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Copepod Crustaceans Collected on and Near Plummers Island, Maryland

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Abstract.—Copepod (Crustacea) species diversity was remarkably low on Plummers Island, Maryland, and its immediate environs over a year-long sampling period in 1996 and 1997, compared to that previously and contemporaneously reported nearby within the Potomac River Basin; only two species were found on the Island and two others in the adjacent side channel of the Potomac River. Subsequent sampling in 2004 resulted in records of eight species, seven of which were not found in 1997; six of these were collected on the Island. One explanation for the paucity of species in 1996–1997 is the extreme floods of January and September 1996; the January flood reached a height not recorded since 1972 and destroyed canal locks. These floods scoured much of the Potomac floodplain and may have caused severe local population losses. The scarcity of aquatic microhabitats on the Island undoubtedly also contributed to the low local diversity.

Key words.—Potomac River, aquatic invertebrates, Cyclopoida, Harpacticoida, flood event.

A total of 65 free-living copepod species, mostly members of the orders Cyclopoida and Harpacticoida, were reported in the Potomac River Basin between 1990 and 1997 (Reid 1988, 1996, 1997; Palmer et al. 1995). This number is typical for a temperate-zone region of similar area (Reid 1994). High-discharge events, such as occurred during the January 1996 flooding in the Potomac River Basin as a result of heavy rainfall, snowmelt, and frozen ground that prevented runoff from being absorbed (National Park Service 1977), can cause severe population losses and changes in community structure (Giller et al. 1991). The January 1996 flood reached a height of about 3 m at Little Falls, the location nearest to Plummers Island at which the flood height was measured (National Park Service 1977). This flood was the second-highest since construction of the Chesapeake and Ohio Canal (C&O Canal), destroying the canal locks and scouring floodplain habitats. A second flood occurred after Hurricane Fran in September 1996. The occurrence of two major floods within one year was unprecedented in the C&O Canal, and resulted in the most damage to the C&O Canal National Historic Park since its construction in 1828 (National Park Service 1977).

Many invertebrate communities are resilient, suggesting that physical patches such as isolated pools and seeps associated with stream channels may facilitate recovery by acting as flow refugia (Palmer et al. 1995, Robertson et al. 1995). These two flooding events provided an opportunity to compare the species diversity of copepod crustaceans in and near Plummers Island during that exceptional flood period, with the species composition several years later, as well as to provide a baseline for future studies. Unfortunately, there are no data on local species composition of copepods prior to the first flood.

We sampled the Potomac River side channel north of Plummers Island, patches of moss on rock outcrops on the Island and pools in the rock outcrops in the channel, and pools and streams in the C&O Canal National Historical Park. In-stream habitats such as these are typical of sites that previously have been identified as refugia for stream organisms (Lancaster & Hildrew 1993). We sampled during several seasons for the first 18 months following the first flood. We resampled some of these locales on two dates seven years later. Although many environmental factors, such as the random nature of passive transport of copepods into suitable microhabitats, affected our results, our data may be used to infer the rate of recovery of species diversity following catastrophic flooding. Finally, this information serves as a prelim-

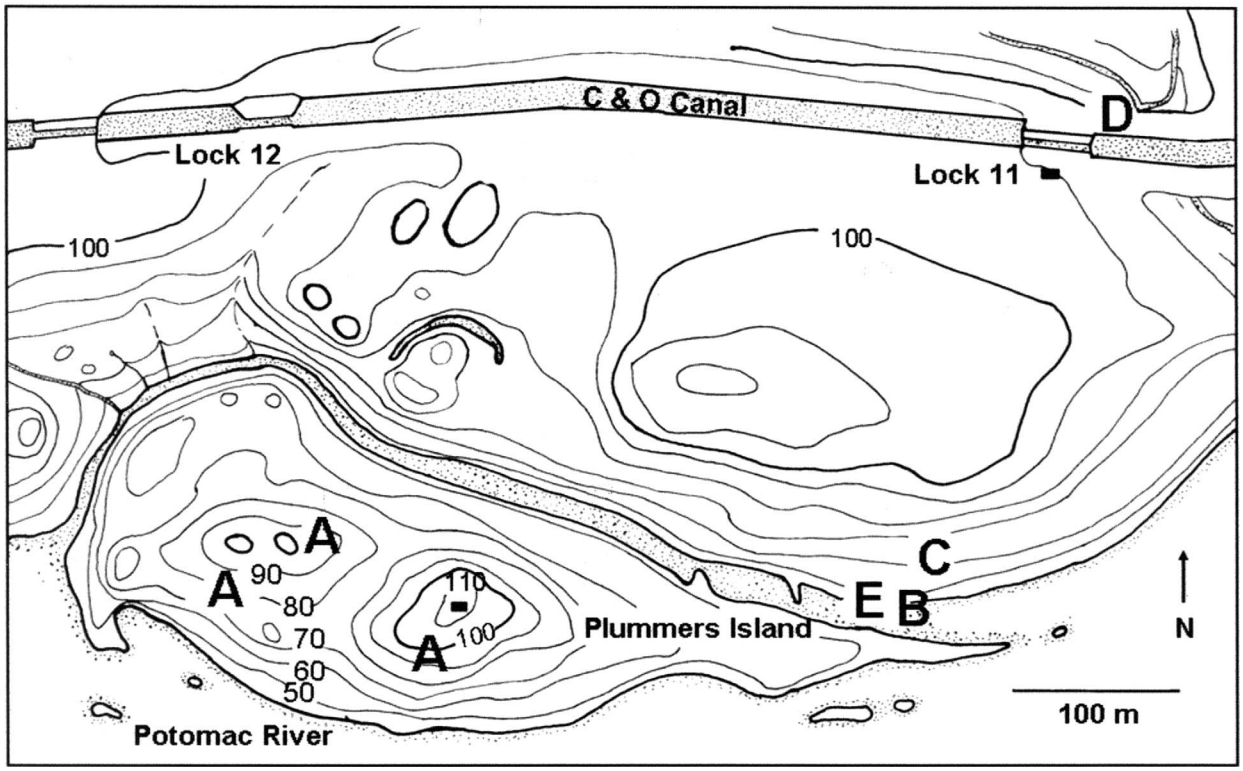

Fig. 1. Sampling sites on Plummers Island (38°55′N, 77°12′W) and in the Chesapeake and Ohio Canal National Historical Park, Montgomery County, Maryland. Map is based on Falls Church Quadrangle, 1949, and aerial photography, 1951. Letters on map refer to individual sites: A, rock outcrops on Plummers Island; B, outcrops in Potomac River side channel; C, intermittent floodplain stream; D, Chesapeake and Ohio Canal near Lock 11; and E, Potomac River side channel. Contour intervals in feet (0.30 m).

inary base from which to make comparisons in the future.

Materials and Methods

The topography, soil, and vegetation of Plummers Island were described by Krombein (1963) and Shetler et al. (2006). All sites sampled are contained within the Chesapeake and Ohio Canal National Historical Park, Montgomery County, Maryland (Fig. 1). Rock outcrops (Fig. 1, site A) on the Island proper have patches of lichen and moss and are at elevations that would be submerged only during major flood events such as occurred in 1996. The outcrops are shaded by the forest canopy. Rock outcrops in the stream channel (Fig. 1, site B) hold small pools of water intermittently and receive little shade.

The Potomac River channel north of the Island was sampled with a Wisconsin plankton net of 64 μm mesh (Fig. 1E). The three rock outcrops on the Island contained deposits of damp moss, leaves, and twigs, which were collected in plastic bags. Two rock outcrops in the Potomac River side channel (Fig. 1B), the streamwaters in the floodplain (Fig. 1B), and the C&O Canal (Fig. 1D) were sampled with a 500-ml capacity bottle. At some times during the year, the channel outcrops contained no visible water. The intermittent floodplain stream typically contained only a few cm of water, had a silty bottom with leaves, or was dry.

Over a year-long period in 1996 and 1997, three rock outcrops on Plummers Island and four sites north of the Island were sampled. In 2004, all the sites except the canal and the intermittent stream north of the Island (Fig. 1, sites C and D) were resampled. Collections were made by GAW or by S. K. McGinnis at most sites on 24 May 1996; 11 June, 1 July, and 8 November 1996; 10 and 17 May 1997; and 24 April and 31 October 2004. Plummers Island itself was not visited on 24 May 1996, because the high water level in the channel prevented passage to the Island. The C&O Canal was sampled only on 24 May 1996. The 2004 collections were made on the Island, in the side channel, and on the channel outcrops. In 1996 and 1997, temperature and pH were measured in midafternoon where and when sufficient water was present. The 10 and 17 May 1997 collections were immediately preserved with 95% ethanol. All other collections were immediately transported to the laboratory and sorted live.

For taxonomic examination (by JWR), specimens were placed in a solution of 70% ethanol-10% glycerol, which was then allowed to evaporate to nearly pure glycerol; specimens then were examined in glycerol or lactic acid. Most of the species were iden-

tified according to Wilson & Yeatman (1959). The specimens attributed to *Acanthocyclops robustus* (G. O. Sars, 1863) fit the description of *A. robustus* ''southern strain'' described by Dodson (1994). Although Dodson et al. (2003) revealed the distinction between American morphs of *A. vernalis* and *A. robustus* to be based on only a single, plastic character, here we use the name *A. robustus* because of the rounded genital double-somite of the specimens, a species character not examined by Dodson et al. (2003). Ascertaining a distinction between *A. vernalis* and the *A. robustus* collected in the present study likely will require molecular markers and tests of reproductive isolation, as have been performed in morphs collected from Wisconsin that originally were assigned to either of these forms (Grishanin et al. 2005, Grishanin et al. 2006). European populations of *A. vernalis* and *A. robustus* differ in their morphology (e.g., Mirabdullayev & Defaye 2002) and ecological requirements (Fryer 1985), although in North America the morphological plasticity and taxonomic confusion in members of the *vernalis-robustus* group make it difficult or impossible to distinguish among populations, let alone characterize their ecological niches. Specimens collected in the early years of the study were deposited in the invertebrate collections of the National Museum of Natural History (USNM), Smithsonian Institution, Washington, D.C.; those collected in 2004 were deposited in the Virginia Museum of Natural History.

Results

A total of 12 copepod species was found: 5 during the initial one-year sampling period and 7 more in two samplings seven years later; only *A. robustus* and *E. agilis* were found in both periods (Table 1). The side-channel outcrops held water only periodically, and the Plummers Island outcrops held mostly moss and leaves. All four species of harpacticoids found, *Phyllognathopus viguieri, Canthocamptus sinuus, Bryocamptus zschokkei,* and *Bryocamptus* sp., plus the cyclopoid *Diacyclops crassicaudis brachycercus* occurred in the Island rock outcrops. The cyclopoid *Acanthocyclops robustus* was found on the rock outcrops in the channel and in the floodplain stream. *Eucyclops agilis, Diacyclops thomasi,* and *Tropocyclops prasinus* were found only on the channel outcrops. The calanoid *Skistodiaptomus pallidus* was found only in the Potomac River side-channel, where it was abundant.

Tadpole larvae of *Bufo americanus* (Holbrook, 1836) were noted as abundantly present in the channel outcrops during May 1996 and 1997.

Table 1.—Species of copepod crustaceans collected on and near Plummers Island, Montgomery County, Maryland, in 1996–1997 and in 2004. Letters refer to locations on map (Fig. 1). A = Three rock outcrops on Plummers Island; B = Two rock outcrops in Potomac River side channel; C = Intermittent floodplain stream; D = Chesapeake and Ohio Canal near Canal Lock 11; E = Potomac River side channel.

Species	Locality	Sampling date	T (°C)	pH
Order Harpacticoida				
Bryocamptus zschokkei (Schmeil, 1893)	A	31 Oct 2004		
Bryocamptus sp.	A	8 Nov 1996		
Canthocamptus sinuus Coker, 1934	A	24 Apr 2004		
Phyllognathopus viguieri (Maupas, 1892)	A	1 Jul 1996		
Order Cyclopoida				
Acanthocyclops robustus (G. O. Sars, 1863)	B	17 May 1997	18	6.5
A. robustus	C	24 May 1997	18	7.6
A. robustus	D	24 May 1997	21	7.7
A. robustus	A, E	31 Oct 2004		
Diacyclops crassicaudis brachycercus Kiefer, 1927	A	31 Oct 2004		
Diacyclops thomasi (S. A. Forbes, 1882)	B	24 Apr 2004		
Eucyclops agilis (Koch, 1838)	B	24 May 1996	23	8.1
E. agilis	A	31 Oct 2004		
Eucyclops elegans (Herrick, 1884)	E	31 Oct 2004		
Macrocyclops albidus (Jurine, 1820)	A	24 Apr 2004		
M. albidus	E	31 Oct 2004		
Tropocyclops prasinus (Fischer, 1860)	B	24 Apr 2004		
Order Calanoida				
Skistodiaptomus pallidus (Herrick, 1879)	E	17 May 1997	17	6.5

Discussion

All of the copepod species found are widespread and also occur in nearby areas of the Potomac River drainage basin (Reid 1988, 1996, 1997; Palmer et al. 1995). *Phyllognathopus viguieri, Bryocamptus zschokkei,* and *Bryocamptus* sp. are typically soil and moss dwellers (Wilson & Yeatman 1959, Lehman & Reid 1993). *Canthocamptus sinuus* has been reported in shallow lakes (Coker & Morgan 1940), but more often appears in vernal pools and floodplain sloughs (Reid 2006 and unpublished data). *Eucyclops agilis* and *E. elegans* are common in ponds and lakes but also frequently occur in streams (Wilson & Yeatman 1959). *Acanthocyclops robustus,* common in ponds and lakes, is often found in temporary ponds (Dodson 1994). *Macrocyclops albidus* is perhaps the most eurytopic of all, and has been reported from the freshwater tidal Potomac River (Sage et al. 1976, Lippson et al. 1980). *Skistodiaptomus pallidus,* a planktonic species, is common in impoundments of the region (Saunders 1975, Reid 1997), and also has been reported previously from the tidal freshwater Potomac River (Sage et al. 1976, Lippson et al.

1980). *Diacyclops thomasi* is normally planktonic in ponds and lakes, but occasionally occurs in rivers; the records of *D. bicuspidatus* by Lippson et al. (1980) and Sellner et al. (1993) from the upper Potomac River estuary likely refer to *D. thomasi.*

One paradigm explains the biodiversity of seasonally flooded marshes as being reduced by disturbances such as floods (Niemi et al. 1990, Giller et al. 1991) and thus assumes that connections to adjacent areas are hydrodynamically depressed. Another paradigm predicts that increases in biodiversity result when floods connect the refugia to the habitats that have lost diversity due to flooding (Lancaster & Hildrew 1993, Palmer et al. 1995). During the initial period of the present study, two extreme floods occurred, destroying the canal locks of the C&O Canal and perhaps scouring much of the pelagic and sediment environments that active and resting stages inhabit. The lower elevations on Plummers Island were submerged during the floods. These floods also may have scoured refugia in the surrounding area from which copepods could recolonize denuded areas. Moreover, suitable habitats for harpacticoid copepods, especially springs and seeps, are scarce on Plummers Island.

Unfortunately, no local records of copepod species composition exist prior to the January 1996 flood in the C&O Canal National Historical Park. Thus we cannot distinguish between the possibility of low diversity resulting from catastrophic disturbance, and other causal factors. Seven years after the floods, species composition changed, but total species diversity remained relatively low. It would be interesting to resample these locales in future years to determine the extent of colonization by copepods, particularly if future flooding is sufficient for transporting copepods but not so extensive so as to scour habitats that could serve as refugia.

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