Biological Monitoring and American Eel Passage in the Patapsco River, Maryland
2022 Update

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Larry Hogan, Governor

Jeannie Haddaway-Riccio, Secretary

MARYLAND DEPARTMENT OF NATURAL RESOURCES

Resource Assessment Service
Monitoring and Non-Tidal Assessment
580 Taylor Ave, C-2
Annapolis, Maryland 21401
410-260-8610 Phone
410-260-8620 Fax
dnr.maryland.gov

Prepared by William Harbold

Additional Telephone Contact Information:
Toll free in Maryland: 877-620-8DNR ext. 8540 OR
Individual unit/program toll-free number
Out of state call: 410-260-8540
Text Telephone (TTY) users call via the Maryland Relay

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Cover Photo: American eels (*Anguilla rostrata*) collected at Daniels Dam. (Photo credit : William Harbold)

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Background

The Maryland Department of Natural Resources' (MDNR) Resource Assessment Service (RAS) has been working to improve passage for American Eel *Anguilla rostrata* (hereafter, eels) with the construction, maintenance and monitoring of an eel ladder on Daniels Dam since 2013. Migration barriers play a major part in recent declines in eel populations, along with other factors such as habitat loss, pollution and historical overfishing (Haro et al. 2000). There are over 15,000 dams on the East Coast of the United States (Macgregor et al. 2009) and most have no provisions for fish passage (Haro el al. 2000). As a result, this could mean the exclusion of eels from up to 84 percent of their historical range along the eastern seaboard (Macgregor et al. 2009).

The Patapsco River was once referred to as one of the most dammed in the United States (Travers 1990). Most dams were constructed to power factories and mills that have since closed, leaving the dams functionally obsolete. Three of these dams have recently been removed. Union Dam and Simkins Dam were removed from the Patapsco River in 2009 and 2010, respectively. The third, Bloede Dam, was breached on Sept. 11, 2018, with complete removal finished in May 2019. As Daniels Dam remained in place, it was targeted for eel passage improvement.

Daniels Dam is likely an impediment to upstream eel migration but is not a complete barrier. As a part of operating the eel ladder, RAS monitors three sites upstream of the dam by electrofishing each summer. Eels have been collected at all of them, even before the construction of the eel ladder (Harbold et al. 2015) and also at Maryland Biological Stream Survey (MBSS) sites for other projects upstream of Daniels Dam dating back to 1995 (Harbold et al. 2018a). Eels may be passing the dam by using the existing fish ladder, climbing over the dam, or going through the structure itself.

Even a partial barrier like Daniels Dam can negatively affect Patapsco River eel populations. By restricting passage, dams decrease eel densities within the watershed upstream (Machut et al. 2007) while increasing densities directly downstream (Goodwin and Angermeier 2003, Wiley et al. 2004, Machut et al. 2007). This influences the size and sex distributions, with smaller male eels most common in dense populations downstream of dams and larger female eels most common in less dense populations upstream (Krueger and Oliviera 1999). As fecundity is highest in the largest females (Barbin and McCleave 1997), the presence of a barrier like the Daniels Dam may alter the reproductive potential of eels that inhabit the Patapsco River.

In an attempt to augment eel passage over Daniels Dam, RAS began moving eels upstream in 2013 and then constructed an eel ladder in the summer of 2014. The eel ladder was operated from approximately April through October each year thereafter. This report highlights the results from April through June 2022, the ninth consecutive year of ladder operation and monitoring.

Methods

This project began in 2013 with the transport and release of 85 eels upstream of Daniels Dam. Eel ladder construction was completed in 2014, and the ladder was open and functioning for the volitional movement of eels that same year and every year thereafter. Descriptions of active eel transport, as well as ladder construction and operation methods, are included in a previous report on 2013-2017 activities (Harbold et al. 2018a). During the normal operating season (April through October) the eel ladder was checked by RAS one to three times per week. Any eels captured were counted and released upstream.

Due to a dramatic increase in the number of eels found using the ladder in 2022, it became impractical to count eels individually during a portion of the monitoring period. Between May 5 and May 13, a total of 300 eels were collected and counted, with an aggregate biomass of 159 grams and a calculated average individual body weight of 1.89 grams per eel. Between May 13 and June 11, all collected eels were weighed in aggregate and passage numbers were estimated based on the previously estimated average individual body weight of 1.89 grams per eel. Eels collected outside this period were counted individually.

As was done in 2020 and 2021, the distribution of eel collections over time in 2022 was compared to concurrent average daily discharge measurements (cubic feet per second) in the Patapsco River at the U.S. Geological Survey gage at Hollofield, Maryland (https://waterdata.usgs.gov/md/nwis/uv/?site_no=01589000&PARAmeter_cd=00065,00060,62615,62620).

RAS has also monitored three sites upstream of Daniels Dam to help assess impacts from the eel ladder since 2013. Eel collections at these sites were performed using the same methods as those described by Harbold et al. (2015). Two of these sites (Sites 213 and 112, Figure 1) are on tributaries of the Patapsco River and are funded via this project. A third site, funded by American Rivers as a control for the assessment of Bloede Dam removal impacts, is on the mainstem Patapsco River (Site 511, Figure 1). All three of these sites were sampled in 2022. The tributary sites were both sampled on June 22 and the mainstem site funded by American Rivers was sampled on July 15.

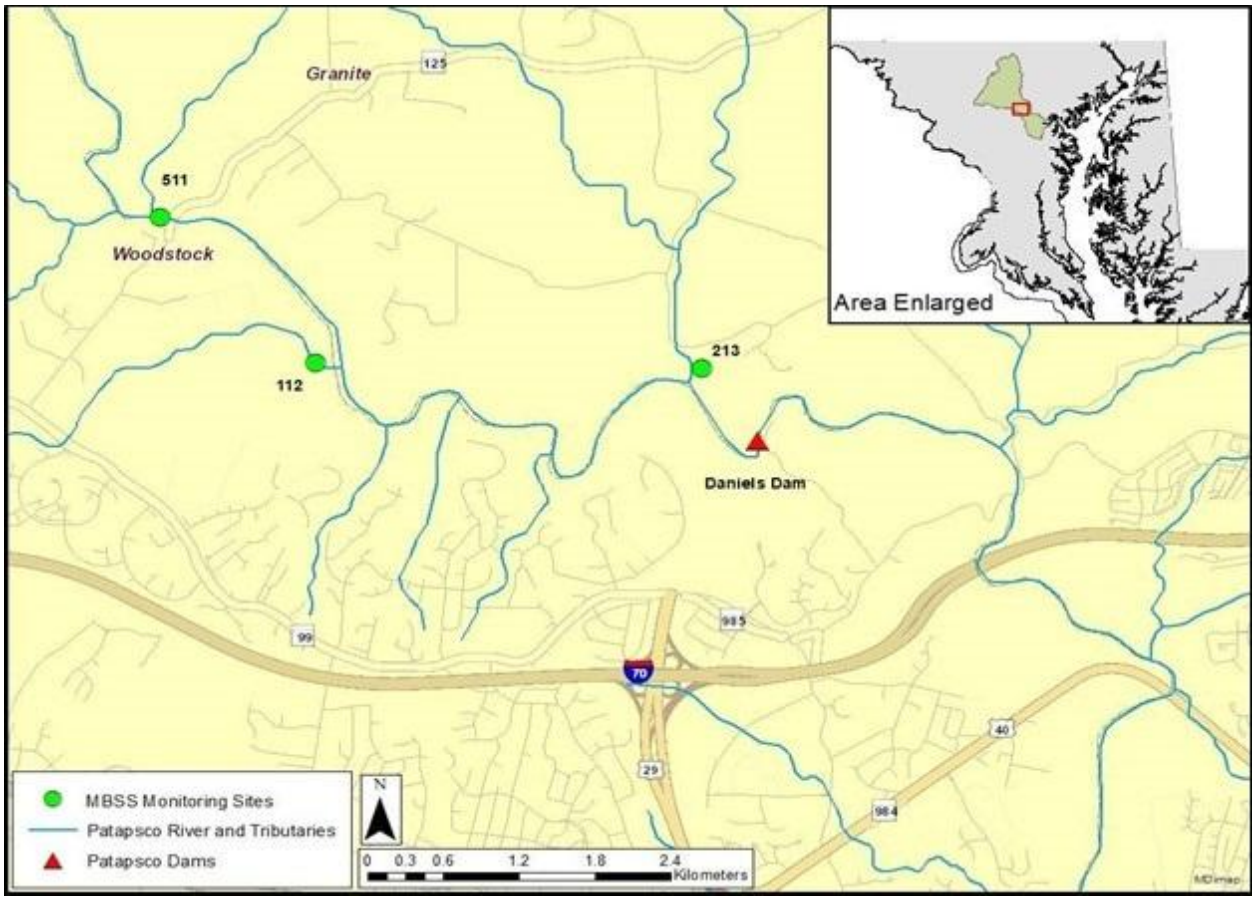

Figure 1: Monitoring sites in the vicinity of Daniels Dam used to assess impacts of improved American Eel passage after constructing an eel ladder.

Data from these sites are used to assess eel relative abundance (eels-caught-per-hour of effort), density (eels caught per square meter of stream bottom), and population size structure (using individual total lengths). Eel density was calculated using the total eel catch and total area of each site (75 m long x mean width).

RAS has been recording individual weights for all eels collected at upstream monitoring sites since 2013. In 2021, using methods developed for the analysis of Bloede Dam removal impacts (Harbold et al. 2018b), RAS used these individual eel weights to estimate the individual lengths of all eels collected since 2013. These calculated lengths were then displayed and compared using length-frequency histograms with a 20mm bin size (Anderson and Neumann 1996). These methods were repeated in 2022.

Results

In 2022, the eel ladder on Daniels Dam operated from 1:00 PM on April 18 until project funding expired on June 30. Accounting for times that the ladder was not running due to pump clogs or equipment failures, it was operational for a total of 1,555 hours. During this time, an estimated 27,243 eels used the structure to migrate upstream of Daniels Dam. In addition to eels,

four Northern Water Snakes and one Common Snapping Turtle were also observed using the ladder to bypass Daniels Dam (Figure 1).

Figure 2: One of four Northern Water Snakes collected in the Daniels Dam eel ladder in 2022.

The majority of eels were collected between May 16 and June 5 (26,418 eels, Table 1). The highest daily total was observed on May 23, when an estimated 9,269 eels were collected, weighed, and released from the ladder at one time. All individuals captured in the eel ladder were between 80 and 120 millimeters in total length.

Figure 3: An estimated 1,164 eels were collected, weighed, and released from the Daniels Dam eel ladder on May 20, 2022.

The period of highest average daily discharge during the monitoring period was bounded by peaks recorded on May 7 (1925 cubic feet per second) and May 28 (452 cubic feet per second). The period when the largest numbers of eels were observed using the ladder (May 16 - June 5) occurred eight and seven days, respectively, after these higher discharges. Relatively few eels were observed using the ladder during periods of lower discharge prior to May 5 and after June 6 (Figure 4).

Table 1: Observations at the Daniels Dam eel ladder during the 2022 monitoring season. Visits with no observation are not included.

Date/Time	Eels	Additional Species	Comments
4/18/2022 13:00	n/a		Ladder assembled, turned on
4/25/2022 11:17	75		Attraction flow pump broken
4/27/2022 15:00	2		1 operable pump, low flow
5/2/2022 11:16	1		Attraction flow pump replaced
5/5/2022 15:30	53	1 Northern Water Snake	
5/9/2022 11:01	48		
5/11/2022 15:48	6		
5/13/2022 9:33	52		
5/16/2022 17:25	1812*		
5/18/2022 13:43	975*		
5/20/2022 10:05	1164*		
5/23/2022 8:49	9269*		
5/24/2022 15:23	4328*		
5/25/2022 13:40	519*		
5/27/2022 9:45	446*	1 Common Snapping Turtle	
5/28/2022 16:05	350*		
5/30/2022 7:30	2989*		
5/31/2022 15:50	1061*		
6/1/2022 13:05	727*	2 Northern Water Snakes	
6/2/2022 9:30	1097*		
6/3/2022 11:30	1010*		
6/5/2022 8:00	671*		
6/6/2022 16:20	6		
6/8/2022 18:13	131*		
6/11/2022 10:50	369*		
6/13/2022 8:20	7		
6/16/2022 7:15	3	1 Northern Water Snake	
6/18/2022 9:30	31		
6/21/2022 7:17	12		
6/23/2022 15:33	9		
6/27/2022 12:55	14		
6/30/2022 13:45	5		End of monitoring

*Eel numbers based on weight.

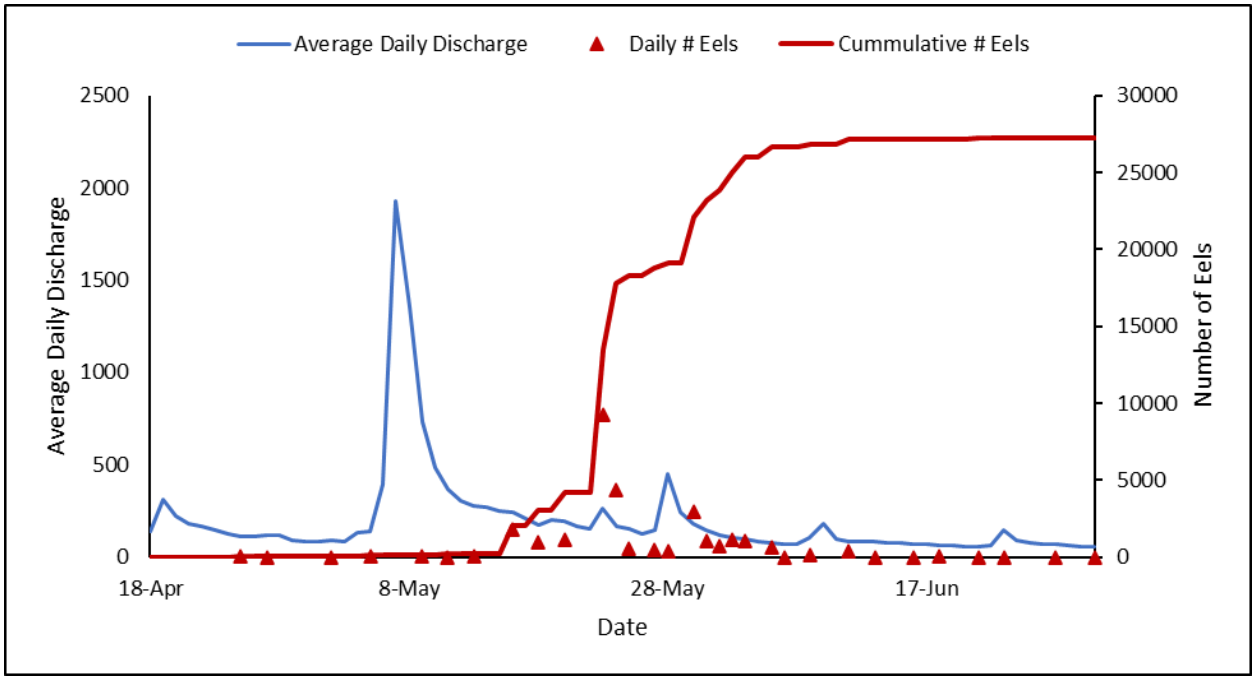

Figure 4: Distribution of eel collections over time at the Daniels Dam eel ladder, as related to average daily discharge (cubic feet per second) in the Patapsco River in 2022 from the U.S. Geological Survey gage at Hollofield, Maryland (https://waterdata.usgs.gov/md/nwis/uv/?site_no=01589000&PARAmeter_cd=00065,00060,62615,62620).

The approximately 27,242 eels collected in the Daniels Dam ladder in 2022 bring the total passage for this project to 31,302 (including active transport in 2013). The number collected in 2022 is the highest to date (Table 2). It is nearly eight times higher than the previous high of 3,419 eels collected in 2021 and nearly 973 times higher than the annual average passage (28) over the five years of ladder operation prior to the removal of Bloede Dam, which occurred between September 2018 and May 2019.

Table 2: Yearly Eel Ladder Passage Totals at Daniels Dam

Year	Total Eel Ladder Passage Above Daniels Dam
2022	27,242[A]
2021	3,419
2020	361
2019	53
2018	32
2017	36
2016	32
2015	28
2014	14
2013[B]	85
Total	**31,302**

[A]Count partially estimated based on eel weights
[B]Eels collected and moved prior to ladder construction

Relative abundance of eels (eels collected per hour of electrofishing) upstream of Daniels Dam in 2022 was higher than in 2021 at one tributary monitoring site, but lower at the other

tributary monitoring site as well as at the mainstem river monitoring site (Figure 5). Eel density (eels per square meter of stream bottom) upstream of Daniels Dam in 2022 was higher than in 2021 at the mainstem river monitoring site, but lower at both tributary monitoring sites (Figure 6). The relative abundance of eels at tributary site 213 in 2022 was the highest since this project began, while density was the third highest.

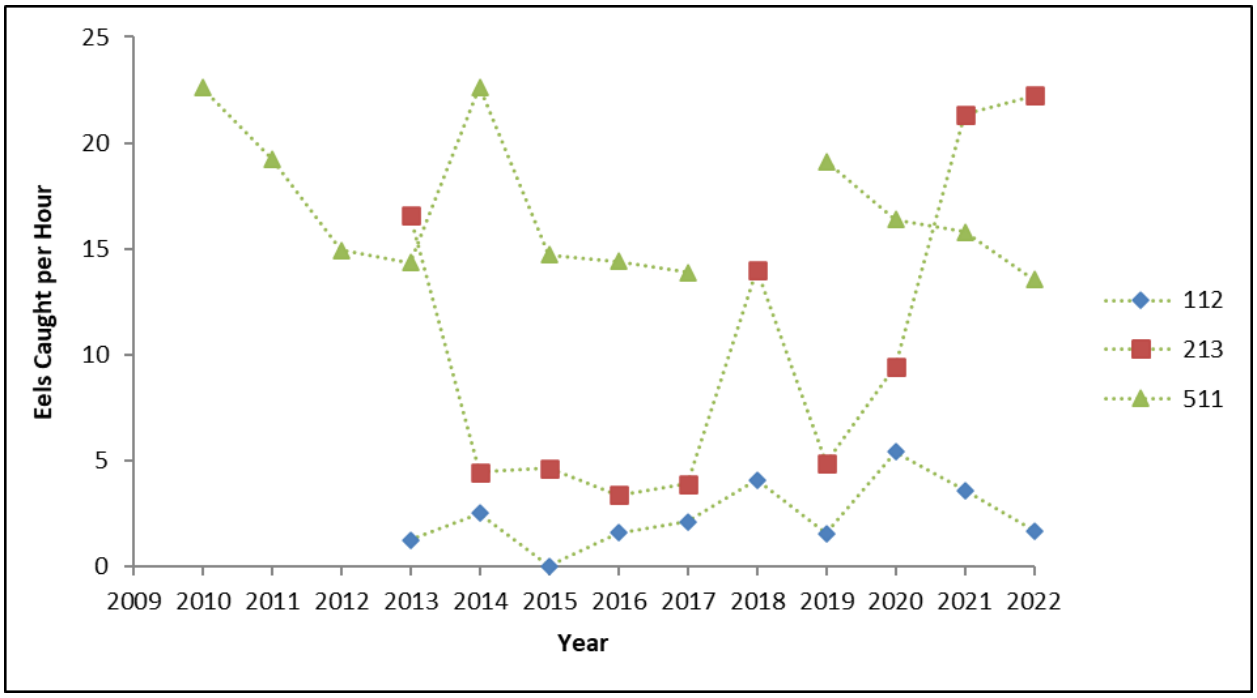

Figure 5: Relative abundance (eels caught per hour of electrofishing) at three monitoring sites upstream of Daniels Dam, 2010-2022. PATL-112-X and PATL-213-X are on tributaries to the Patapsco River and were not sampled before 2013. PATL-511-X is on the main stem Patapsco River and was not sampled in 2018.

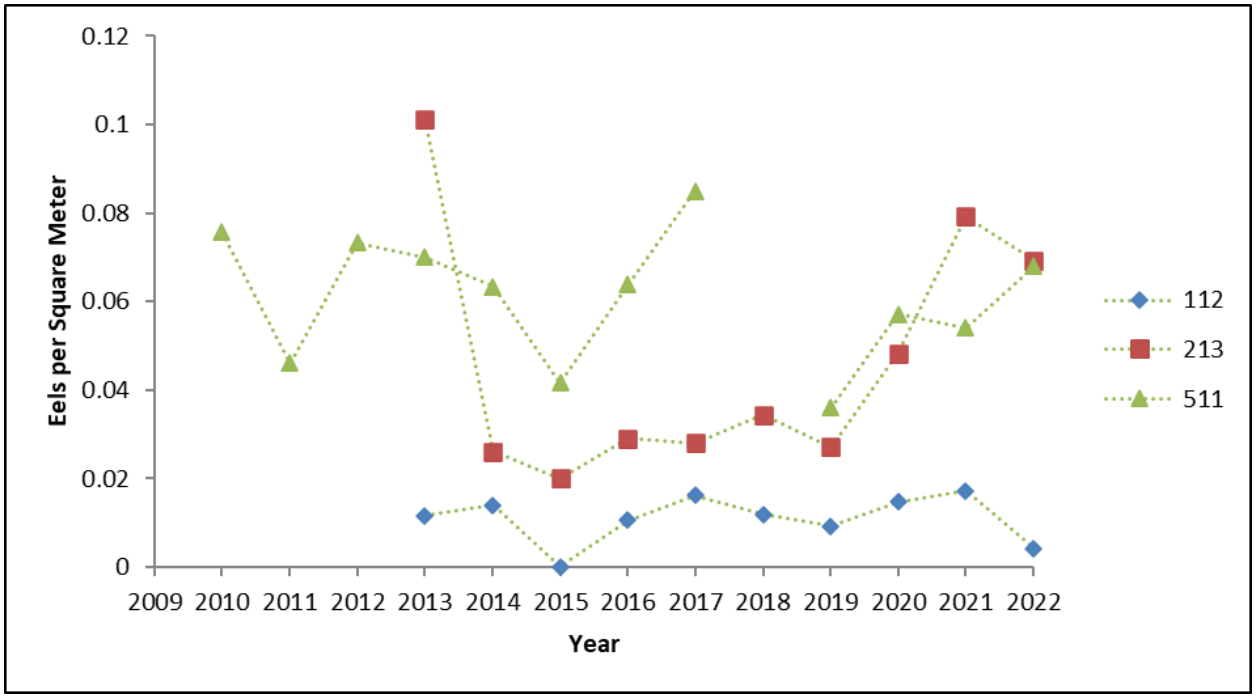

Figure 6: Eel density (eels per square meter of stream bottom) at three sites upstream of Daniels Dam, 2010-2022. PATL-112-X and PATL-213-X are on tributaries to the Patapsco River and were not sampled before 2013. PATL-511-X is on the main stem Patapsco River and was not sampled in 2018.

Prior to the removal of Bloede Dam (2013-2018), 3.6% of the eels collected at monitoring sites upstream of Daniels Dam were less than 120 mm total length. There were no eels less than 120 mm total length collected upstream of Daniels Dam in 2019, the first year post-removal, but in subsequent years the proportion of eels collected that measured less than 120 mm total length varied between 6.6% (2020) and 20.4% (2021). In 2022, 10.7% of eels collected upstream of Daniels Dam were under 120mm (Figure 7). In 2022 the mean and median total length of eels collected upstream of Daniels Dam was the lowest of the post-removal period while the total number of eels collected was the highest (Table 3).

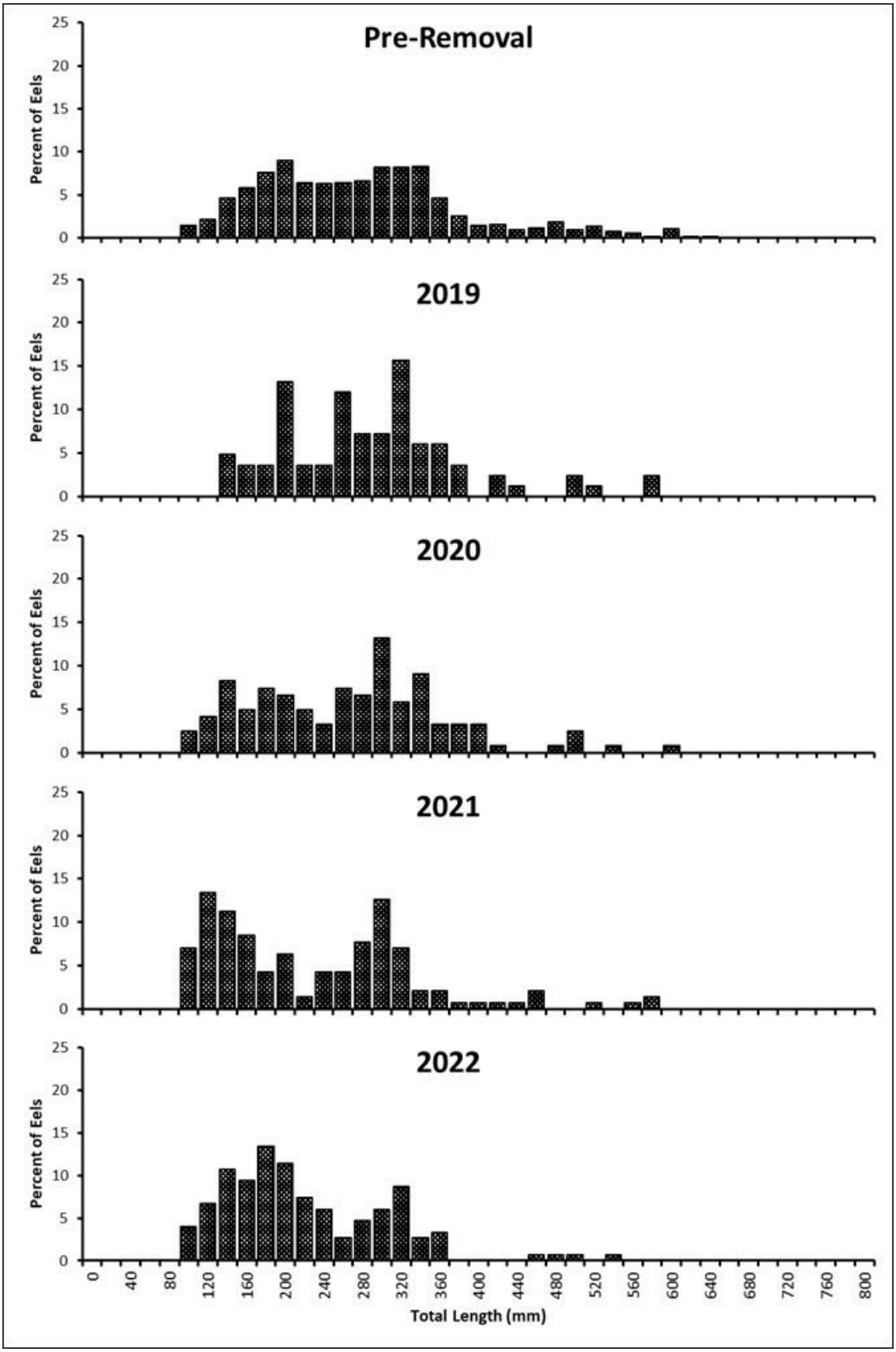

Figure 7: Total lengths (estimated from total weight) of American Eels collected upstream of Daniels Dam pre- (2013-2018) and post (2019-2022) Bloede Dam removal.

Table 3: Total length of eels collected at monitoring sites upstream of Daniels Dam pre- (2013-2018) and post (2019-2022) Bloede Dam removal.

	Pre-Removal	2019	2020	2021	2022
Mean	268	279	255	220	209
Median	261	274	261	192	187
Mode	169	192	123	108	108
Count	760	83	121	142	149

Discussion

Daniels Dam eel ladder operations and monitoring in 2022 have shown that movement of small eels in the Patapsco River has continued at a high level following the removal of Bloede Dam downstream. During the five years of ladder operation prior to the removal of Bloede Dam (2014-2018), an average of 28 eels used the ladder on Daniels Dam annually. Passage in 2020 was over twelve times higher than this "pre-removal" average (361 eels) and in 2021 was over 122 times higher (3,419 eels). Most recently, the 27,242 eels passed between April 18 and June 30, 2022 are nearly 973 times higher than the "pre-removal" average. It remains unclear why eel passage at the Daniels Dam ladder has increased exponentially in recent years, but it may be attributable to both the removal of Bloede Dam downstream and to potential increases in eel recruitment regionally.

Bloede Dam had been the only downstream barrier between Daniels Dam and the Chesapeake Bay. This likely contributed to an inflation of eel numbers below it, as well as a reduction above (Harbold et al. 2015, Harbold et al. 2018a). Considering that increases in eel passage at Daniels Dam had not been observed until after Bloede Dam's removal, it was assumed that this removal was responsible for the apparent increase in eel migration. In other systems after a dam has been removed, there has been a release of eels into upstream habitats (Hitt et al. 2012). That trend certainly appears to have held true in the Patapsco River, with eel passage at Daniels Dam increasing each year post-removal; extraordinarily so in 2022.

The lack of a barrier between Daniels Dam and the Chesapeake Bay seems to be allowing greater numbers of eels to find their way upstream to this new "first" obstacle on their upstream migration. In 2021, we documented a large increase in eel passage at Daniels Dam. This increase was attributed in part to an overall increase in small eel abundance detected regionally at Conowingo Dam on the Susquehanna River and in Maryland's Coastal Bays (Harbold 2021b). In 2022, the number of eels collected at Daniels Dam increased nearly eight times in comparison to 2021. However, regional eel numbers (i.e., those detected at Conowingo Dam and Maryland's Coastal Bays) were considerably lower than those of 2021. At the time of this reporting, the total passage of eels at Conowingo Dam in 2022 was 120,755- just one-fifth of the 623,094 eels that passed through the facility in 2021 (Bob Sadzinski, MDNR). It is unclear why small eel abundance increased as dramatically as it did in 2022 in the Patapsco River, especially given that eel abundance at other regional locations did not see similar increases. The removal of Bloede Dam could have played a part in this increase, but the magnitude of influence is unknown.

The large numbers of eels now observed migrating in the Patapsco River seem to be smaller individuals, and that may be causing a shift in population size structure at monitoring sites upstream of Daniels Dam. The proportion of eels collected at all three upstream monitoring sites that are 80-120mm total length (the same size as those using the ladder at Daniels Dam) has been higher than the 2014-2018 average in every year following the Bloede Dam removal (Figure 7). The mean

and median total length of all eels collected has dropped annually over the same period (Table 3). Combined, these results indicate that there are more smaller eels in the Patapsco River and its tributaries upstream of Daniels Dam than there were previously.

The migration of eels in the Patapsco River appears to maintain a relationship with increased water flow. In 2020 and 2021, larger numbers of eels seemed to use the ladder on Daniels Dam following periods of higher flows, while fewer eels passed the ladder during baseflow conditions (Harbold 2021b). This matched the link between eel passage and increased river flow described in the literature, where studies in the Potomac and Hudson River watersheds showed upstream eel migration and ladder use commenced with increased river flow in the springtime (Hildebrand 2005, Schmidt et al. 2009, Welsh and Liller 2016, Welsh et al. 2016). This same pattern may have continued for the Patapsco River in 2022. Relatively few eels used the ladder during periods of base flow during the months of April and June, while high flow events in May seemed to be followed by large spikes in eel movement.

The future of the eel ladder on Daniels Dam is unknown. The structure has exceeded its originally intended lifespan and is in need of repair. It is possible that Daniels Dam itself may be removed in the coming years (Jim Thompson, MDNR, personal communication) which will improve eel passage beyond anything that is possible with a ladder. However, if Daniels Dam is not removed, it would be beneficial to the Patapsco River ecosystem and its eel population to repair the eel ladder and continue its operation given the success we have observed thus far.

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