Potential Recovery of the Mussel Fauna of the Clarion River, Pennsylvania

Author: Williams, Charles E.

Source: Freshwater Mollusk Biology and Conservation, 25(1) : 7-14

Published By: Freshwater Mollusk Conservation Society

URL: https://doi.org/10.31931/fmbc-d-21-00009

Freshwater Mollusk Biology and Conservation 25:7–14, 2022

DOI:10.31931/fmbc-d-21-00009

REGULAR ARTICLE

POTENTIAL RECOVERY OF THE MUSSEL FAUNA OF THE CLARION RIVER, PENNSYLVANIA

Charles E. Williams[1]*

[1] *Williams Ecological, LLC, 103 Hillcrest Lane, Shippenville, PA 16254 USA*

ABSTRACT

The Clarion River, a tributary of the Allegheny River in northwestern Pennsylvania, underwent heavy industrialization during the late 19th and early 20th centuries. In the early 1900s, eight tanneries, 11 wood chemical plants, and a large paper mill operated on the Clarion River, releasing a cumulative 98 million liters of industrial effluent daily, in addition to the discharge of coal-mining wastes. By 1911, aquatic life was considered eliminated from the river, but **its original mussel fauna was never recorded. In 1993, four living individuals of *Strophitus undulatus*, the Creeper, were discovered by chance near Clarington, Forest County, which constituted the first documented collection of mussels from the river. I conducted qualitative shell surveys from 2007 to 2019 at 157 sites to document past and present mussel distribution along a 55-km reach of the river. Recently dead shells, weathered shells, or living individuals of *S. undulatus* were encountered at 146 sites within the study reach. Relic shells of *Actinonaias ligamentina* were found at 12 sites, recently dead shells and one living individual of *Lampsilis fasciola* were found at five sites, and a single recently dead shell of *Lampsilis ovata* was collected. Ages of a subsample of 60 recently dead *S. undulatus* ranged from 2 to 16 yr (mean = 8.0 yr) and length ranged from 26.8 to 81.7 mm (mean = 29.8 mm), suggesting that natural recruitment may be occurring in the river. Source populations for recolonization of the river are unknown, but tributaries of the Clarion River are a possibility. My results suggest that the Clarion River now supports a substantial mussel population, but additional surveys are needed to provide a baseline for monitoring future recovery.**

KEY WORDS: Clarion River, industrial pollution, mine waste, Pennsylvania, river recovery

INTRODUCTION

Unregulated pollution by coal mine drainage and industrial effluents decimated the aquatic biota of many streams in western Pennsylvania by the early 1900s (Ortmann 1909). Ortmann (1909) singled out the Clarion River in northwestern Pennsylvania as "possibly one of the worst streams in the state" with regard to water pollution. Eight tanneries, 11 wood chemical plants, and a large paper mill operated on the river, chiefly in Elk County, releasing a cumulative 98 million liters of industrial effluent daily in addition to mine wastes entering the river from tributaries (Department of Health of the Commonwealth of Pennsylvania 1915). Ortmann's description of the condition of the Clarion River at the time was stark: "The water of [the] Clarion River…is black like ink, and retains its peculiar color all the way down to where it empties into the Allegheny [River]." He later concluded that the aquatic fauna of the Clarion River was "entirely destroyed" (Ortmann 1913) but acknowledged that no historical mussel records were known from the stream (Ortmann 1919).

Mussels remained unknown from the Clarion River until 1993, when biologists conducting an odonate survey made a chance discovery of four living individuals of *Strophitus undulatus*, the Creeper, near Clarington, Forest County (Carnegie Museum and Western Pennsylvania Conservancy 1993). The authors suggested that *S. undulatus* might be slowly recolonizing formerly degraded habitat but doubted that the river could support substantial mussel populations; however, they gave no specific reasons for their doubt.

I conducted qualitative shell surveys from 2007 to 2019 to document past and present mussel distribution along a 55-km reach of the Clarion River. I measured and aged a representative sample of recently dead *S. undulatus* shells to

*Corresponding Author: chuckwilliams2019@outlook.com

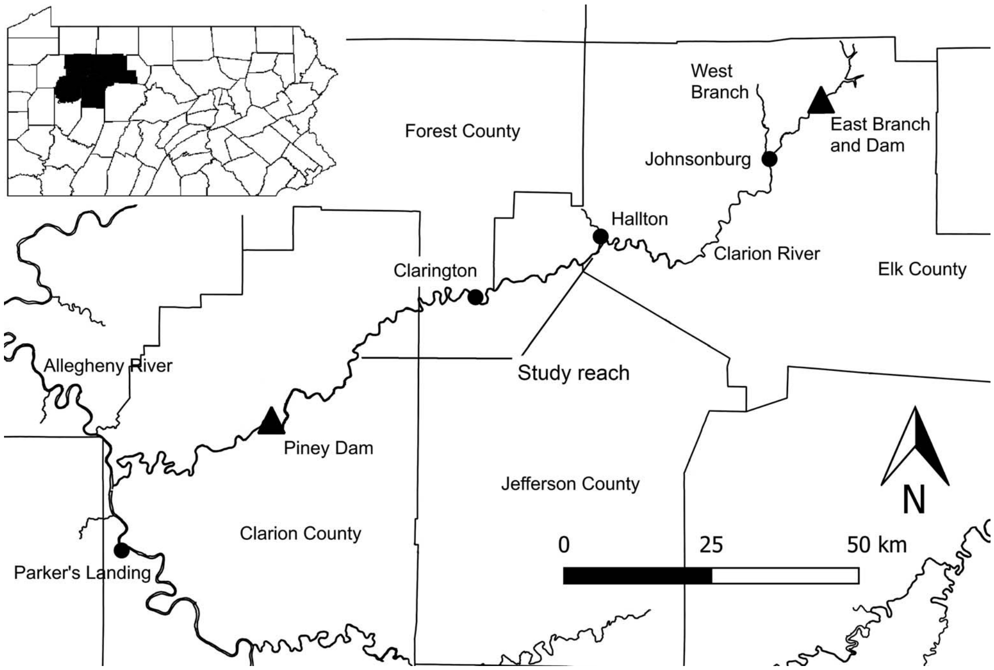

Figure 1. Map of the Clarion River, Pennsylvania, with study reach and key locales. Insert map shows the four-county region drained by the river.

provide demographic information about the population. I discuss my findings with regard to the potential recovery of the mussel fauna of the Clarion River.

STUDY AREA

The Clarion River is a tributary of the Allegheny River in northwestern Pennsylvania. The Clarion River watershed encompasses 2,850 km^2 located in two sections of the nonglaciated Appalachian Plateau physiographic province: the Allegheny High Plateau in the north and the Pittsburgh Low Plateau to the south (Commonwealth of Pennsylvania 2018). Landscapes of the High Plateau include broadly rounded uplands of moderate to high relief with deep, angular valleys; those of the Low Plateau consist of irregular to smooth, undulating uplands of low to moderate relief with relatively shallow valleys. Drainage patterns in both sections are dendritic with sandstone, siltstone, and shale as the predominant bedrock types (Commonwealth of Pennsylvania 2018). Forestry and oil and natural gas extraction are dominant land uses on the High Plateau. On the Low Plateau, agriculture and strip mining for bituminous coal are common (Williams 1995).

The Clarion River proper forms at Johnsonburg, Elk County, at the confluence of the East Branch and West Branch and flows 164 km southwest to meet the Allegheny River upstream of Parker's Landing, Armstrong County (Fig. 1). The watershed has two major dams, Piney Dam, completed in 1924 on the mainstem in Clarion County for flood control and hydropower generation (Williams 1995), and East Branch Dam, completed in 1952 on the East Branch Clarion River for flood control and summer flow enhancement (USACOE 2021). Piney Dam both isolates the upper Clarion River from the rich aquatic fauna of the Allegheny River and creates irregular flows downstream that can affect aquatic biota (Bardarik 1965).

Efforts to abate industrial pollution of the Clarion River began in the 1940s with improved waste treatment technologies and effluent retention facilities, particularly at the paper mill in Johnsonburg (Anonymous 1949; Camp, Dresser, and McKee, Consulting Engineers 1949). Water quality improved significantly from the 1960s to the 1980s as additional point source pollution and abandoned mine drainage issues were addressed (Williams 1995). These efforts were largely successful: in 1996, an 83-km reach of the Clarion River upstream of Piney Dam was given National Wild and Scenic River status. Presently, the Clarion River is an important recreational resource for the region and was named Pennsylvania River of the Year in 2019 (POWR 2019).

METHODS

I conducted qualitative shell surveys from 2007 to 2019 at 157 sites along a 55-km reach of the Clarion River between river kilometer (rkm, measured from the mouth of the river) 64, just above the slack water of Piney Reservoir in Clarion County, to rkm 119 at the mouth of Spring Creek in Hallton, Elk County (Fig. 1). I chose this reach because it contained ample access points, and it included the 1993 collection site for *S. undulatus* at about rkm 97 (Carnegie Museum and Western Pennsylvania Conservancy 1993). I searched for shells by walking gravel point bars, wading the river, and kayaking. I classified shells as either recently dead, having intact periostracum and lustrous nacre; weathered shells,

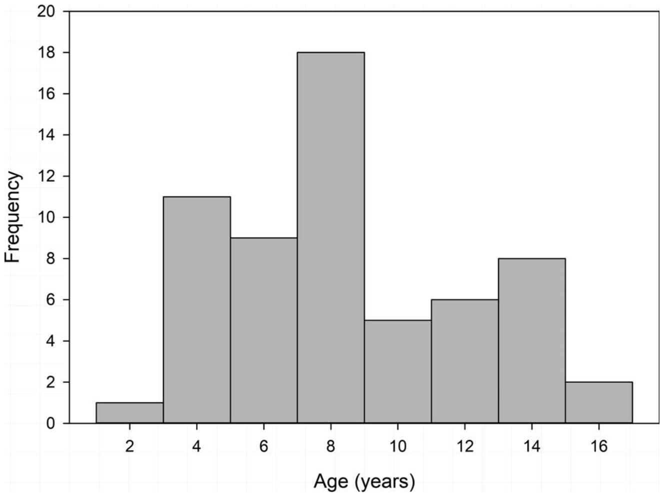

Figure 2. Age-frequency distribution for recently dead shells (n = 60) of *Strophitus undulatus* collected from the Clarion River.

having weathered periostracum and nacre; or relic shells, having heavy wear and little periostracum, indicative of having been dead for an extended time (Blodgett and Sparks 1987; Sietman et al. 2001). Because this was an initial survey of mussel occurrence in the river, I made no consistent efforts to find live mussels, but I report incidental occurrences of live mussels encountered during shell surveys. Live mussels were returned to the area of collection after identification.

I measured and aged a random sample ($n = 60$) of recently dead shells of *S. undulatus* to provide demographic information on the species in the Clarion River. I measured the anterior-to-posterior shell length (nearest 0.1 mm) with digital caliper prior to sectioning. I selected one valve from each specimen and cut the valve radially from the umbo into two halves using a fine jeweler's saw. Instead of cutting thin sections from the valve (e.g., Neves and Moyer 1988), I lightly sanded the cut edge of the valve with 400-grit sandpaper and examined the wetted, cut edge under a dissecting microscope; wetting the shell accentuated shell rings. I identified annuli and distinguished them from nonannual rings as rings that could be traced from the umbo to the shell margin (Neves and Moyer 1988). Aging mussel species with slow growth and closely spaced annuli requires thin-sectioning techniques (Neves and Moyer 1988), but rapidly growing species such as *S. undulatus* can be aged effectively without thin sectioning (Neves and Moyer 1988; Haag and Commens-Carsons 2008; Harriger et al. 2009)). I examined the relationship between age and shell length with linear regression using QED Statistics version 1.5.1.456 (Pisces Conservation Ltd. 2015).

RESULTS

A total of 321 shells and living individuals of four mussel species were collected; at least one shell or mussel was collected from each of the 157 sites (Table 1). Two hundred forty-one recently dead shells, 58 weathered shells, and four live individuals of *S. undulatus* were collected from 146 sites (93% of total shells collected across sites; mean = 2.1 shells or live mussels/site at sites with *S. undulatus*). Twelve relic shells of *Actinonaias ligamentina* were found at 12 sites (3.7% of total shells collected across sites), five recently dead shells and one live *Lampsilis fasciola* were found at five sites (3.2% of total shells collected across sites), and one recently dead shell of *Lampsilis ovata* was found at one site (0.6% of total shells collected across sites). The few living individuals of *S. undulatus* and *L. fasciola* were found in slow-moving reaches of the river with substrates of fine sand and gravel.

Ages of 60 recently dead *S. undulatus* shells ranged from 2 to 16 yr, with a mean age of 8.0 yr (±1.0 SE; Fig. 2). Length of sampled shells ranged from 26.8 to 81.7 mm with a mean length of 29.8 mm (±0.5 SE). Shell length was positively associated with age ($r^2 = 0.86$, $P = 0.005$, shell length = 3.8[age] + 23.8).

DISCUSSION

Contrary to previous ideas that the Clarion River is unsuitable for mussels (Carnegie Museum and Western Pennsylvania Conservancy 1993), my results show that mussels, particularly *S. undulatus*, are of widespread occurrence, at least in my 55-km study reach. Species richness was low, and I have no information about the abundance of live mussels in the river. Nevertheless, the frequent occurrence of recently dead shells suggests that the study reach supports a substantial mussel population. Suitability of the river for mussels is further supported by a recent mussel relocation project; survival of several mussel species translocated from the Allegheny River to the upper Clarion River was 98% after 1 yr (Western Pennsylvania Conservancy 2015).

Strophitus undulatus possesses several life history traits that may allow it to readily recolonize streams recovering from severe pollution. First, *S. undulatus* is a host generalist whose glochidia can parasitize many different fish species (Cliff et al. 2001; Van Snik Gray et al. 2002; Ford and Oliver 2015). Second, *S. undulatus* is a widespread species and occurs across a range of environmental conditions (Ortmann 1919; Strayer and Jirka 1997), but it is predominantly found in smaller rivers and streams (Haag 2012). Finally, *S. undulatus* is classified as having a periodic life-history strategy, intermediate in position on the *r*–*K* continuum, with moderate life span, low to moderate age at maturity, and moderate to high growth rate, traits that can allow rapid population growth in some situations (Haag 2012). My results support a low–moderate life span of at least 16 yr. The wide range of ages represented in the population, including individuals as young as 2 yr old, suggests that natural recruitment is occurring in the river.

The other three species found in the Clarion River were rare. *Lampsilis fasciola* and *L. ovata* both were represented by live individuals or recently dead shells, suggesting that at least small populations currently exist in the river. *Actinonaias ligamentina* was represented only by relic shells. These shells may indicate occurrence of the species in the river prior to

Table 1. Sites on the Clarion River sampled for mussel shells from 2007 to 2019.

Site	Date	Coordinates	Findings
1	September 7, 2007	41.39583, 79.27611	2 RD *Strophitus undulatus*
2	September 10, 2007	41.55028, 79.39000	1 RD *S. undulatus*
3	September 20, 2007	41.36361, 79.35139	1 RD *S. undulatus*
4	September 20, 2007	41.32667, 79.46917	1 RD *S. undulatus*
5	September 25, 2007	41.45222, 79.15389	2 RD, 1 W *S. undulatus*
6	September 25, 2007	41.34250, 79.16250	1 RD *S. undulatus*
7	September 25, 2007	41.35111, 79.07750	1 RD *S. undulatus*
8	September 26, 2007	41.42889, 79.37278	1 RD *S. undulatus*
9	September 26, 2007	41.38528, 79.41472	1 RD *S. undulatus*
10	September 26, 2007	41.39056, 79.38306	1 RD *S. undulatus*
11	April 15, 2008	41.38778, 79.26361	1 RD, 2 W *S. undulatus*
12	April 29, 2008	41.39778, 79.49333	2 RD *S. undulatus*
13	April 29, 2008	41.39667, 79.38028	2 RD *S. undulatus*
14	April 30, 2008	41.39306, 79.38217	1 RD *S. undulatus*
15	April 30, 2008	41.40361, 79.33972	2 RD *S. undulatus*
16	April 30, 2008	41.29694, 79.27278	1 RD *S. undulatus*
17	April 30, 2008	41.43833, 79.27194	2 RD *S. undulatus*
18	April 30, 2008	41.40972, 79.33556	2 RD *S. undulatus*
19	May 5, 2008	41.39417, 79.37972	1 RD *S. undulatus*
20	May 6, 2008	41.38389, 79.25111	2 RD *S. undulatus*
21	May 6, 2008	41.37306, 79.49944	1 RD *S. undulatus*
22	May 6, 2008	41.37667, 79.47194	1 RD *S. undulatus*
23	May 6, 2008	41.37944, 79.25611	1 RD *S. undulatus*
24	May 12, 2008	41.39361, 79.38000	1 RD *S. undulatus*
25	May 15, 2008	41.37917, 79.46778	2 RD, 1 W *S. undulatus*
26	May 15, 2008	41.37306, 79.49611	1 RD *S. undulatus*
27	June 6, 2008	41.49111, 79.36833	2 RD *S. undulatus*
28	June 6, 2008	41.42250, 79.40222	1 R *Actinonaias ligamentina*; 1 RD *S. undulatus*
29	June 13, 2008	41.39250, 79.42667	1 RD *S. undulatus*
30	July 2, 2008	41.39306, 79.39222	1 RD *S. undulatus*
31	September 21, 2008	41.33167, 79.43694	1 RD *S. undulatus*
32	September 21, 2008	41.33639, 79.43972	1 RD *S. undulatus*
33	October 6, 2008	41.38278, 79.26056	1 RD, 1 W *S. undulatus*
34	October 6, 2008	41.37750, 79.51083	1 RD *S. undulatus*
35	October 8, 2008	41.47639, 79.30972	1 RD *S. undulatus*
36	October 8, 2008	41.46083, 79.28889	1 RD *S. undulatus*
37	October 8, 2008	41.36361, 79.30861	2 RD *S. undulatus*
38	October 8, 2008	41.37861, 79.18083	1 RD, 1 W *S. undulatus*
39	October 8, 2008	41.38528, 79.31306	1 RD *S. undulatus*
40	October 9, 2008	41.33444, 79.21778	1 RD *S. undulatus*
41	October 10, 2008	41.38528, 79.31306	1 R *A. ligamentina*
42	October 10, 2008	41.43917, 79.39361	1 RD *S. undulatus*
43	October 10, 2008	41.34250, 79.37306	1 RD, 1 W *S. undulatus*
44	October 10, 2008	41.42444, 79.37306	1 RD *S. undulatus*
45	October 10, 2008	41.42167, 79.36917	1 RD *S. undulatus*
46	October 10, 2008	41.41556, 79.36361	1 RD, 3 W *S. undulatus*
47	October 10, 2008	41.41056, 79.35861	1 RD *S. undulatus*
48	October 10, 2008	41.40806, 79.35500	2 RD *S. undulatus*
49	October 10, 2008	41.41028, 79.36056	1 L *S. undulatus*
50	October 13, 2008	41.51389, 79.03500	1 R *A. ligamentina*
51	April 27, 2009	41.30083, 79.25944	1 RD *S. undulatus*
52	April 27, 2009	41.38222, 79.25778	1 RD *S. undulatus*
53	April 27, 2009	41.38167, 79.25083	1 RD *S. undulatus*

Table 1, continued.

Site	Date	Coordinates	Findings
54	April 27, 2009	41.37278, 79.49778	1 RD *S. undulatus*
55	April 27, 2009	41.37306, 79.49806	1 RD *S. undulatus*
56	April 28, 2009	41.44417, 79.33000	1 RD *S. undulatus*
57	April 28, 2009	41.44667, 79.33139	1 RD *S. undulatus*
58	April 28, 2009	41.44250, 79.33583	1 RD *S. undulatus*
59	April 28, 2009	41.44222, 79.33917	2 RD, 1 W *S. undulatus*
60	April 28, 2009	41.44194, 79.34000	1 RD *S. undulatus*
61	April 28, 2009	41.44139, 79.35056	1 RD *S. undulatus*
62	April 28, 2009	41.44111, 79.35611	1 RD *S. undulatus*
63	April 28, 2009	41.44139, 79.35861	1 RD *S. undulatus*
64	April 28, 2009	41.44250, 79.36972	1 RD *S. undulatus*
65	April 28, 2009	41.32917, 79.37167	1 RD *S. undulatus*
66	April 28, 2009	41.32972, 79.20333	1 RD *S. undulatus*
67	April 28, 2009	41.44861, 79.38917	1 W *S. undulatus*
68	April 28, 2009	41.44806, 79.31861	1 RD *S. undulatus*
69	June 5, 2009	41.44528, 79.17417	1 RD *S. undulatus*
70	August 8, 2009	41.37250, 79.49917	1 RD *S. undulatus*
71	April 6, 2010	41.39861, 79.28111	1 RD *S. undulatus*
72	April 6, 2010	41.44778, 79.37917	1 RD *S. undulatus*
73	June 15, 2010	41.37638, 79.46139	1 RD *S. undulatus*
74	June 25, 2010	41.39389, 79.37972	1 RD *S. undulatus*
75	June 25, 2010	41.39000, 79.42611	1 RD *S. undulatus*
76	August 31, 2010	41.38333, 79.26278	1 RD *S. undulatus*
77	August 31, 2010	41.38028, 79.25583	1 RD *S. undulatus*
78	September 5, 2010	41.36083, 79.31750	1 RD *S. undulatus*
79	September 5, 2010	41.35528, 79.31083	1 RD *S. undulatus*
80	April 21, 2011	41.37333, 79.50083	1 R *A. ligamentina*; 27 RD, 12 W *S. undulatus*
81	June 1, 2011	41.40583, 79.42306	1 R *A. ligamentina*
82	June 15, 2011	41.38667, 79.43222	1 RD *S. undulatus*
83	June 15, 2011	41.36222, 79.31444	1 RD *S. undulatus*
84	September 2, 2011	41.40056, 79.26444	2 RD *S. undulatus*
85	September 2, 2011	41.37278, 79.48556	2 RD *S. undulatus*
86	September 2, 2011	41.37444, 79.49750	1 RD *S. undulatus*
87	September 2, 2011	41.38444, 79.26417	1 RD *S. undulatus*
88	September 2, 2011	41.39028, 79.27111	1 RD *S. undulatus*
89	September 2, 2011	41.39556, 79.27861	1 R *A. ligamentina*; 1 RD *S. undulatus*
90	March 5, 2012	41.38472, 79.26167	2 RD *S. undulatus*
91	March 5, 2012	41.37333, 79.50028	1 RD *S. undulatus*
92	March 5, 2012	41.37472, 79.50250	1 RD *S. undulatus*
93	May 20, 2012	41.47556, 79.14028	1 R *A. ligamentina*
94	May 20, 2012	41.47861, 79.11972	1 RD, 1 W *S. undulatus*
95	August 24, 2012	41.38056, 79.25639	1 RD *S. undulatus*
96	August 24, 2012	41.37444, 79.50222	1 RD *S. undulatus*
97	August 24, 2012	41.40306, 79.29250	1 RD *S. undulatus*
98	April 15, 2013	41.32361, 79.24139	1 RD *S. undulatus*
99	May 27, 2013	41.47528, 79.13222	1 R *A. ligamentina*; 1 RD *S. undulatus*
100	May 27, 2013	41.46972, 79.16361	3 RD, 2 W *S. undulatus*
101	May 27, 2013	41.60722, 79.33944	1 R *A. ligamentina*
102	June 15, 2013	41.36667, 79.33861	1 RD *S. undulatus*
103	July 21, 2013	41.37889, 79.37972	1 R *A. ligamentina*
104	May 26, 2014	41.31806, 79.30333	23 RD, 11 W *S. undulatus*
105	May 26, 2014	41.56500, 79.32750	1 L *S. undulatus*
106	June 8, 2014	41.46611, 79.16611	1 R *A. ligamentina*

Table 1, continued.

Site	Date	Coordinates	Findings
107	June 8, 2014	41.46861, 79.16694	5 RD, 4 W *S. undulatus*
108	July 23, 2014	41.39306, 79.27500	2 RD *S. undulatus*
109	July 23, 2014	41.38806, 79.26806	1 RD *S. undulatus*
110	July 23, 2014	41.38944, 79.26972	1 RD *S. undulatus*
111	September 1, 2014	41.32194, 79.28972	2 RD, 1 W *S. undulatus*
112	October 17, 2014	41.44306, 79.36917	1 RD *S. undulatus*
113	April 18, 2015	41.36500, 79.33833	2 RD *S. undulatus*
114	April 18, 2015	41.36583, 79. 33611	1 RD *S. undulatus*
115	May 3, 2015	41.39528, 79.26139	2 RD *S. undulatus*
116	May 3, 2015	41.60472, 79.33750	1 L, 1 RD *Lampsilis fasciola*
117	May 4, 2015	41.46056, 79.17000	1 RD *L. fasciola*; 1 L, 1 RD, 2 W *S. undulatus*
118	May 4, 2015	41.47667, 79.20528	7 RD *S. undulatus*
119	May 21, 2015	41.44583, 79.32139	2 RD, 2 W *S. undulatus*
120	May 21, 2015	41.50444, 79.24167	2 RD *S. undulatus*
121	May 21, 2015	41.44361, 79.35139	1 RD *S. undulatus*
122	May 21, 2015	41.44417, 79.37833	1 RD *S. undulatus*
123	May 21, 2015	41.45000, 79.39278	1 RD *S. undulatus*
124	May 21, 2015	41.45278, 79.39917	1 RD *S. undulatus*
125	June 6, 2015	41.35722, 79.18611	1 RD *S. undulatus*
126	June 6, 2015	41.46444, 79.16222	1 RD *S. undulatus*
127	June 11, 2015	41.32806, 79.21917	1 W *S. undulatus*
128	June 11, 2015	41.36417, 79.33778	1 RD *S. undulatus*
129	August 13, 2015	41.46333, 79.17389	1 RD *S. undulatus*
130	September 13, 2015	41.36556, 79.33722	1 RD *S. undulatus*
131	September 23, 2015	41.34528, 79.31361	1 RD *L. fasciola*
132	September 23, 2015	41.35028, 79.31000	1 L *S. undulatus*
133	September 23, 2015	41.59417, 79.31944	1 RD *S. undulatus*
134	September 24, 2015	41.57778, 79.32472	1 W *S. undulatus*
135	September 24, 2015	41.55111, 79.32583	1 RD *S. undulatus*
136	September 24, 2015	41.53500, 79.32611	1 RD *S. undulatus*
137	September 24, 2015	41.50306, 79.32111	1 RD *S. undulatus*
138	September 24, 2015	41.50972, 79.32278	1 RD *S. undulatus*
139	September 24, 2015	41.50944, 79.32278	1 RD *S. undulatus*
140	September 24, 2015	41.51889, 79.32333	1 RD, 1 W *S. undulatus*
141	September 24, 2015	41.52694, 79.32528	1 RD *S. undulatus*
142	September 24, 2015	41.54194, 79.32667	1 RD *S. undulatus*
143	September 24, 2015	41.56778, 79.32611	1 RD *S. undulatus*
144	October 21, 2015	41.32000, 79.28972	3 RD *S. undulatus*
145	November 3, 2015	41.45167, 79.17333	2 RD, 1 W *S. undulatus*
146	March 30, 2016	41.46861, 79.30111	2 RD *S. undulatus*
147	April 19, 2017	41.31833, 79.29639	1 RD *L. fasciola*
148	May 16, 2017	41.43750, 79.22556	1 RD, 1 W *S. undulatus*
149	July 29, 2017	41.32028, 79.29306	1 R *A. ligamentina*; 1 RD *S. undulatus*
150	August 15, 2017	41.46750, 79.28611	1 RD *S. undulatus*
151	August 5, 2018	41.55472, 79.16778	1 RD *S. undulatus*
152	October 7, 2018	41.46056, 79.28917	14 RD, 6 W *S. undulatus*
153	June 28, 2019	41.36333, 79.20222	1 RD *L. fasciola*; 3 RD *S. undulatus*
154	June 29, 2019	41.33956, 79.14048	1 RD *S. undulatus*
155	July 14, 2019	41.29887, 79.26907	1 RD *S. undulatus*
156	September 11, 2019	41.32536, 79.17357	1 RD *S. undulatus*
157	September 11, 2019	41.32536, 79.35700	1 RD *Lampsilis ovata*

RD = recently dead shells; W = weathered shells; R = relic shells; L = live mussels.

severe water pollution, but the time of death of the specimens is unknown, and it is unknown if the river currently supports a natural population of the *A. ligamentina*.

The absence of any historical mussel records prior to severe pollution in the early 1900s or any contemporary mussel surveys prior to this study make it impossible to reconstruct the Clarion River's original mussel fauna and difficult to assess the extent to which the fauna may be recovering. Possibly, the river never supported a substantial mussel fauna, but this seems unlikely in a region characterized by diverse mussel faunas in most streams (e.g., Ortmann 1919). More likely, the Clarion River supported a diverse fauna similar to other tributaries of the Allegheny River. If so, the widespread occurrence of mussels in the river today may represent recovery of the river and recolonization by the mussel fauna.

Potential source populations and dispersal routes for recolonization of the Clarion River likely differ among mussel species. *Actinonaias ligamentina* and *L. ovata* are generally restricted to larger streams such as the Allegheny River, where *A. ligamentina* is a dominant species (Anderson 2000; Smith et al. 2001). The Allegheny River was likely the source population for both species prior to the completion of Piney Dam, but the dam is currently a barrier to recolonization. *Strophitus undulatus* and *L. fasciola* inhabit both small tributary streams and the mainstem Allegheny River (Ortmann 1919; Harriger et al. 2009). Populations of both species in the Clarion River could have originated from the Allegheny River, but they are uncommon in the latter river (Anderson 2000; Smith et al. 2001). The apparently substantial population of *S. undulatus* in the Clarion River suggests the presence of a nearby source population in a tributary stream. Many tributaries within the Clarion Basin escaped pollution in the early 1900s (Department of Health of the Commonwealth of Pennsylvania 1915), but it is unknown if they support mussel faunas that serve as source populations for recolonization of the Clarion River. Tributaries are proposed as source populations for recolonization of the historically polluted upper Illinois River by mussels (Seitman et al. 2001) and for recolonization of fishes in the Clarion River (Bardarik 1965).

Another possible source for recovery of the mussel fauna is the Clarion River itself—if some species survived severe pollution. This seems unlikely given the severity and duration of pollution. However, the conclusion that the aquatic fauna was eliminated (Ortmann 1913) was not based on a comprehensive survey, and the lack of subsequent mussel surveys makes it impossible to determine whether any species survived. A third possible source of mussel fauna is the release of fishes infected with glochidia from other populations (Hayes 2000), but to my knowledge, this possibility has not been examined.

The decimation of the aquatic fauna of the Clarion River by pollution is a great tragedy, but so is the fact that no record of the historical fauna exists. The shell collections made during this study provide a glimpse of what the mussel fauna of the Clarion River may have looked like. All four species I found are characteristic members of mussel assemblages in small to midsized streams in the Ohio River basin of western Pennsylvania (Walsh et al. 2007). Other characteristic species of these assemblages, such as *Lasmigona costata*, *Alasmidonta marginata*, *Lampsilis cardium*, and *Ptychobranchus fasciolaris,* were not collected during this study. However, in 2015, I found a relic shell of *Lasmigona costata* in the Clarion River below Piney Dam just above the mouth of Deer Creek (C. Williams, personal observation). My results show that the Clarion River is now capable of supporting mussel populations, but additional surveys are needed to document mussel abundance and provide a baseline for monitoring future natural recovery. Conservation actions meant to hasten mussel recovery, such as translocation from other populations or release of hatchery-propagated individuals, face the challenge of determining appropriate species for reintroduction or augmentation, and these decisions will need to be made based on assumptions about the original fauna of the river.

ACKNOWLEDGMENTS

I thank Pat and Peggy Kearney, Nancy Pyle, and Kim, Kelsey, and Tara Williams for assisting in shell surveys. Charles Bier and Beth Meyer verified species identifications. Serena Ciparis, Wendell Haag, Kim Williams, and an anonymous reviewer provided helpful comments on the manuscript.

LITERATURE CITED

Anderson, R. M. 2000. Assessment of freshwater mussels in the Allegheny River at Foxburg, Pennsylvania, 1998. U.S. Geological Survey Water-Resources Investigations Report 00-4058. Available at: https://pubs.usgs.gov/wri/2000/4058/wri20004058.pdf (accessed November 5, 2021).

Anonymous. 1949. Paper mill abates pollution. Pennsylvania Angler 18(10):24.

Bardarik, D. G. 1965. Distribution and composition of fish communities in a polluted and unpolluted stream in the Upper Ohio River basin. Pages 79–94 *in* C. A. Tryon, Jr., R. T. Hartmann, and K. S. Cummins, editors. Studies of the Aquatic Ecology of the Upper Ohio River System. Special Publication No. 3, Pymatuning Laboratory of Ecology, University of Pittsburgh, Pittsburgh, Pennsylvania.

Blodgett, K. D., and R. E. Sparks. 1987. Analysis of a mussel die-off in pools 14 and 15 of the Upper Mississippi River. Aquatic Biology Technical Report 87/15. Illinois Natural History Survey River Research Laboratory, Havana.

Camp, Dresser, and McKee, Consulting Engineers. 1949. Report on Clarion River pollution abatement. Commonwealth of Pennsylvania, Department of Health, Sanitary Water Board, Harrisburg. Available at: https://archive.org/details/reportonclarionr00camp (accessed 12 June 2021).

Carnegie Museum and Western Pennsylvania Conservancy. 1993. A survey of the dragonflies and damselflies of the Clarion River and its tributaries near the Allegheny National Forest, Pennsylvania. Carnegie Museum and Western Pennsylvania Conservancy, Pittsburgh, Pennsylvania.

Cliff, M., M. Hove, and M. Haas. 2001. Creeper glochidia appear to be host generalists. Ellipsaria 3:18–19.

Commonwealth of Pennsylvania. 2018. Physiographic provinces of Pennsylvania. Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey, Harrisburg, Pennsylvania. Available at: http://elibrary.

dcnr.pa.gov/PDFProvider.ashx?action=PDFStream&docID=1752507&chksum=&revision=0&docName=Map13_PhysProvs_Pa&nativeExt=pdf&PromptToSave=False&Size=810216&ViewerMode=2&overlay=0 (accessed May 21, 2021).

Department of Health of the Commonwealth of Pennsylvania. 1915. Report on the sanitary survey of the Allegheny River Basin. Harrisburg, Pennsylvania. Available at: https://archive.org/details/reportonsanitary00penn (accessed 10 November 2021).

Ford, D. F., and A. M. Oliver. 2015. The known and potential hosts of Texas mussels: Implications for future research and conservation. Freshwater Mollusk Biology and Conservation 18:1–14.

Haag, W. R. 2012. North American Freshwater Mussels: Natural History, Ecology, and Conservation. Cambridge University Press, New York.

Haag, W. R., and A. M. Commens-Carsons. 2008. Testing the assumption of annual ring shell deposition in freshwater mussels. Canadian Journal of Fisheries and Aquatic Sciences 65:493–508.

Harriger, K., A. Moerke, and P. Badra. 2009. Freshwater mussel (Unionidae) distribution and demographics in relation to microhabitat in a first-order Michigan stream. Michigan Academician 39:149–162.

Hayes, T. 2000. Our native mussels. American Currents 26(4):21–22. Available at: http://www.nanfa.org/ac/our-native-freshwater-mussels.pdf (accessed 15 May 2021).

Neves, R. J., and S. N. Moyer 1988. Evaluation of techniques for age determination of freshwater mussels (Unionidae). American Malacological Bulletin 6:179–188.

Ortmann, A. E. 1909. The destruction of the fresh-water fauna in western Pennsylvania. Proceedings of the American Philosophical Society 48:90–110.

Ortmann, A. E. 1913. The Alleghenian Divide, and its influence upon the freshwater fauna. Proceedings of the American Philosophical Society 52:287–390.

Ortmann, A. E. 1919. A monograph of the naiades of Pennsylvania. Part III. Systematic account of the genera and species. Memoirs of the Carnegie Museum 8:1–385.

Pisces Conservation Ltd., 2015. QED Statistics. Available at: http://qedstatistics.com/ (accessed 7 July 2020).

POWR (Pennsylvania Organization for Watersheds and Rivers). 2019. 2019 River of the year, the Clarion River. Available at: http://pariveroftheyear.org/2019-river-of-the-year-2/ (accessed 12 June 2021).

Sietman, B. E. S. D. Whitney, D. E. Kelner, K. D. Blodgett, and H. L. Dunn. 2001. Post-extirpation recovery of the freshwater mussel (Bivalvia: Unionidae) fauna in the upper Illinois River. Journal of Freshwater Ecology 16:273–281.

Smith, D. R., R. F. Villella, and D. P. Lemarie. 2001. Survey protocol for assessment of endangered freshwater mussels in the Allegheny River, Pennsylvania. Journal of the North American Benthological Society 20:118–132.

Strayer, D. L., and K. J. Jirka. 1997. The Pearly Mussels of New York State. New York State Museum Memoir 26, Albany.

USACOE (U.S. Army Corps of Engineers, Pittsburgh District). 2021. East Branch Clarion River Lake. Available at: https://www.lrp.usace.army.mil/Missions/Recreation/Lakes/East-Branch-Clarion-River-Lake/ (accessed 12 June 2021).

Van Snik Gray, E., W. A. Lellis, J. C. Cole, and C. S. Johnson. 2002. Host identification for *Strophitus undulatus* (Bivalvia: Unionidae), the creeper, in the Upper Susquehanna River Basin, Pennsylvania. American Midland Naturalist 147:153–161.

Walsh, M. C., J. Deeds, and B. Nightingale. 2007. User's Manual and Data Guide to the Pennsylvania Aquatic Community Classification. Pennsylvania Natural Heritage Program and Western Pennsylvania Conservancy, Pittsburgh. Available at: http://www.naturalheritage.state.pa.us/aquaticsUserMan.aspx (accessed 11 June 2021).

Western Pennsylvania Conservancy. 2015. Mussels have new homes in the Clarion, other rivers. Conserve 61(4):6–7. Available at: https://waterlandlife.org/publications/e-conserve/winter_15/ (accessed 10 November 2021).

Williams, C. E. 1995. A clean slate for the Clarion. Pennsylvania Wildlife 16(1):27–29. Available at: https://www.academia.edu/4004029/A_clean_slate_for_the_Clarion (accessed 11 June 2021).