.151
berg-1.6	8	76.3	1.134	0.860	91.3	0.135	0.123
berg-1.6D	8	97.5	1.146	1.116	96.3	0.141	0.136
berg-2.0	8	92.9[a]	0.983[a]	0.909[a]	98.8	0.140	0.139
elli-2.3	8	92.5	1.147	1.058	96.3	0.132	0.128
elli-2.6	8	96.3	0.910	0.871	92.5	0.117	0.108
gill-0.3	8	92.5	1.005	0.921	96.3	0.132	0.127
lnia-1.5	8	98.8	1.203	1.187	97.5	0.212	0.207
lnia-1.5D	8	96.3	1.220	1.175	96.3	0.178	0.172
niag-23.7	8	93.8	0.884	0.826	97.5	0.131	0.128
niag-24.3	8	92.5	1.054	0.975	97.5	0.124	0.121
niag-31.6	8	91.3	1.021	0.924	92.5	0.139	0.129
niag-32.0	8	96.3	0.877	0.842	96.3	0.116	0.112
niag-36.6	8	88.8	1.044	0.923	98.8	0.102	0.100
ratt-0.1	8	87.5	0.871	0.751	97.5	0.120	0.116
tona-5.8	8	98.8	1.024	1.011	97.5	0.133	0.130
tona-6.0	8	93.8	1.082	1.008	91.3	0.119	0.109
twom-0.2	8	**42.5**	0.736	**0.281**	90.0	0.127	0.114
twom-0.4	8	**6.3**	1.376[b]	**0.094**	95.0	0.162	0.154
twom-2.0	8	**21.3**	1.373[b]	**0.278**	93.8	0.166	0.156

[a] Only seven replicates analyzed because of glassware contamination in one replicate.

[b] Replicates in which complete mortality occurred were not used to estimate mean growth.

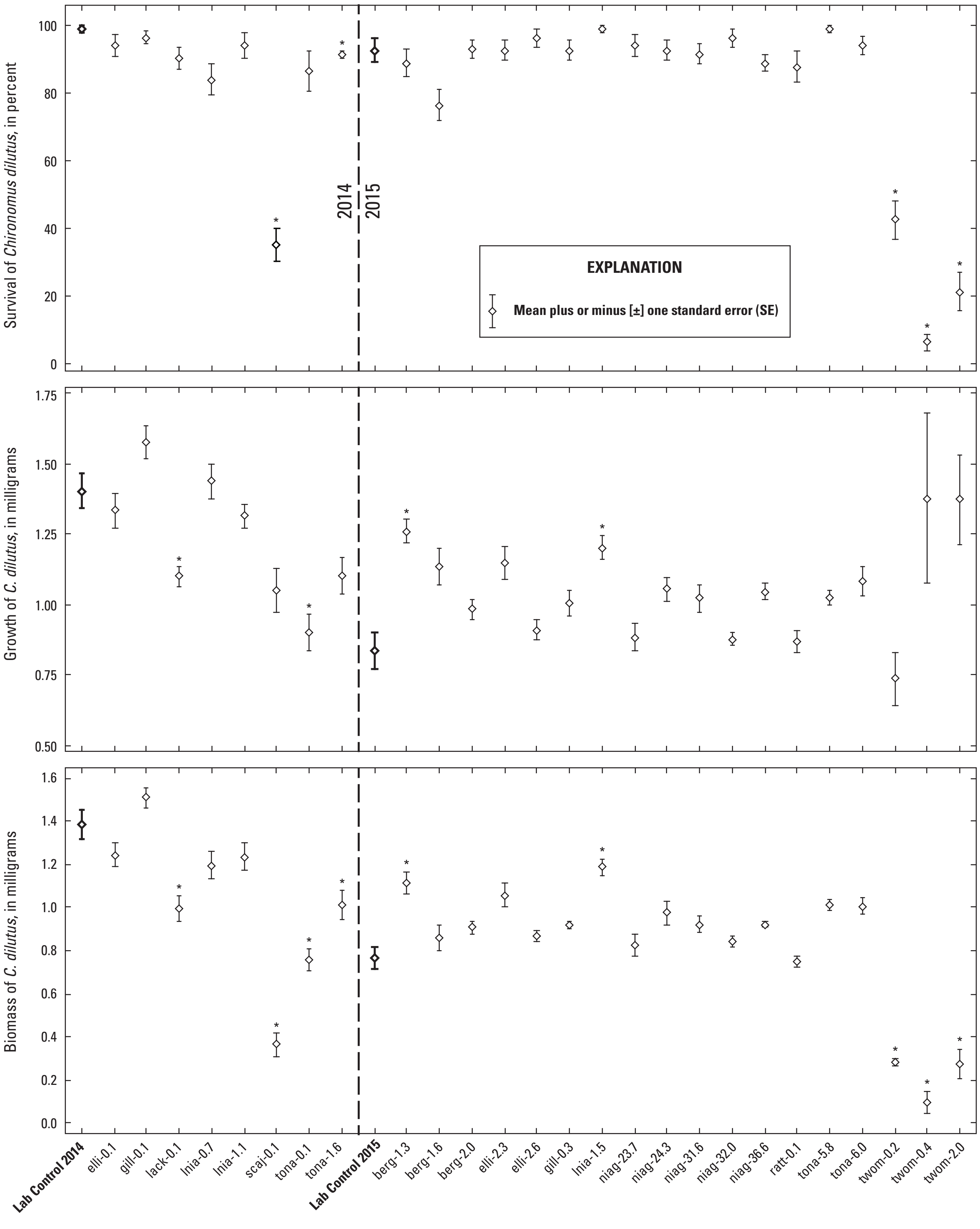


Figure 2. Interval plots (mean plus or minus [±] one standard error [SE], n=8) showing the survival, growth, and biomass of *Chironomus dilutus* from 10-day toxicity tests in sediments from eight study sites and one laboratory control in 2014 and 18 study sites and one laboratory control in 2015 on the main stem and tributaries of the Niagara River, New York. Sites labelled with an asterisk are significantly different from their corresponding laboratory control.

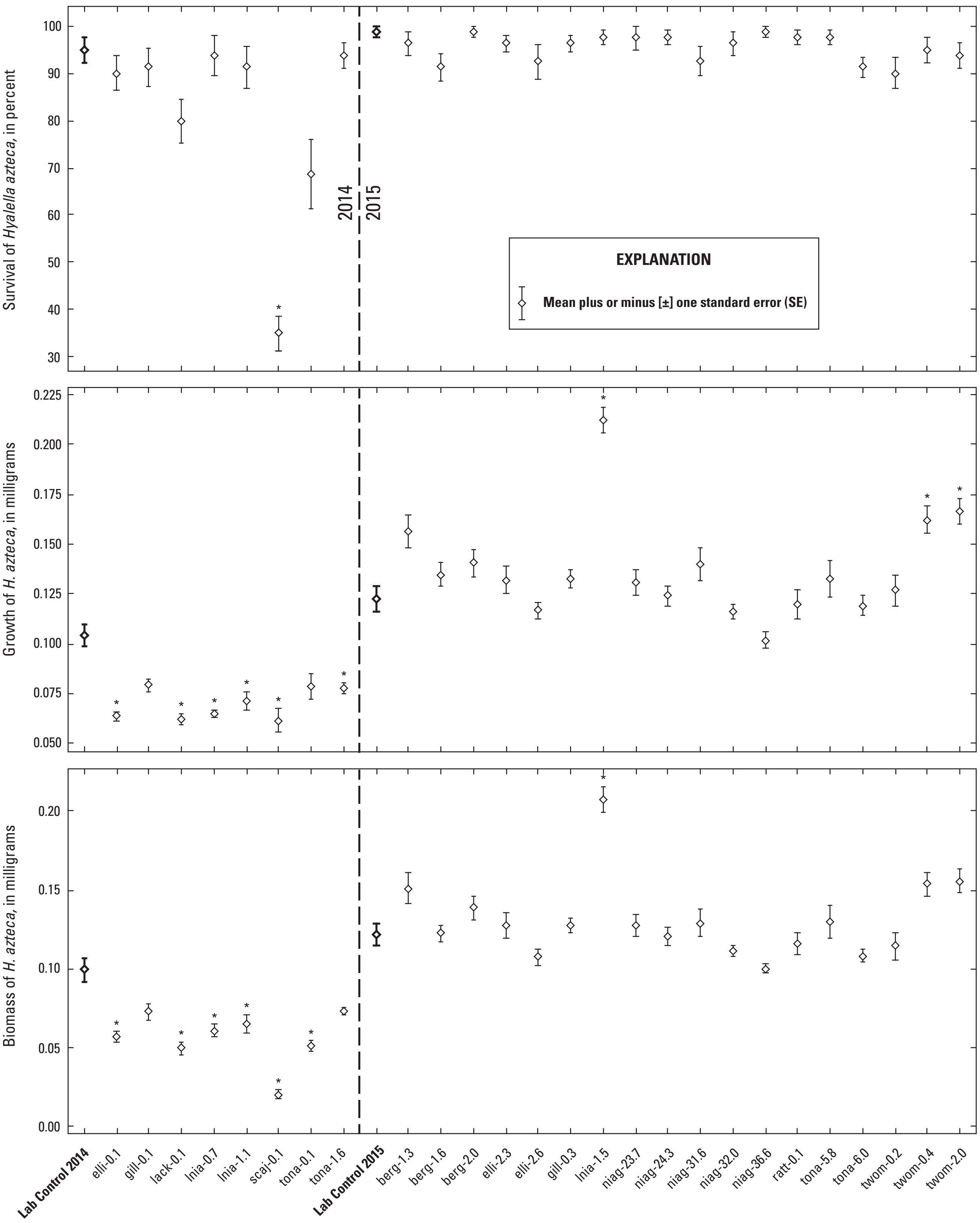


Figure 3. Interval plots (mean plus or minus [±] one standard error [SE], n=8) showing the survival, growth, and biomass of *Hyalella azteca* from 10-day toxicity tests in sediments from eight study sites and one laboratory control in 2014 and 18 study sites and one laboratory control in 2015 on the main stem and tributaries of the Niagara River, New York. Sites labelled with an asterisk are significantly different from their corresponding laboratory control.

results from site scaj-0.1 differed significantly from its respective laboratory control (fig. 3). Growth of *H. azteca* ranged from 0.062 mg in sediments from sites lack-0.1 and scaj-0.1 to 0.212 mg at lnia-1.5 (table 2). Results from sites elli-0.1, lack-0.1, lnia-0.7, lnia-1.1, scaj-0.1, tona-1.6, lnia-1.5, twom-0.4, and twom-2.0 differed significantly from their respective laboratory controls (fig. 3). Biomass of *H. azteca* ranged from 0.021 mg in sediments from site scaj-0.1 to 0.207 mg at lnia-1.5 (table 2). Results from sites elli-0.1, lack-0.1, lnia-0.7, lnia-1.1, scaj-0.1, tona-0.1, and lnia-1.5 differed significantly from their respective laboratory controls (fig. 3). Similar to patterns in the growth and biomass of *C. dilutus*, there were a few sites at which the growth and biomass of *H. azteca* exceeded and differed significantly from laboratory controls, which may not imply toxicity of sediments but rather suggests greater ambient productivity of test sediments. Together, the results of the *C. dilutus* and *H. azteca* toxicity tests indicate that sediment toxicity was negligible at most sites. However, poor performance of one or both test species in sediments from several sites suggest that bed sediments may be adversely affecting benthic macroinvertebrate communities in some tributaries to the Niagara River.

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