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Update and analysis of fish occurrences in the lower Potomac River drainage in the vicinity of Plummers Island, Maryland—Contribution XXXI to the natural history of Plummers Island, Maryland

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Abstract.—On a local scale, the biota of the Plummers Island, Maryland, vicinity is among the most intensively studied in the world. The fishes occurring in Potomac River and its tributaries in the vicinity of that island have been subjected to periodic scrutiny since the early 1900s, with the latest thorough analysis published in 2002. Herein, we present an updated and comparative analysis of this fish fauna using data gathered over the past decade. Our findings reveal that the complement of fish species that inhabits the area is particularly dynamic in nature. Compared to data presented in 2002, we report a net increase in the numbers of species (up to 93 species) occurring or formerly occurring near Plummers Island. These changes are the result of the return of several migratory species fostered by improved fish passage on the Potomac River, the return of some native resident fishes, and the establishment of additional nonnative species that now constitute 22–35% of the fauna, balanced against several probable extirpations. Species involved in these changes are treated in detail, and a number of novel records, vouchered and nonvouchered, are discussed. Factors that likely play key and interrelated roles in the dynamic nature of the Plummers Island area fish fauna, including hydrographic context and anthropogenic activities, are revisited and discussed. Particular emphasis is placed on the importance of improved practices in the documentation of local species occurrences in the future.

Keywords: C&O Canal, fishes, fish distributional determinants, fish passage, invasive species, nonnative fishes, Plummers Island, Potomac River

Over 350 publications have contributed to our ample knowledge of the biota of the Plummers Island area, many of them spurred by the strong interests of the Washington Biologists Field Club, which had ownership of the island for over half a century and encouraged investigations of the area biota (Brown 2008). One of the earlier works was that of McAtee & Weed (1915), which provided a comprehensive compilation of fishes known from the vicinity of the island. Their focal area included the mainstem Potomac River from approximately the District of Columbia (D.C.) line lying two kilometers below Little Falls upstream 15.7 km to Great Falls, along with the adjacent C&O

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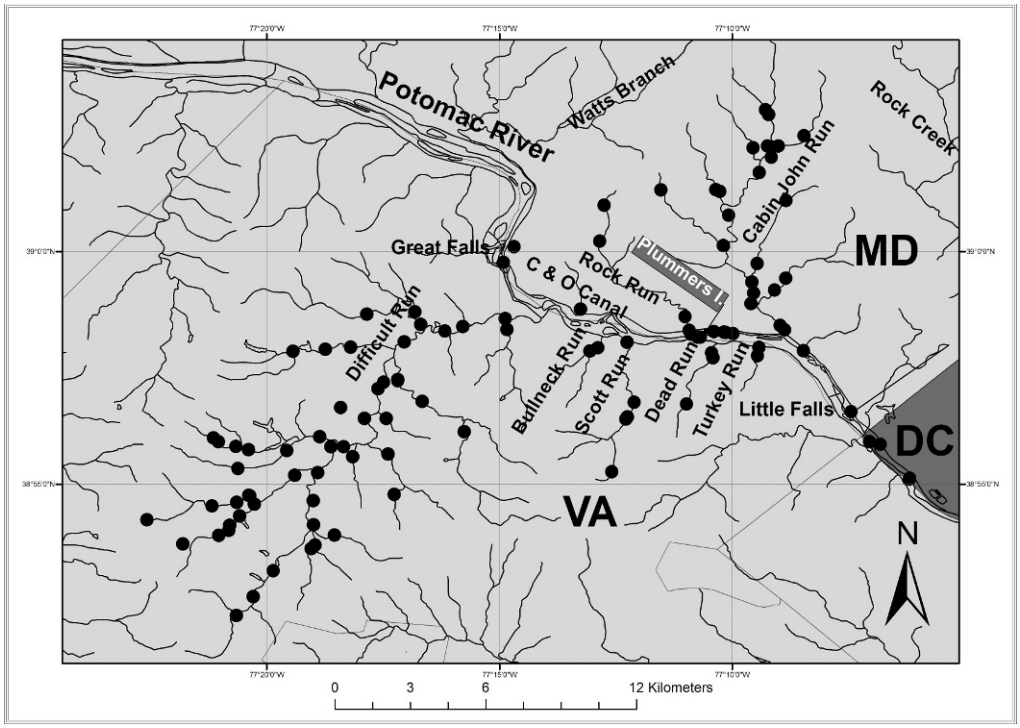

Fig. 1. Water bodies in vicinity of Plummers Island, Maryland, indicating study area and sampling locations upon which current analysis of fish occurrence is based (prepared by J. A. Raine, NCSM).

Canal. Also surveyed were six tributaries entering that reach (Fig. 1), including, on the Virginia shore, Turkey, Dead, and Scott runs, sampled both within and above Potomac Gorge, and lowermost Difficult Run within the gorge only. On the Maryland shore, only the lowermost reaches of Cabin John and Rock runs were sampled. From their collections and previous literature, they reported 55 nominal species (though they stated only 54 in their summary), ten of which were considered nonnative and the native status of several others held in question. Other important early contributions, though not specifically targeted to the environs of Plummers Island, provide early baseline knowledge of historical fish occurrence in the area. These include Uhler & Lugger (1876), Smith & Bean (1899), Bean & Weed (1911), Radcliffe & Welsh (1916) and Truitt et al. (1929). Manville (1968), in the twentieth formal contribution to the knowledge of the biota of the Plummers Island area, assembled a list of all vertebrates known from the area, including fishes. That work consisted of an uncritical recapitulation of the earlier works of McAtee & Weed (1915), Smith & Bean (1899), Bean & Weed (1911), and also incorporated some previously unpublished records from collections made in nearby tributaries in 1944. Many of the specimens yielded by the above surveys were deposited at the National Museum of Natural History, Smithsonian Institution (USNM) and continue to serve as valuable vouchers for verification of historical occurrences. More recently, the regional faunal work of Jenkins & Burkhead (1994) has important bearing on the study area. Additionally, there have been a host of survey reports prepared by regional resource management agencies, academic institutions, and consultants that provide the bulk of recent insights on the lower Potomac fish fauna.

Starnes (2002), in the twenty-seventh formally titled contribution to the natural history of Plummers Island (but listed as twenty-eighth in Brown 2008, Table 1), compended and analyzed the history of fish occurrence in the area dating from the mid 1800s. This compilation included an analysis of records gleaned from existing literature, the collections of USNM, a critical assessment of numerous reports by resource agencies and various consultants, and targeted surveys conducted in 1995 by the author and assistants. The latter revisited all streams surveyed by McAtee & Weed (1915) but expanded the collection area to include Bullneck Run and additional sites in the systems of Difficult, Rock, and Cabin John runs. In the main river, the study area was expanded downstream to 0.5 kilometers above Chain Bridge so as to include a reach less treacherous to navigation and thus one that could be effectively sampled by netting or electroshocking from boats. Due to flood damage and draining of the C&O Canal during that time, this habitat was unfortunately not re-surveyed in 1995. Voucher specimens for the 1995 survey reside at the North Carolina State Museum of Natural Sciences, Raleigh (NCSM).

Starnes (2002) recorded a total of 86 (with an eighty-seventh possible) species of fish having occurred in the general vicinity of Plummers Island, including 56–60 probable native species, of which at least 16 were believed to be extirpated, and a large complement of 30 definite or probable nonnatives. The native/nonnative status of several species was not resolved at the time of that publication. It was hypothesized that the Potomac River may have had an unusually dynamic early history of nonnative species introductions, including a number of Eurasian species, due to its proximity to the seat of the U.S. Government and the headquarters of the former U.S. Bureau of Fisheries and the early experimental projects that agency showcased. Nine nonnative species formerly recorded from the area were reported as no longer established (Starnes 2002). He also pointed out that the nearly 180 year-old C&O Canal, which lies close to the Potomac River along its north bank, has probable significance as a conduit for passage of certain fish species, including coastal plain inhabitants, to areas within and upstream of the higher gradient Plummers Island reach of the Potomac.

In addition to historical analyses of occurrence, Starnes (2002) assessed streams and fish populations of tributary streams that were surveyed in 1995, using an Index of Biotic Integrity (IBI). This IBI was tailored to the Plummers Island area streams surveyed, using historical occurrence data specific to those streams rather than on broad based regional IBI criteria that often rely on metrics derived from index streams remote from those being investigated. This specificity may be particularly important in this area because it lies in the upper portions of the Fall Line ecotone. Moreover, tributaries on the Virginia versant of the Potomac and dropping into the Potomac Gorge have precipitous lower reaches that limit or curtail access to fishes. The faunal implications of this topography were first noted by McAtee & Weed (1915) and discussed at some length by Starnes (2002). Given the topography of the area, native species composition and natural richness can vary significantly among streams over a relatively small expanse. This approach permitted a more critical assessment of current versus past species richness and composition and provided comparative baseline data for future surveys that may help detect improving or declining trends in the fish populations or the health of streams in the study area.

In the following study, we update and supplement the findings of Starnes (2002). Due to its recent publication date, we limit the present treatment to discussions of fish species for which we are aware of significant changes in occurrence, recently

Table 1.—Historic and recent occurrences and native/nonnnative status of fish species from the Potomac River, C&O Canal, and tributaries in the vicinity of Plummers Island, Maryland, based on compilations in Starnes (2002) and more recent records (see Amendments section in text for sources). Under each water body, the range of collection dates reported in Starnes (2002) (before semicolons) and the most recent subsequent record (**bold**) appear along with the presumed current population status (P = present, X = extirpated). Native status indicated by "N", nonnative "NN"; migratory (anadromous/catadromous) species indicated by "M", resident year-round (including locally migratory/potadromous) species by "R"; species with emendments to Starnes (2002) or otherwise as discussed in the text are indicated by "***".

Species (native/migratory status)	Potomac river/C&O Canal	Turkey run, Virginia	Dead run, Virginia	Scott run, Virginia	Bullneck run, Virginia	Difficult run, Virginia	Cabin john run, Maryland	Rock run, Maryland
Lampetra aepyptera— Least Brook Lamprey (N/R) ***							**2003?** P?	
Lampetra appendix— American Brook Lamprey (N/R) ***							**2003?** P?	
Petromyzon marinus— Sea Lamprey (N/M) ***	1899–1960; P						1944; **2009** P	
Acipenser brevirostrum— Shortnose Sturgeon (N/M) ***	1876; **2006** P							
Acipenser oxyrinchus— Atlantic Sturgeon (N/M) ***	1899; P?							
Lepisosteus osseus— Longnose Gar (N/R) ***	1861–1899; **2010** P							
Amia calva—Bowfin (N/R) ***	1979; **2009** P							
Anguilla rostrata— American Eel (N/M)	1899–1996; **2010** P	1995–1999; **2004** P	1976–1995; P	1995; P	1983–1999; **2001** P	1975–1999; **2010** P	1944–1996; **2010** P	1912–1974; **2003** P
Anchoa mitchelli— Bay Anchovy (N/R)	1984; **2010** P (occasional)							
Alosa aestivalis— Blueback Herring (N/M)	1899–1992; **2010** P							
Alosa mediocris— Hickory Shad (N/M) ***	1876–1899; **2009** P							
Alosa pseudoharengus— Alewife (N/M)	1876–1992; **2009** P							
Alosa sapidissima— American Shad (N/M) ***	1876–1993; **2010** P							

Table 1.—Continued.

Species (native/migratory status)	Potomac river/C&O Canal	Turkey run, Virginia	Dead run, Virginia	Scott run, Virginia	Bullneck run, Virginia	Difficult run, Virginia	Cabin john run, Maryland	Rock run, Maryland
Dorosoma cepedianum—Gizzard Shad (N/R)	1876–1992; **2010** P							
Dorosoma petenense—Threadfin Shad (NN/R) ***	X?							
Campostoma anomalum—Central Stoneroller (N/R) ***	1996; **2010** P	1912; **2004** P				1986–1999; **2010** P	1987–1996; **2010** P	**2003** P
Carassius auratus—Goldfish (NN/R)	1876–1992; **2009** P						1996; P?	
Clinostomus funduloides—Rosyside Dace (N/R)	1996; P (transient)	1912; **2004?** P?	1983–1995; P	1912; X?	1912–1995; P	1912–1999; **2010** P	1912–1996; **2010** P	1912–1996; **2003** P
Ctenopharyngodon idella—Grass Carp (NN/R)	occasional (stocked)							
Cyprinella analostana—Satinfin Shiner (N/R) ***	1899–1985; P?	1912; P?		1912; X?	**2001** P?	1901–1999; **2010** P	1912–1996; **2009** P	1912–1974; X?
Cyprinella spiloptera—Spotfin Shiner (N?/R) ***	1899?–1996; **2010** P	**1999?** P?				**1999?** P?	1974; **2010** P	1974; P?
Cyprinus carpio—Common Carp (NN/R)	1899–1996; **2010** P						1996; P?	
Ericymba buccata—Silverjaw Minnow (N?/R) ***	1906; **2010** X	1912; X					1909–1996; **2010** P	
Exoglossum maxillingua—Cutlip Minnow (N/R)						1975–1999; **2010** P	1912–1996; P	1912–1996; **2003** P
Hybognathus regius—Eastern Silvery Minnow (N/R) ***	1876–1992; **2008** P	1912?–1999; P (below falls)						
Leuciscus idus—Ide (NN/R)	1899; X							
Luxilus cornutus—Common Shiner (N/R) ***	1912–1995; P	1912; P?			**2001** P?	1975–1999; **2010** P	1912–1996; **2010** P	1912–1974; P?
Margariscus margarita—Pearl Dace (N/R)							1899–1909; X	
Nocomis micropogon—River Chub (N/R) ***	1899–1985; **2010** P					1986–1992; P?	1912–1944; **2008?** P?	

Table 1.—Continued.

Species (native/migratory status)	Potomac river/C&O Canal	Turkey run, Virginia	Dead run, Virginia	Scott run, Virginia	Bullneck run, Virginia	Difficult run, Virginia	Cabin john run, Maryland	Rock run, Maryland
Notemigonus crysoleucas—Golden Shiner (N/R)	1912–1996; **2008** P					1975–1999; **2010** P	1912; **2008** P	
Notropis amoenus—Comely Shiner (N/R) ***	1899–1912; **2010** P	1912; P? (below falls)		1912; P? (below falls)		**1999?**	1909–1910; P?	1912; P?
Notropis bifrenatus—Bridle Shiner (N/R) ***	1908; X?							
Notropis hudsonius—Spottail Shiner (N/R)	1899–1996; **2010** P	1912; **2000?** P?				1989–1999; **2007** P	1912–1996; **2008** P	1912; X?
Notropis procne—Swallowtail Shiner (N/R)	1899–1996; **2010** P		1912; X			1975–1999; **2010** P	1912–1996; **2010** P	
Notropis rubellus—Rosyface Shiner (N/R) ***	1984–1995; P?						1912; **2009?** P?	1912; X?
Pimephales notatus—Bluntnose Minnow (NN?/R)	1909–1996; **2010** P	1912–1999?; P?		1912–1983; P?	1893; X?	1975; **2008** P	1909–1996; **2010** P	1912–1974; **2003** P
Pimephales promelas—Fathead Minnow (NN/R) ***						1995–1999; P?		
Rhinichthys atratulus—Blacknose Dace (N/R)	1912; **2010** P (transient)	1912–1999; **2004** P	1912–1999; **2004** P	1912–1999; **2006** P	1995–1999; **2001** P	1912–1999; **2010** P	1912–1996; **2010** P	1912–1996; **2003** P
Rhinichthys cataractae—Longnose Dace (N/R)	1912; P (transient)	1912–1999; **2004** P	X	1912–1983; X?	1983–1999; **2001** P	1975–1999; **2010** P	1912–1996; **2010** P	1912–1996; **2003** P
Semotilus atromaculatus—Creek Chub (N/R)	1912; **2010** P (transient)	1912–1999; **2004** P	1912–1999; **2004** P	1912–1999; P	1995–1999; **2001** P	1912–1999; **2010** P	1912–1996; **2010** P	1912–1996; **2003** P
Semotilus corporalis—Fallfish (N/R) ***	1955–1996; P					1999?; P?	1912–1996?; **2010** P	
Tinca tinca—Tench (NN/R)	1899; X							
Carpiodes cyprinus—Quillback (N/R)	1899–1996; **2010** P							
Catostomus commersonii—White Sucker (N/R)	1899–1992; **2010** P	1999; P	1976–1999; **2004** P	1912–1999; **2001** P		1975–1999; **2010** P	1912–1996; **2010** P	1912–1996; **1996** P
Erimyzon oblongus—Creek Chubsucker (N/R) ***	1899–1912; **2008** P					**2007?** P?		1913; X?

Table 1.—Continued.

Species (native/migratory status)	Potomac river/C&O Canal	Turkey run, Virginia	Dead run, Virginia	Scott run, Virginia	Bullneck run, Virginia	Difficult run, Virginia	Cabin john run, Maryland	Rock run, Maryland
Hypentelium nigricans—Northern Hogsucker (N/R) ***	1899–1996; **2010** P	1912; X				1986–1999; **2010** P	1912–1974; **1996?** P?	1912–1974; P?
Moxostoma erythrurum—Golden Redhorse (NN?/R) ***	1992; **2010** P						1996; **2004** P	
Moxostoma macrolepidotum—Shorthead Redhorse (N/R) ***	1899–1996; **2010** P							1912; P?
Ameiurus catus—White Catfish (N/R)	1876–1992; **2010** P							
Ameiurus natalis—Yellow Bullhead (N/R)	1899–1995; **2010** P	1999; P		1995; **2001** P	1999; P	1999; **2008** P	**2009** P	1995–1996; P
Ameiurus nebulosus—Brown Bullhead (N/R)	1899–1995; **2009** P					1975–1999; **2007** P		
Ictalurus furcatus—Blue Catfish (NN/R) ***	1905?–1992?; **2009** P							
Ictalurus punctatus—Channel Catfish (NN/R) ***	1889–1992; **2010** P					**2008** P	**2004** P	
Noturus gyrinus—Tadpole Madtom (N/R)	1911? P?							
Noturus insignis—Margined Madtom (N/R)	1876–1978; **2010** P					1982–1999; **2010** P	1912; **2009** P	1912–1996; P
Pylodictis olivaris—Flathead Catfish (NN/R) ***	P?							
Umbra pygmaea—Eastern Mudminnow (N/R) ***	1912; P?					1999; **2001?** P?		
Esox lucius—Northern Pike (NN/R)	1993?							
Esox masquinongy—Muskellunge (NN/R) ***	**2009** occasional (stocked)							
Esox niger—Chain Pickerel (N/R) ***	1912 P?							

Table 1.—Continued.

Species (native/migratory status)	Potomac river/C&O Canal	Turkey run, Virginia	Dead run, Virginia	Scott run, Virginia	Bullneck run, Virginia	Difficult run, Virginia	Cabin john run, Maryland	Rock run, Maryland
Salmo trutta—Brown Trout (NN/R) ***	occasional (stocked)					1982–1992; X? (stocked)		
Oncorhyncus mykiss—Rainbow Trout (NN/R) ***	occasional (stocked)							
Salvelinus fontinalis—Brook Trout (NN?/R) ***						1899–1982; X		
Percopsis omiscomaycus—Trout-perch (N/R)	1876–1911; X						1899; X	1899; X
Menidia beryllina—Inland Silverside (N/R)	1984–1992; **2010** P							
Strongylura marina—Atlantic Needlefish (N/R)	1899–1992; **2010** P							
Fundulus diaphanus—Banded Killifish (N/R)	1910; **2010** P							
Gambusia holbrooki—Eastern Mosquitofish (N?/R) ***	**2010** P		1999; P?			**2002** P?	**2002** P	
Cottus caeruleomentum—Blue Ridge Sculpin (N/R) ***							X?	X?
Cottus girardi—Potomac Sculpin (N/R) ***		**1999?** P?					1944–1996; **2010** P	
Morone americana—White Perch (N/M)	1876–1992; **2010** P							
Morone saxatilis—Striped Bass (N/M)	1876–1993; **2010** P							
Ambloplites rupestris—Rock Bass (NN/R) ***	1899–1996; **2010** P						**2009** P	1912; P?
Chaenobryttus (=*Lepomis*) *gulosus*—Warmouth (NN?/R)	1899–1996; P					1999; **2002** P		1912; P?
Enneacanthus gloriosus—Bluespotted Sunfish (N/R) ***	1899–1926; P?							

Table 1.—Continued.

Species (native/migratory status)	Potomac river/C&O Canal	Turkey run, Virginia	Dead run, Virginia	Scott run, Virginia	Bullneck run, Virginia	Difficult run, Virginia	Cabin john run, Maryland	Rock run, Maryland
Lepomis auritus—Redbreast Sunfish (N/R)	1899–1996; **2010** P	1912–1999; P		1912; X?		1912–1999; **2010** P	1912–1996; **2010** P	1912–1995; **2003** P
Lepomis cyanellus—Green Sunfish (NN?/R)	1912–1992; **2010** P	2000; P			1999; **2001** P	1975–1999; **2010** P	1974–1996; **2008** P	1911–1996; **2009** P
Lepomis gibbosus—Pumpkinseed (N/R)	1899–1996; **2010** P	1912; X?		1912–1999; **2001** P		1912–1999; **2008** P	1912–1996; **2010** P	1912–1974; P?
Lepomis macrochirus—Bluegill (NN/R)	1900–1996; **2010** P			1999; P	1995–1999; P	1975–1999; **2010** P	1974–1996; **2008** P	1974–1995; **2009** P
Lepomis megalotis—Longear Sunfish (NN/R) ***	1911?, 1984–1995; **2010** P					1975–1999?; P?	**2009** P	
Lepomis microlophus—Redear Sunfish (NN/R) ***	1995; P					**2010** P		
Micropterus dolomieu—Smallmouth Bass (NN/R) ***	1899–1996; **2010** P	1999; P?		1912; X?		1912–1992; P?	1995–1996; **2010** P	1974; P?
Micropterus salmoides—Largemouth Bass (NN?/R) ***	1876?, 1899–1996; **2010** P	**2000** P?		1999; P?	1995; P?	1982–1999; **2008** P	1974–1996; **2009** P	1974; P?
Pomoxis annularis—White Crappie (NN/R)	1894–1993; **2008** P							
Pomoxis nigromaculatus—Black Crappie (N?/R) ***	1894–1995; **2009** P					1975; **2007** P	**2008** P	
Etheostoma blenniodes—Greenside Darter (NN/R) ***	1976; **2010** P						1995; **2010** P	**2003** P
Etheostoma flabellare—Fantail Darter (N/R) ***	P?	**2000?** P?				1989–1999; P?	1909–1996, **2010** P	1912–1996; **2003** P
Etheostoma olmstedi—Tesselated Darter (N/R) ***	1912–1996; **2010** P	1912; **1999** P (below falls)		1912; X?		1975–1999; **2010** P	1912–1996; **2010** P	1912–1996; P
Perca flavescens—Yellow Perch (N/R)	1912–1992; **2009** P					**2007** P		

Table 1.—Continued.

Species (native/migratory status)	Potomac river/C&O Canal	Turkey run, Virginia	Dead run, Virginia	Scott run, Virginia	Bullneck run, Virginia	Difficult run, Virginia	Cabin john run, Maryland	Rock run, Maryland
Percina bimaculata—Chesapeake Logperch (N?/R) ***	1876–1938; X							
Percina notogramma—Stripeback Darter (N/R) ***	X?							
Percina peltata—Shield Darter (N/R) ***	1899–1976; **2010 P**							
Sander vitreus—Walleye (NN?/R) ***	1901–1992; **2009 P**							
Channa argus—Northern Snakehead (NN/R) ***	**2010 P**							

discovered species, species with changes of taxonomic status, and other noteworthy observations. A relatively thorough description of the Potomac River and its tributaries, including geology, physiography, and current and historical water quality estimates was given in Starnes (2002). One recent event not discussed by Starnes (2002) that has likely impacted fish occurrences in the Plummers Island area was the modification of Little Falls (=Brookmont) Dam to incorporate a major fish passage structure (completed in 2000; D. Winer, in litt.). This passage has promoted immigration of fish into the study area.

Amendments to Starnes (2002)

Table 1 presents a concise history of fish species occurrences in each of the water bodies of the study area (Fig. 1), limited to the earliest and most recent records reported in Starnes (2002), the most recent records of species subsequent to Starnes (2002), species newly recorded from the area, and the current presumed population status of each based on recent records, detection probabilities, and trends in habitat quality. The scope (Fig. 1) of the present analysis corresponds generally to that of Starnes (2002). Several county, state, and federal resource management agencies maintain jurisdictions within the relatively compact study area and, thus, the tributary streams and some accessible portions of the river are relatively well sampled on a repeated basis, providing ample opportunities for updating occurrence data.

Sources for updated records are: District of Columbia Department of the Environment (DCDE), Fairfax County (Virginia) Stream Protection Strategy Program (FCSPSP), Interstate Commission on the Potomac River (ICPR), Maryland Department of Natural Resources (MDDNR), Montgomery County (Maryland) Department of Environmental Protection (MOCODEP), University System of Maryland,

Frostburg (USMF), and Virginia Department of Game and Inland Fisheries (VDGIF). Unvouchered records were accepted if the species in question had a relatively recent and independently documented history of occurrence in the water body from which the record was reported. Those records lacking such independent confirmation were not rejected out of hand but were called into question and held up for discussion. Finally, very recently, in summer of 2010, using boat and backpack electrofishing equipment and seines, the authors of this contribution engaged in additional targeted surveys of the Potomac River at selected areas within the Plummers Island study reach and at some tributary locations in the Cabin John and Difficult runs systems from which questionable fish records had been previously reported. These included comprehensive collections made in the river near Plummers and Swainson Islands and, in the lower portion of the study reach, between Little Falls and Chain Bridge. Voucher collections are deposited at NCSM.

The following accounts correspond to those species denoted by "***" in Table 1.

Petromyzon marinus.—Sea Lamprey. While we cannot be certain that some occurrences of this anadromous species have not escaped the canvass of data from recent decades, its reappearance in the area after more than four decades (based on 1960 Potomac R. record), represented by the recent captures of immature ammocoetes stages in Cabin John Run in 2003, 2004, 2008 (verified via photo), and 2009 may be due to improved fish passage at the Little Falls Dam. Prior to these, the most recent record in Cabin John Run was 1944. Adult sea lampreys, which are parasitic on fishes most of their adult life, typically migrate well inland to spawn in rivers and tributaries. The larval ammocoetes stages remain in inland freshwaters for several years before transforming and outmigrating to marine environments (Jenkins & Burkhead 1994). Based on their overall broad distributions, two nonparasitic lamprey species, *Lampetra aepyptera* (Least Brook Lamprey) and *L. appendix* (American Brook Lamprey) could also potentially occur in the study area but have not been documented as adults; lacking vouchers, it is impossible to determine if they may have been represented among catches of some of the ammocoetes stages reported above.

Acipenser brevirostrum.—Shortnose Sturgeon. This federally endangered species continues to be very uncommon throughout its range along the Atlantic coast and particularly in the Potomac River estuary. However, much of the earlier history of sturgeon captures in the Potomac River is poorly documented with regard to catch composition (Kynard 1997, Welsh et al. 2002, Kynard et al. in litt.). Thus, the relative occurrence of this species compared to that of the Atlantic Sturgeon (below) is speculative. Until recently, the Shortnose Sturgeon had not been definitely recorded from the D.C. area since 1876 (Starnes 2002). However, based on telemetry studies and periodic recaptures of this migratory species, Kynard et al. (in litt.) reported a few individuals were year-round residents in the Potomac estuary, including a gravid female that entered the study reach to near Little Falls in April 2006. This observation indicates that this stretch of the Potomac may serve as spawning habitat for the Shortnose Sturgeon.

Acipenser oxyrinchus.—Atlantic Sturgeon. Starnes (2002) reported the last documented occurrence of Atlantic Sturgeon in the D.C. area as 1899. While nearly 190 Atlantic Sturgeon captures have been documented in the Potomac estuary in recent years (data of U.S. Fish & Wildlife Service, Annapolis, Maryland), monitoring efforts have not been focused near D.C., and there have been no recent records reported. Given that this species typically migrates to shoal areas to spawn, the reach of river below Little Falls (and now possibly

above, due to the newly opened fish passage) presents a good possibility of spawning habitat for the Potomac population.

Lepisosteus osseus.—Longnose Gar. Starnes (2002) did not locate any documented records of this riverine species from the study reach, though it was regularly recorded a few kilometers down river. It was suspected that the failure to record this highly distinctive and easily identified species over the years may have been due to a focus on mainly recording data for game species. The occurrence of this species was recently confirmed by the authors from the lower portion of the study reach just below Little Falls (NCSM 59983) and, while summer 2010 survey efforts yielded no specimens from upstream of that obstacle, it likely occasionally negotiates the improved fish passage at that dam to enter waters nearer Plummers Island, especially during spring spawning migrations.

Amia calva.—Bowfin. This mainly coastal plain species has been rarely reported from the area with a single prior record published from the Great Falls area (Jenkins & Burkhead 1994, Starnes 2002). A recent record was also reported from the Potomac River just downstream of the study area near Fletchers Boathouse along the D.C. shore (L. Lyon DCDE, pers. com.). Bowfin occurring in the area may represent the upstream extent of coastal plain populations, which perhaps occasionally enter and traverse the C&O Canal (Starnes 2002), or stem from stocks that were introduced into upriver portions of the Potomac three or more decades ago (Jenkins & Burkhead 1994).

Alosa mediocris.—Hickory Shad. This anadromous species was of rare occurrence in the Potomac in the D.C. area throughout most of the 1900s and had not been definitively documented from the Plummers Island study reach in prior years (Starnes 2002). However, shad restoration efforts in the lower Potomac (J. D. Cummins ICPR, in litt.) and Chesapeake Bay area, beginning in the late 1990s, resulted in strong early spring runs of this fish to the area below Little Falls Dam (VDGIF and DCDE data) and this vagile species should easily negotiate the improved fish passage at this obstacle, thus reaching Great Falls.

Alosa sapidissima.—American Shad. Highly sought after by anglers during its upriver spring migrations, this shad, which historically reached Great Falls, maintained some minor runs to the Little Falls area over the past century. However, like the Hickory Shad, its numbers were much depleted compared to historical population levels. It benefitted from the Potomac River American Shad Restoration Project (J. D. Cummins ICPR, in litt.), which included closing the fishery in the early 1980s, supplemental propagation and stocking of fry, and construction of the fishway at Little Falls in 2000; good runs have now returned to the base of Great Falls.

Dorosoma petenense.—Threadfin Shad. Though reported near the lower study area in the mid 1970s (Jenkins & Burkhead 1994, Starnes 2002), no recent occurrences of this nonnative and somewhat cold intolerant species (formerly introduced as forage) were found and it may be extirpated from the Potomac River system.

Cyprinella analostana.—Satinfin Shiner. Although this species was reported from the main stem of the Potomac River between 1899 and 1985 (Starnes 2002), most of those reports were unvouchered, leaving open to speculation the possibility of partial confusion with the similar Spotfin Shiner, *C. spiloptera* (below). There are no recent records of Satinfin Shiner from the river and, while some of the earlier records are valid based on vouchers, it would appear this minnow might be effectively extirpated from the main river. The early 1900s records (Table 1) from Scott and Turkey runs on the Virginia

shore were from below the falls, within the gorge and accessible to the river (McAtee & Weed 1915). This shiner was not found in collections from the lower reaches of Cabin John Run made in 2010, where only Spotfin Shiners were found, and there were no Rock Run records since 1974 (unvouchered). Though the Satinfin Shiner remains abundant throughout most of its wide range in Atlantic coastal drainages, this situation raises the specter of competitive exclusion by the Spotfin Shiner, which may not be native to the drainage (see below). Satinfin Shiner populations remain strong in the Difficult Run system, which is protected from invasion by riverine populations of Spotfin Shiners by the precipitous lower reach of the creek. They may also persist in Bullneck Run based on an unvouchered 2001 record (though not corroborated by collections made in 1995; Starnes 2002). They likely also persist in smaller tributaries to the Cabin John system that are probably not frequented by Spotfin Shiners, which have a penchant for somewhat larger streams.

Cyprinella spiloptera.—Spotfin Shiner. Previously known to occur only in the mainstem Potomac, this questionably native species (Starnes 2002) was verified from lower Cabin John Run in 2002 (R. L. Raisly USMF, pers. com.) and by the authors in 2010 (NCSM 60009). More recent records (2008–2009, MDDNR, MOCODEP) from smaller order streams within the Cabin John Run system are regarded with skepticism because this species does not typically enter headwater streams and photo vouchers from the 2008 sample appear to represent *C. analostana*. Unvouchered records from upper Turkey and Difficult runs in Virginia (1999, VDGIF permits report database) are regarded with equal skepticism due to lack of corroborating records, small stream order in the case of Turkey Run, and the improbability of this fish surmounting the gorge to invade these streams. The native status of this minnow has been debated (Jenkins & Burkhead 1994, Starnes 2002), but the possible elimination (see above) of its close relative, *C. analostana*, from the main Potomac and lower reaches of some tributaries may be indicative of competitive displacement by a nonnative species.

Ericymba buccata.—Silverjaw Minnow. This distinctive, possibly nonnative (see Starnes 2002) minnow (currently regarded by some workers as *Notropis buccatus*), is reported from the Potomac River for the first time since 1906, based on a 2010 collection made by the authors from a side channel in the Plummers-Swainson islands area (NCSM 60074). It continues to be common in the Cabin John Run system (e.g., NCSM 60000), but records are lacking from other area tributaries. If native, it has likely been extirpated from some areas, but its absence from the well-collected Difficult Run system, protected in recent geologic times from invasion from the river, may suggest it does not have a long history in the area. It also continues to be found in the Rock Creek system (D.C.–Maryland) downriver of the study area (MDDNR & MOCODEP data).

Hybognathus regius.—Eastern Silvery Minnow. This species does not typically enter small, low order, high gradient streams (Jenkins & Burkhead 1994). However, McAtee & Weed (1915) reported it from ''above the falls'' and ''upper part of the stream'' in the Turkey Run system (USNM 73357, as *H. nuchalis*), the only tributary from which this species was recorded. Those authors also listed a collection of fishes from the lower reach of this stream within the gorge in proximity to the river, but they did not report *Hybognathus*, raising the possibility of a data transposition. There was a record (unvouchered) of 65 specimens from this stream in 1999 (FCSPSP) from near the river where this species probably remains common. Oddly, this normally common

species was not taken in the study reach in 2010 collections (last reported in 1992; Starnes 2002) but was found to be common in the river a few kilometers downstream (e.g., NCSM 60026).

Nocomis micropogon.—River Chub. The presence of this denizen of rivers and larger tributaries was confirmed in the Potomac River near Plummers Island by the authors in 2010 (NCSM 60083, 60127), the first report since 1985. It was reported from the two largest tributaries in the study area, Difficult and Cabin John runs, as recently as 1992 and 2008, respectively, but these collections are unvouchered, and the status of tributary populations is thus uncertain. The authors failed to find this species in either system during 2010 sampling.

Notropis amoenus.—Comely Shiner. Inhabiting less easily collected pools and deeper runs in generally larger streams, this species tends to be of sporadic occurrence in collections, even where known to persist. Following a dearth of vouchered records since 1912, the authors confirmed the presence of this species in the Potomac River in the study area based on just one specimen from near Plummers Island (NCSM 59957), two from above Chain Bridge (NCSM 60039), and two from just below the study area at Fletchers Boathouse (NCSM 60036). Starnes (2002) regarded this minnow as possibly extirpated from the Plummers Island area with the caveat that a small population may have been overlooked in the main river due to low detection probabilities and lack of targeted effort. Either this was the case or this species is experiencing increased success in recruiting from populations that persist further up the Potomac drainage, perhaps aided by improving water quality. Based on the considerable collecting effort expended, this species evidently occurs at very low densities in the study area and may only be recruiting from those upstream populations at present. The early 1900s tributary records (Table 1) reported by McAtee & Weed (1915) were all from near the mouths of these streams in proximity to the river and occasional individuals may continue to stray to these areas. Regional agencies continue to report occurrences in surrounding portions of the Potomac outside the study area (e.g., Occoquan system, FCSPSP). A single 1999 record (VDGIF permit report data) from Difficult Run is regarded as very questionable.

Notropis bifrenatus.—Bridle Shiner. This species has not been recorded from the study area since 1908–1911, including several from its lower reaches below Little Falls; it was documented as late as 1935 farther down river (Starnes 2002). This species has apparently declined throughout its range and may be extirpated from the Potomac River and elsewhere in the state of Maryland based on recent survey efforts of MDDNR and USMF. The demise of certain species of native submerged vegetation with which this species is usually closely associated (Harrington 1947, W. C. Starnes per. obs.), brought on by the invasion of nonnative plants, may be partially to blame. However this minnow frequents areas that are difficult to collect effectively and has highly specific habitat preferences and patchy distributions; thus, detection probabilities can be very low, even for populations known to persist (W. C. Starnes per. obs.). While chances of rediscovery in the Potomac may be remote, cooperative targeted efforts (by VDGIF-NCSM) are currently underway to determine the status of former populations of this rare species across eastern Virginia.

Notropis rubellus.—Rosyface Shiner. While there are a couple of reports (Table 1) of this shiner from the Potomac River between 1984 and 2008, including a single recently reconfirmed specimen taken near Plummers Island by the first author in 1995 (NCSM 26980), sizeable fish collections made by the authors in 2010 failed to reveal its continued

presence. Older records (1912) from the lower reaches of Cabin John and Rock runs are vouchered at USNM serving to verify its former presence in those areas, though they had been partially confounded with the similar *N. amoenus* (Starnes 2002). The recent (2009) record, based on a single specimen collected in Cabin John Run about 1.6 km above the mouth (MOCODEP), is unvouchered, and the current status of this species in the study area is questionable and troubling.

Pimephales promelas.—Fathead Minnow. This nonnative minnow, commonly used in the bait trade and often released into lakes and streams, was recorded from Difficult Run in both 1995 (1 specimen, NCSM 26997) and 1999 (3, FCSPSP) but with no subsequent reports. In the eastern U.S., this species rarely becomes established where introduced, except in closed systems such as farm ponds, and it is doubtful whether those records represented an established population. However isolated occurrences from bait releases may be expected to continue.

Semotilus corporalis.—Fallfish. While this species in known to occur both above and below the study area in the Potomac drainage (Jenkins & Burkhead 1994, MDDNR data), formerly, the status of the Fallfish, the largest native eastern North American cyprinid, was somewhat questionable in the area with only unvouchered reports from the Potomac River, plus larger tributaries, Cabin John and Difficult runs (Starnes 2002). In 2010, the authors confirmed the presence of Fallfish in Cabin John Run based on a single specimen collected about 1.7 km above the mouth (NCSM 60008). There is a single questionable 1999 record (VDGIF permit data) from South Fork Difficult Run. However, efforts by the authors in the Potomac River and at several locations in the Difficult Run system did not yield specimens of this fish nor has extensive sampling throughout Difficult Run by FCSPSP and others revealed its presence. Based on its confirmed presence in Cabin John Run and in streams adjacent to the study area, and on unvouchered records from 1996 (Leathery 1999) and 2003 (MDDNR) from the main river and mouth of a small tributary, this inhabitant of principally larger creeks and smaller rivers is likely of transient occurrence in the main stem Potomac. It is likely absent from the Difficult Run system, having either failed to colonize that system prior to deepening of the Potomac Gorge, or being extirpated decades ago prior to comprehensive sampling in the area.

Erimyzon oblongus.—Creek Chubsucker. While there are numerous scattered tributary and main channel records of this species in piedmont and coastal plain portions of the Potomac River basin (Jenkins & Burkhead 1994), Starnes (2002) reported no records from within the study area more recent than the early 1900s and speculated on whether it might be verging on extirpation therein. However it has recently been reported as abundant in one section of the C&O Canal (2008, MDDNR) and was recorded from Snakeden Branch in the Difficult Run system (2007, VGDIF permit report database), though both reports lacked vouchers. Based on ease of identification, the Canal records are regarded as valid. Targeted efforts in Snakeden Branch and nearby streams by the authors in 2010 failed to reveal the presence of this species and it was not reported from numerous other collections made throughout the Difficult Run system in recent decades (Fig. 1). Therefore, the possibility of data transposition is raised and the status of this fish in that system remains problematic. If it is absent, the Creek Chubsucker may be among those species that do not have a long history in the area predating the deepening of Potomac Gorge and have failed to surmount the precipitous lower reach of Difficult Run, albeit its presence in the Potomac drainage above an even more imposing barrier, Great Falls, would then beg explanation. As with the

Eastern Mudminnow, *Umbra pygmaea*, passage of the falls via the C&O Canal (Starnes 2002) might be a possibility.

Moxostoma erythrurum.—Golden Redhorse. This presumably introduced species (Jenkins & Burkhead 1994, Starnes 2002), which prefers riverine and larger tributary habitats, continues to be represented in collections from the main river and one larger tributary, Cabin John Run. Difficult Run would also offer suitable habitat for invasion by this sucker but precipitous barriers in the lower reach prevent this.

Moxostoma macrolepidotum.—Shorthead Redhorse. This species is the only native redhorse to the Potomac River but was not mentioned in recently acquired records (those since 1996). However, using electrofishing boats, the authors collected numerous specimens of juveniles and adults (NCSM 59975, 59949, 60132) from the Potomac River within the study area near Plummers Island and downstream above Chain Bridge and it would appear a strong population persists there. A Rock Run record for 1912 was from just above the mouth and below the culvert passing beneath the C&O Canal (McAtee & Weed 1915, USNM 73390) and reportedly many suckers entered this lowest reach from the river during spring (note: a second 1912 record, for Cabin John Run, tabulated in Starnes 2002 was a typographical error). This slight inmigration may continue to the present but the Shorthead Redhorse does not typically inhabit smaller streams.

Ictalurus furcatus.—Blue Catfish. This, the largest of North American catfishes, is native to the Mississippi Basin and the Gulf slope but was introduced to most major tidal rivers of Virginia during the 1970s, resulting in large established populations (Jenkins & Burkhead 1994). However, the Potomac River proper (entirely within Maryland's jurisdiction) was not among those waters stocked. Starnes (2002) cast doubt on records from the early 1900s and dispelled reports from 1911 and the 1930s based on re-identification of vouchers as Channel Catfish, though all such earlier reports could not be definitively refuted. He also reported that young Blue Catfish were becoming numerous in the Potomac downstream of the study area in the late 1990s. It is unknown if this population resulted from migration from other Virginia tributaries to Chesapeake Bay during periods of high freshwater runoff or from more proximate small impoundments (e.g., Burke Lake, Pohick Creek system) where they were stocked in the 1980s (VDGIF data). Regardless, this population appears to be increasing rapidly (VDGIF unpublished data), and the Maryland state record Blue Catfish (30.5 kg) was landed in 2008. Blue Catfish have been classified as opportunistic and omnivorous feeders, but larger individuals are generally piscivorous (Graham 1999). The combined impacts of nonnative Blue and Flathead (below) catfishes to native catfish species in other Atlantic Slope drainages has apparently been profound (e.g., Moser & Roberts 1999) and the effects these predators/competitors will have on the Potomac ecosystem remain to be seen. Blue Catfish are now numerous in at least the lower portions of the study reach in the main river, but this species typically does not inhabit smaller tributaries.

Ictalurus punctatus.—Channel Catfish. Although, not previously reported beyond the confines of the main river (Starnes 2002), this nonnative catfish has been reported from the two largest tributaries in the study area, Cabin John and Difficult runs. These occurrences probably stem from recent introductions within the watersheds of these systems, as this species is frequently stocked in small impoundments and ponds.

Pylodictis olivaris.—Flathead Catfish. This very large and predatory species is native to the Mississippi River and other Gulf slope basins but has been introduced into several Atlantic slope systems (Jenkins & Burkhead 1994). The Flathead Catfish

has been categorized as a voracious piscivorous predator and has been known to prey heavily on native and beneficial naturalized fish species, thus having the potential to significantly depress native fish biomass (e.g., Moser & Roberts 1999, Odenkirk et al. 1999, Pine et al. 2005, 2007). It is a denizen of both impoundments and free-flowing rivers and is particularly common in shoal areas. Some individuals are highly migratory with extensive home ranges (Malindzak 2006) and dispersal through brackish waters is likely possible (Bringolf et al. 2005). The earliest known introduction of Flathead Catfish in the Potomac River drainage occurred in the Occoquan Reservoir in 1965 (VDGIF unpublished data). This stocking of only 12 individuals produced a viable population that thus far seems to have stabilized at a fairly low level, considering the exploding populations that have derived from other small Atlantic slope stockings with seemingly detrimental effects on native species (e.g., Guier et al. 1981, Thomas 1993, Pine et al. 2007). The Occoquan Reservoir produced the Virginia state record Flathead Catfish (30 kg) in 1994, and this species is now present in the tidal tailwater below Occoquan Dam (first documented in the 1990s) as well as the tidal Potomac River adjacent to the Occoquan River's confluence (VDGIF unpublished data). Based on considerable sampling, the Potomac population of Flathead Catfish has remained curiously localized for a decade or more, but the history of this potential menace in other drainages suggests that it may eventually invade upriver and find favorable habitat among the shoals of the Plummers Island area.

Umbra pygmaea.—Eastern Mudminnow. There are isolated but unvouchered reports (FCSPSP) of this primarily coastal plain species from sites in two tributaries of Difficult Run and from Wolf Trap (1999) and Little Difficult (2000, 2001) runs. Although currently lacking vouchers, the ease of identification of this distinctive fish and multiple reports of its occurrence should impart some veracity to these records. Mudminnows typically inhabit sluggish, swampy, lowland habitats and are associated with soft substrates and thick cover, such as woody debris, detritus, submerged vegetation, and undercut banks. Any localized pockets of such habitat in the otherwise relatively upland Difficult Run system may allow relict populations to persist. But thorough collecting efforts by the authors in 2010 at the same sites where this species was previously reported, using electrofishing and seining techniques concentrated on the most favorable habitat available, failed to duplicate the above records. Further, none of these sites were particularly lowland in character and therefore the 1999–2001 reports remain somewhat puzzling. Aside from these recent problematic records, Starnes (2002) summarized documented reports of a 1912 record from either the main stem Potomac or C&O Canal, plus occurrences well upstream of the Great Falls area, likely due to upstream passage via the C&O Canal.

Esox masquinongy.—Muskellunge. This large predatory game species, native to the Great Lakes, Hudson Bay, and Mississippi River basin drainages, is occasionally stocked into the Potomac upstream of the study area (MDDNR data), along with "Tiger Muskie" (Muskellunge x Northern Pike hybrids). Both were recorded (captured and released) near the lowest reaches of the study area as recently as 2009 by DCDE biologists.

Esox niger.—Chain Pickerel. This species was reported in 1912 collections from the C&O Canal by McAtee & Weed (1915), plus they collected several from the Potomac River near Chain Bridge in 1905–1911 (vouchered at USNM) but failed to report them. As reported in Starnes (2002), there were no recent records from the study area [map points

in Jenkins & Burkhead (1994) are based on the older records above] with nearest recent records (DCDE data) stemming from the Anacostia River system 12–15 km to the east. This continues to be the case and, with this pickerel's preferences for vegetated slack water habitats, the C&O Canal might have offered excellent habitat for this species in the past but frequent drainings over the ensuing years has possibly curtailed recruitment to the study area.

Oncorhynchus mykiss.—Rainbow Trout; and *Salmo trutta* – Brown Trout. These two nonnative salmonid species are occasionally encountered while sampling the Potomac (DCDE data). Historically, Rainbow Trout are not known to have been stocked in the study area, but Brown Trout were stocked for a time in the Difficult Run system during the 1980s–1990s with some apparent reproduction (Starnes 2002); this practice was discontinued (VGDIF) and these encounters probably represent migrants from scattered stockings of tributaries outside the Plummers Island reach.

Salvelinus fontinalis.—Brook Trout. This trout, native to the Blue Ridge region and questionably some cooler piedmont streams, was present in some headwaters of Difficult Run between 1899 and 1982, but its origins and local native status were questionable. It was considered to be possibly extirpated based on lack of recent records (Starnes 2002). Despite numerous collections from this system in recent decades, no further occurrences were recorded. Stranko et al. (2008) reported increasing extirpations in Piedmont streams of Maryland coincident with increasing urbanization.

Gambusia holbrooki.—Eastern Mosquitofish. Formerly based on only a single unvouchered 1999 record from Dead Run (Starnes 2002), the presence of this species was since confirmed in lower Cabin John Run in 2002 by R. L Raesly (USMF data). Further, the authors captured specimens of *G. holbrooki* in a side channel of the Potomac River in the Plummers-Swainson islands area (NCSM 60112) and also observed them in shallow seepage water collected in the drained reach of the adjacent C&O Canal at Lock 10 in 2010. Another capture (unvouchered) was reported from the Difficult Run system in 2002 (FCSPSP). The study area lies near the northern extent of this species' natural range and occurrences are sporadic. This range may extend northward into Delaware (Jenkins & Burkhead 1994, Starnes 2002) but is poorly understood due to numerous local introductions of this species, spanning many decades, in attempts to control mosquitoes. Isolated populations in the study area, as well as nearby systems (e.g., Rock Creek, MDDNR data) may stem from introductions dating well into the past.

Cottus caeruleomentum.—Blue Ridge Sculpin. Though there were no historic records to indicate this species occurred in either system, Starnes (2002) speculated that it might have been extirpated from the Cabin John Run and possibly Rock Run systems due to the fact that extant populations may flank those watersheds in closely adjacent creeks on the northern versant of the Potomac (Watts Branch, confirmed by NCSM 26955, and Rock Creek system, agency records but not confirmed by authors). While there were one or two "Mottled Sculpin" records (the group in which this species was formerly included prior to its recent description) from the Cabin John Run system in recent years, no vouchers exist despite a decade of diligent monitoring (MDDNR, MOCODEP). Targeted efforts in that system by the authors in 2010 revealed only Potomac Sculpins (below). Sculpins are notoriously difficult to identify to all but the best trained eyes and the Mottled Sculpin records might have been based on that species. The seeming absence of *C. caeruleomentum* from the study area might be best

explained by the fact that this inhabitant of cool and rapid waters effectively skipped over the shorter Cabin John and Rock runs via direct headwater exchange between the more extensive and overarching Watts Branch and Rock Creek systems (Fig. 1) rather than experiencing extirpation.

Cottus girardi.—Potomac Sculpin. Starnes (2002) reported this species as occurring only in the Cabin John Run system and there are now vouchered records (NCSM 60013, 60058) taken by the authors in that system in 2010, where it seemed very localized in certain streams (e.g., Buck Branch) rather than pervasive of all tributaries. While being relatively generally distributed in numerous tributaries along the Maryland shore of the Potomac, extending down river to and beyond the study area, this species is curiously absent from Virginia tributaries for many kilometers up the river above that area (Jenkins & Burkhead 1994). A recently discovered unvouchered 1999 record from Turkey Run (VDGIF permit reports database) is therefore considered to be in error. Gravel shoals of the Potomac River in the study area appear to offer good physical habitat for sculpins, which clearly have access to the area, but, while there are main stem records from well upriver, there continue to be no records from within the study reach, including from targeted efforts made by the authors in 2010. Though Potomac Sculpins are considered more eurythermal and tolerant of warmer water temperatures than many species (Jenkins & Burkhead 1994), summer water temperature maxima in this reach may exceed those tolerances.

Ambloplites rupestris.—Rock Bass. This nonnative game fish continues to be recorded from the main river (e.g., NCSM 60081, 60125). It was reported from lower Rock Run below the C&O Canal in 1912 (McAtee & Weed 1915, Starnes 2002) and was recently captured from lower Cabin John Run (2002, USMF; 2009, MOCODEP). This nonnative species normally inhabits rivers and all but the smallest of creeks (e.g., Etnier & Starnes 1993) and might be expected to further colonize that system and possibly Rock Run, given the ready accessibility from the river.

Enneacanthus gloriosus.—Bluespotted Sunfish. Based on its former abundance in the D.C. area (e.g., Uhler & Lugger 1876, Smith & Bean 1899), Starnes (2002) speculated this small and brightly adorned lowland sunfish may have inhabited slack and vegetated waters of the C&O Canal. However all records of this species continue to be from the Potomac River a few kilometers downstream of the study area. Lack of records from the canal suggests the previous supposition of Starnes (2002) may have been unfounded, despite the apparent successes of other lowland species that have utilized this habitat from time to time.

Lepomis megalotis.—Longear Sunfish. Within the past decade, this introduced species has entered Cabin John Run (MOCODEP data) from the large population residing in the Potomac River (and very likely enters the scarcely sampled lower reach of Rock Run for some distance as well). Earlier reports of Longear Sunfish from Difficult Run (1975 &1999) were unconfirmed by vouchers, nor were these reports corroborated by numerous collections made in that system by various workers in subsequent years or by several collections made therein by the authors in 1995 (Starnes 2002) and 2010. Barring introductions by humans, due to the precipitous lower reaches of Difficult Run and other Virginia tributaries, this sunfish should not be able to invade those systems.

Lepomis microlophus.—Redear Sunfish. This nonnative sunfish was previously documented only from the Potomac River in 1995 (Starnes 2002), but the authors collected it in the Difficult Run system in 2010 (NCSM 60099) in addition to

another reported occurrence in 2007 (FCSPSP). This species is occasionally stocked in combination with Bluegill and Largemouth Bass in ponds and impoundments and scattered local populations stemming from escapees sometimes result.

Micropterus dolomieu.—Smallmouth Bass. Though regarded as nonnative but long established in the Potomac River, the status of tributary populations of this game species has been uncertain. However several recent records from the Cabin John Run system from 1995–2010, including small juveniles (Starnes 2002, MOCODEP data, and NCSM 60016) indicate an established population. There are no records from Virginia tributaries, save sparse unvouchered 1990s reports from Turkey and Difficult runs, and the status of Smallmouth Bass populations in those systems remains unclear. Early (1912) records (Table 1) from Scott and Difficult runs reported by McAtee & Weed (1915) were from within the gorge reach of these streams in proximity to the river where this species was already well established by that time (Starnes 2002).

Micropterus salmoides.—Largemouth Bass. The northern extent of the native range of this valuable food and sport fish is not well understood but it was generally regarded as nonnative to mid Atlantic drainages (e.g., Jenkins & Burkhead 1994, Starnes 2002) north of the Tar River drainage of North Carolina. However, recent zooarcheological findings of bones (Whyte 2001, 2008, material verified by Starnes) from 600–700 year-old sites along the upper and lower Roanoke River system of the Albemarle Sound basin indicate the Largemouth Bass may have been indigenous to that basin barring very early introductions from drainages further south by pre-Europeans. This extends the native range further north than previously thought by most workers. The hydrographic history of fresh or low salinity connections between the adjacent tributaries of the Albemarle Sound basin and Chesapeake Bay tributaries, especially during Pleistocene low sea level periods, is not well understood (e.g., Hocutt et al. 1986), but the recently confirmed early presence of northerly distributed species as far south as the Roanoke River drainage, such as the Walleye (see below), raises the possibility of low salinity connections and calls into question whether Largemouth Bass might also have used these avenues to disperse northward. There has been little change in the distribution of occurrences of this fish in the study area over the past decade, except for an unvouchered first occurrence record (2000) from Turkey Run. However, established populations of this game fish might be expected anywhere due to frequent introductions and escapes from small impoundments.

Etheostoma blennioides.—Greenside Darter. Jenkins & Burkhead (1994) and Starnes (2002), in contrast to earlier workers, regarded this inhabitant of rivers and larger creeks as a nonnative and very successful invader of the Potomac River basin (based on no records in basin prior to 1950s). Starnes (2002) documented the first known occurrence in Cabin John Run and related an earlier (1976) unvouchered report from the main river. The continued presence of Greenside Darters in shoal areas of the river (NCSM 60068, 60114) and Cabin John Run (NCSM 60001) was documented by the authors in 2010 and there are recent records from Rock Run (MOCODEP, MDDNR). A similar but more recent explosive invasion of a sister Chesapeake Bay drainage, the Susquehanna River, was recently documented by Neely & George (2006). Two recent wide-ranging molecular studies of the Greenside Darter complex (Haponski & Stepien 2008, Piller et al. 2008) indicate that Susquehanna populations are genetically highly similar to and likely derived from upper Ohio River basin populations. However, neither of these studies included samples

from the Potomac and, while the proximate Ohio basin is a most likely source of introductions, the origin of the Potomac population remains unclear.

Etheostoma flabellare.—Fantail Darter. This inhabitant of riffle areas continues to be reported (MOCODEP, MDDNR, NCSM 60003, 60064) from Cabin John and Rock runs on the Maryland shore, but vouchered records in Virginia tributaries are lacking, despite 1980s–1990s agency reports (summarized in Starnes 2002) from the Difficult Run system and a 2000 report from Turkey Run (VDGIF permit report database). It was not regarded as present in those tributaries by Jenkins & Burkhead (1994). Given the general ease of collecting this species in small streams when present and the lack of vouchers or recent collections, despite targeted collecting by the authors in 1995 and 2010, these reports are puzzling. Perhaps localized populations exist that have escaped recent detection, but the status of Fantail Darters in Virginia tributaries remains unclear. This darter maintains populations in the main stem of the Potomac a few kilometers upstream of the study area (Jenkins & Burkhead 1994) and it was suspected that shoal areas in the Plummers Island reach might support a population as well. But targeted efforts in these areas by the authors have thus far not revealed any. The polytypic Fantail Darter complex has recently been under extensive study (Blanton 2001, 2007, Blanton & Schuster 2008). The Potomac populations have only recently become the focus of increased study, but indications are they may be assignable to the nominal *humerale* (Girard 1859) of mid-Atlantic drainages, currently regarded as a subspecies of *flabellare*. Based on recent trends of recognition of other distinctive clades in the complex, this taxon may eventually be recognized at the species level.

Percina bimaculata.—Chesapeake Logperch. Reported as *Percina caprodes*, the Logperch, by Starnes (2002). Populations of logperch from rivers entering Chesapeake Bay, based on molecular and morphological evidence, were recently assigned (Near 2008) to the re-elevated taxon, *Percina bimaculata* (Haldeman 1844) which had long been considered a synonym of *P. caprodes* [also regarded at times by the older combination *Percina nebulosa* (Haldeman 1842) but that name is a junior homonym and not available, Near 2008]. While some populations persist in the Susquehanna River drainage and smaller upper Chesapeake Bay tributaries in Maryland and Pennsylvania (Ashton & Near 2010), there have been no records of this darter in the Potomac since 1938 and it is considered as probably extirpated from this portion of its former range.

Percina notagramma.—Stripeback Darter. While there are sparse older records in Potomac tributaries both upstream and downstream of the study area (Jenkins & Burkhead 1994), there are no records from within it. Whether Plummers Island area streams once supported this species, followed by extirpation, or whether these habitats were locally unsuitable, even in pristine state, is open to question.

Percina peltata.—Shield Darter. This species had not been reported in the study area since an unvouchered main river record in 1976 (Starnes 2002). However, the authors collected one juvenile in the Potomac River from the shoal area at Swainson Island (just downstream of Plummers Island) in June 2010 (NCSM 60086), indicative of a reproducing population in the river or recruitment from a nearby tributary. The considerable effort expended in two collecting events in this area indicated the population is small. Outside the study area, this darter continues to be reported from some nearby tributaries (e.g., Rock Creek, MDDNR data).

Sander vitreus.—Walleye. Formerly reported by Starnes (2002) as *Stizostedion*

Fig. 2. *Channa argus*, Northern Snakehead, latest known arrival and infamous invader to lower Potomac River (rendered by S. Trammel; U.S. Geological Survey, illustration in public domain).

vitreum, the genus name has since been changed to the senior synonym *Sander* (Nelson et al. 2003). Jenkins & Burkhead (1994) and Starnes (2002) regarded Potomac populations of Walleye as probably introduced based on the scarcity of early records and the fact that introductions to the proximate Susquehanna drainage were known in the 1800s and to the Potomac in the early 1900s. However, recent zooarcheological evidence (Whyte 2004, 2008) indicates that Walleye were present to the south of Chesapeake Bay in Albemarle Sound tributaries (e.g., Roanoke River) 600–700 years ago. This presents the strong possibility of native status in mid Atlantic Slope drainages for this otherwise generally northerly-distributed species. Whether the perceived need by early fishery workers to stock this species in the Potomac in the early 1900s was due to a diminished native population or to no prior occurrence of such a population is speculative. Walleye remain relatively common in the main river and scarce in the C&O Canal but do not enter tributaries.

Channa argus.—Northern Snakehead (Fig. 2). This highly predatory species is native to eastern Asia, but a naturally reproducing population was found in the Potomac River in 2004 (Odenkirk & Owens 2005). The source of this introduction is unknown but, based on genetic evidence (Orrell & Weigt 2005), was not related to the well-publicized population (e.g., Dolin 2003) reported from a pond in Crofton, Maryland, in 2002, since thought to be eradicated. Since then, the population size and range of the Northern Snakehead have exploded (Odenkirk & Owens 2007). It now occurs over nearly 200 km of the main stem Potomac, virtually to the mouth, including in the entire study area reach (e.g., NCSM 59984) from Great Falls downstream, and much further down river to at least Northumberland County, Virginia (VDGIF data), including the lower reaches of all tributaries in Maryland and Virginia below the fall line. It has been captured in salinities as high as 7.6‰ (MDDNR data), which may have implications concerning further dispersal about the periphery of the Chesapeake Bay basin. Members of the snakehead family have several traits, including air breathing (thus a high tolerance of low dissolved oxygen) and high fecundity (Courtenay & Williams 2004), which may give them a competitive advantage in vegetated slackwater habitats of Potomac River. Northern Snakeheads are piscivorous, even at a young age. They have been reported to consume 15 fish species in the Potomac River (Odenkirk & Owens 2007). The shallow water-dwelling Banded Killifish, *Fundulus diaphanus*, had the highest frequency of occurrence in the diet, indicating a propensity for snakeheads to forage in such habitats. While no Northern Snakeheads were captured in a targeted survey of the C&O Canal conducted in 2008 (MDDNR), the potential of this waterway to serve as a conduit for this species to invade reaches of the

Potomac above Great Falls is of great concern. Elsewhere, this species is established in the Susquehanna River drainage in the Philadelphia, Pennsylvania area and in waterways of eastern Arkansas (USGS 2009) where a recent massive eradication effort failed to control the rapidly expanding population (C. R. Johnson, in litt.).

Miscellaneous questionable occurrences.—Since the compilations of Starnes (2002), there were unvouchered records for five fish species (Table 1) from tributaries in which they were not previously recorded or had not been recorded for many decades. These species have a history of occurrences in other tributaries in the study area and were often common where they occurred; in this context, these newer records from adjacent streams might seem plausible. However, for reasons given below, some of these records are held in some doubt and require qualification. The Central Stoneroller, *Campostoma anomalum*, was recorded from Turkey Run (2004, FCSPSP) for the first time since 1912 (McAtee & Weed 1915) and in Rock Run for the first time ever based on a single specimen (2003, MDDNR). The FCSPSP collection site was from lowermost Turkey Run (same site as 1912 record) within Potomac Gorge in proximity to the river where this species was confirmed to persist in 2010 (NCSM 60070, 60121). However, the Rock Run record needs further substantiation, especially given that small specimens of stonerollers are sometimes based on misidentifications of *Rhinichthys* species or similar minnows. As previously noted for *Cyprinella analostana,* Satinfin Shiner, *Luxilus cornutus*, the Common Shiner, was newly reported from Bull Neck Run (2001, FCSPSP). This occurrence may be plausible based on the relatively scant history of surveys in that tributary, albeit not present in one thorough sample conducted in 1995 (Starnes 2002). It is common in several other tributaries in the area but is uncommon in the main Potomac River. McAtee & Weed (1915) recorded this species from lower Turkey Run within the gorge in 1912, but it was not reported from this site in 1999 (FCSPSP). In the river, relatively recent records were confined to a single specimen taken near Plummers Island in 1995 (Starnes 2002, NCSM 26976) despite multiple thorough samples conducted in 2010. The 1996 record of the Northern Hogsucker, *Hypentelium nigricans*, from the Cabin John Run system (MOCODEP), though uncorroborated by other occurrences since 1974, including at three sites surveyed by the authors in 2010, seems plausible based on habitat preferences of this species and accessibility to the Potomac River where this species remains relatively common (e.g., NCSM 59955, 60078, 60122). However, it is noteworthy that young of this species are sometimes confounded with the similar appearing young of the White Sucker, *Catostomus commersonii*, which are common in Cabin John Run. This sucker may have a long history in the area based on its presence in Difficult Run perched above Potomac Gorge. The unvouchered 2007 record of the Black Crappie, *Pomoxis nigromaculatus*, from Difficult Run (FCSPSP) is deemed probable based on the common practice of introducing this popular and easily identifiable panfish in small impoundments. Finally, the 1999 record of Tessellated Darter, *Etheostoma olmstedi*, from Turkey Run (FCSPSP) is regarded as valid based on the location of the sample site, the lower reach in the gorge near the river where this species is known to persist (e.g., NCSM 59989, 60075, and others). The 1912 record reported by McAtee & Weed (1915) was from the same location; however, they recorded none from Turkey Run above the gorge nor were there subsequent records to suggest this darter ever surmounted the escarpment of the gorge. The upper Scott Run Tessellated Darter population documented by those

authors, though well above the escarpment, may be extirpated based on absence from collections in recent decades (Starnes 2002).

Summary and Conclusions

Though the Plummers Island study area covers less than 2025 square kilometers of watersheds, compared to the perceived status of fish populations and species composition less than a decade ago (Starnes 2002), there are a considerable number of changes to report. This study revealed a total of 88 species of native and nonnative fishes definitely or very probably having occurred in the Potomac River and its tributaries in the Plummers Island study area over the past 135 years (as derived from Table 1 and the above analyses). This is a slight increase in the overall total of 86 species reported by Starnes (2002). In addition, there are four species (*Lampetra aepyptera*, *L. appendix*, *Cottus caeruleomentum*, and *Percina notagramma*) that may have occurred in the area based on overall regional distribution, but, to date, lack local records to support this assumption. Another nonnative and potentially menacing species, *Pylodictis olivaris*, will likely invade the area if it does not already occur there. These additions raise the total number of species occurring or possibly occurring in the area to 93, of which 61 (65%) are regarded as probably native, 12 (13%) are of uncertain native status, and 21 (22%) are definitely nonnative. Of those 88 species definitely or probably having occurred in the area, eight are likely or certainly extirpated from all habitats surveyed, including five native (*Notropis bifrenatus*, *Esox niger*, *Percopis omiscomaycus*, and *Percina bimaculata*, and possibly *P. notagramma*) and four nonnative species that were established for a time in the past (*Dorosoma petenense*, *Leuciscus idus*, *Tinca tinca*, and *Salvelinus fontinalis*). In addition, there has been a troubling absence of the native Rosyface Shiner, *Notropis rubellus*, in more recent collections, though there is an unvouchered report from the Cabin John Run system. This total is down considerably from the 24 possible extirpations estimated by Starnes (2002); this is due in part to the welcomed reappearances of several native species (below) but also because earlier estimates were based on stricter presence/absence data. There are three species completely new to the area, including the introduced species *Ictalurus furcatus*, *Channa argus*, and possibly *Pylodictis olivaris*. Eight native species not previously recorded or not reported for many decades have been documented in the study area recently and may be on the increase: *Petromyzon marinus*, *Acipenser brevirostrum*, and *Lepisosteus osseus* (possibly previously overlooked in routine catch data recording?), *Alosa mediocris*, *Notropis amoenus*, *Erimyzon oblongus*, *Gambusia holbrooki*, and *Percina peltata*. Also, there are several new tributary records to report of species otherwise known to occur in nearby tributaries, some valid, some questionable. These changes indicate the dynamic nature of fish occurrences in this particular area, as well as probably the vagaries inherent in effective sampling of fish populations.

The dynamic nature of the Plummers Island area fish fauna is likely the product of a particular combination of natural and anthropogenic factors that can result in changes on an unusually local scale. One of the major natural factors is the general setting of the study area, situated at the narrow fall line ecotone just above the Potomac's tidal reaches and where the topographical context of tributaries changes from upland piedmont to coastal plain over a relatively small expanse; thus, the respective fish faunal complements typical of those environments are brought into close proximity, promoting some admixture. Other factors are the natural

barriers to fish migration. The Potomac Gorge, whose precipitous escarpment on the south (Virginia) side of the river presents a formidable obstacle to migration of fishes into tributaries from the main river, has likely had a profound effect on local fish distributions. Though some introductions cannot be ruled out, most of those species that seemingly maintain naturally occurring populations in the upper reaches of Virginia tributaries above the gorge likely have a very long history in those systems, perhaps dating to a geologic time when the gorge was less formidable (e.g., prior to possible down cutting during periods of reduced sea levels in the Pleistocene). Only the American Eel, *Anguilla rostrata*, whose immigrating young are notable for surmounting large obstacles throughout its range, seems to be able to negotiate the escarpment with relative ease and has been reported from all tributaries within the study area. Those species native to nearby Potomac tributaries that do not currently maintain populations in some or all tributaries on the Virginia versant either failed to colonize those streams when the geological setting was more conducive, were since extirpated by natural processes in the Pleistocene, or were much more recently eliminated by human impacts. While conditions in some of these habitats may have improved in recent decades sufficiently to host populations of these species, they are currently barred from natural recolonization. The Potomac Gorge is much less defined on the Maryland shore of the river and tributaries entering on that shore have been much more accessible to immigration. This has likely led to the somewhat increased diversity of species in the two Maryland tributaries under study as compared to their Virginia counterparts, though this increase is due in part to the relatively late entry of introduced nonnative species from the river that are effectively denied access to Virginia tributaries.

The roles of humans in shaping the ever changing fish faunal characteristics of the Plummers Island study area is to be further considered, and it would be difficult to identify the greatest of these among the first three discussed. First, the Potomac has received a huge complement of nonnative fish introductions, composed principally of extralimital North American species, as well as some Eurasian fishes. Many of these are principal elements of the fauna today and have already shaped or have the potential to shape the future character of riverine and tributary fish populations. Secondly, both the main river and its tributary habitats have received heavy impacts from human activities over the past two and half centuries or more. Locally, a succession of agricultural and urban/suburban landscape alterations, with attendant clear cutting and sediment runoff, fertilizers, pesticides, sewerage, ingress of runoff from urban roads, establishment of invasive nonnative aquatic vegetation, and construction of small mill dams and impoundments have all taken their toll on area streams over the centuries and have likely brought about the extirpations of several species. Stemming from outside the environs of D.C., the Potomac River itself has sustained heavy impacts from agriculture, industrial and poorly treated municipal wastes, and mining in the extensive coal fields of its headwaters for well over a century (Starnes 2002). A third anthropogenic influence on the area fish fauna was the construction of the C&O Canal. This canal projects a shaft of slack water habitat alongside the otherwise high gradient Potomac Gorge area. In addition to providing artificial habitat for lowland fishes, which might have found their way into the canal from below the fall line, there is evidence that this waterway has provided a conduit for such fishes to surmount the fall line and establish populations in localized moderate/low gradient habitats above. However, frequent draining and

washouts of sections of the canal over much of its history has made this in itself a stochastic situation. Finally, the construction of Brookmont Dam and its predecessor structures on the Potomac at Little Falls, spanning 1831–1959, has denied upstream access to many migrating fishes over that long time span up until 2000 when better fish passage was opened. Prior to 2000, the dam prevented anadromous and potadromous species from accessing former spawning grounds. Beyond excluding these fishes from much of the study area, the dam, along with other factors, probably had a depressing effect on the overall levels of these species throughout the Potomac River estuary.

On the other hand, just as surely as humans have altered aquatic ecosystems and the communities of organisms that inhabit them in a negative sense over the centuries, they have also partially reversed some of these effects. First, due to restoration of riparian habitats, better management of sewerage, establishment of parklands, and other factors, water quality has improved significantly in both the Potomac River and some tributaries; thus, habitats may again have the capacity to support richer aquatic communities. However, some tributaries, even though visibly improved, still have depressed native fish diversity and biotic integrity (Starnes 2002), perhaps partially due to a combination of degraded habitat quality (Southerland et al. 2005) and the aforementioned natural impediments to recolonization. Also, despite appearances of cleaner, less sedimented streams, more subtle impacts of chemical runoff from suburban lawns and streets may be at play. A highly significant reversal of human habitat modifications was the completion of the much improved passage structure at Brookmont Dam in 2000 to restore fish migrations to a reach of the Potomac, extending several kilometers upstream to Great Falls. There are several indicators accounted above that connote immediate positive effects this project may have had on fish populations in the Plummers Island area and ostensibly on overall recruitment of these species in the Potomac.

The impacts of nonnative fish introductions and possibly the C&O Canal construction may be more profound in the long term and less reversible. Unfortunately, once established, it is difficult to manage nonnative fishes and their impacts on native aquatic communities. These impacts are determined by the innate characteristics of these species as measured against the constraints of the environment into which they have been thrust. While we lack the historical perspective on native species population levels to assess the impacts of invasive species with certainty, fortunately it appears some nonnative species may have had relatively negligible or tolerable effects. However, the potential of some (e.g., Northern Snakehead, possibly Blue and Flathead catfishes) could be much more profound in future years. The C&O Canal, with its iconic status as a major historical symbol and curiosity in the Potomac River area, will probably be maintained by the U.S. National Park Service in its present state for the foreseeable future. However, how it is managed in coming decades may determine its ability to function as both an isolated swath of lowland fish habitat and as a conduit for passage of fish upstream beyond Great Falls. With the invasion of such nonnative predators as Northern Snakeheads and perhaps Flathead Catfishes, this passage is of concern. It will be important, even in the face of river flood stages, to attempt to permanently maintain some completely dewatered reaches of the canal below Great Falls, especially given the Northern Snakehead's capacity, as an air breather, to survive for periods in habitats consisting of little more than deep mud.

Finally, this exercise has once again illustrated the importance of vouchering all survey collections. The uncertainties

imposed by the lack of such documentation in combination with factors that cast possible doubt on some reports are painfully obvious. They impede our ability to characterize with complete accuracy the aquatic fauna of habitats that are routinely subjected to such monitoring and data collection without substantiation. Such monitoring activities are overwhelmingly the best or only source of updated occurrence information for many areas and, along with recent targeted surveys conducted by the authors, have served as the principal resource for the updated faunal analysis presented here. Unfortunately, their utility often falls short of its potential due to shortcomings in documentation. The importance of good preservation of vouchers in formalin solution, fixative, or documentation with good quality photographs cannot be overemphasized; however, in some instances, photos fall well short of being definitive. At the time field collections are being conducted, identifications of released or discarded fishes or other organisms may seem routine to some. But nonvouchered collections can later lead to unanswerable questions regarding less obvious species identifications, particularly where juvenile phases may be concerned. These questions remain forever unresolved in the absence of vouchers or possibly corroborating evidence taken by subsequent targeted sampling once the problem is realized. Clearly, there is not the capacity to maintain unlimited permanent voucher collections at the facilities of resource management agencies, or even at existing museum repositories. However, those potentially more significant captures need to be recognized and adequately documented to the exclusion of species that are already well documented from a given stream system. This can only be achieved by the better training of field biologists to be sufficiently acquainted with a local fauna to recognize those captures that may have particular significance, due either to the possibilities of new occurrences or uncertainties of identification. The potential benefits to a better understanding the composition of our aquatic communities on a local scale would be considerable, especially in such a complex and dynamic arena as the Plummers Island area.

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