Evaluating the Thermal Impact of Small Ponds in Maryland Trout Watersheds

Alterations to landscape conditions in a watershed can impact stream water temperatures. Increasing stream temperatures from changes to forest cover, increased impervious surface area, and point sources of warm water discharge have all been well documented. Less thoroughly studied are the cumulative effects that small ponds or impoundments may potentially have on stream water temperatures, particularly in trout and coldwater watersheds. Small ponds are very abundant and found throughout the state. Ponds collect and store water. The increased surface area and direct exposure to sunlight results in warmer water temperatures. The cumulative impact that this warmer outflowing water has to downstream temperature conditions is unknown. In 2020, the Freshwater Fisheries Program launched a GIS project to identify these ponds and model their thermal impact to stream water temperatures in trout watersheds in central Maryland.

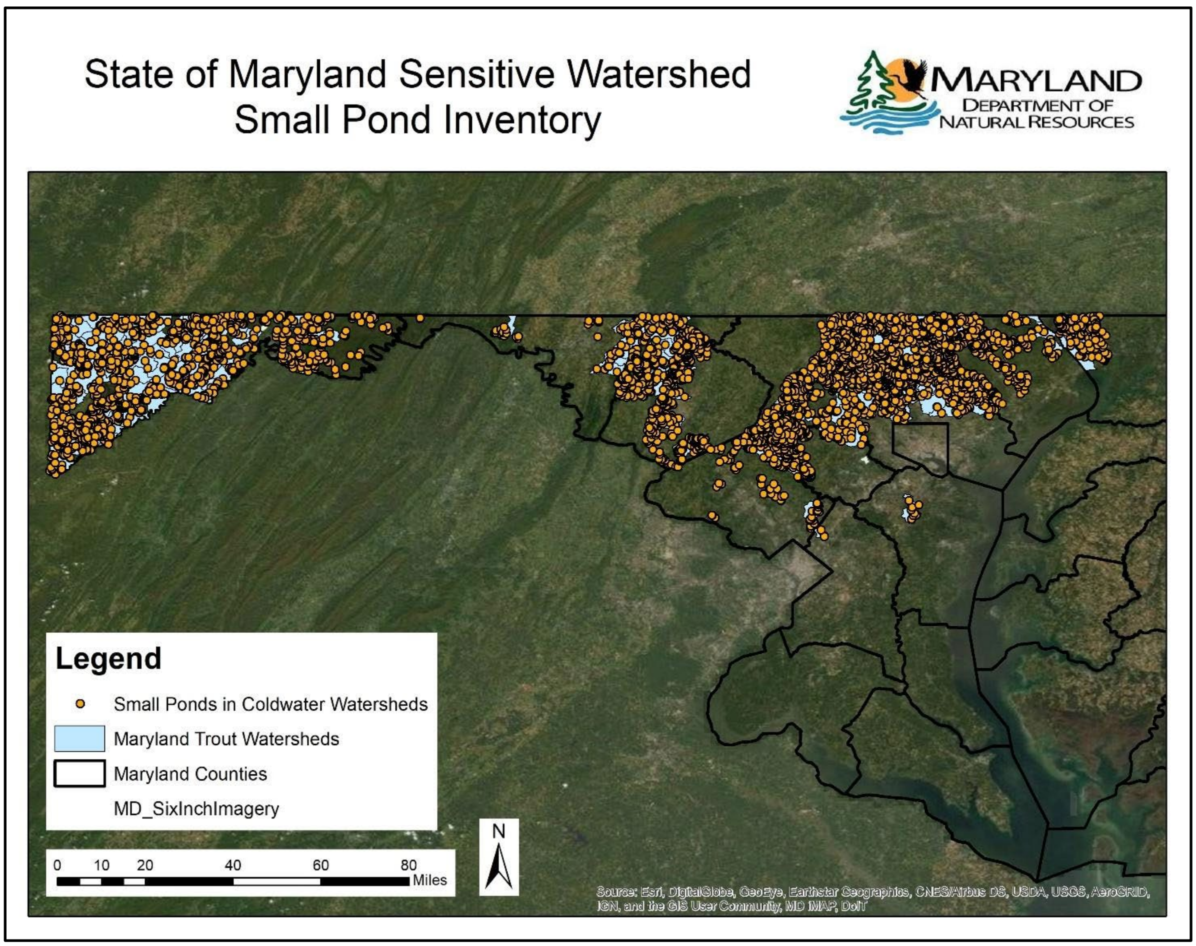


Figure 1. Map showing the statewide distribution of small ponds in coldwater watersheds.

Study Area

The map in Figure 1 illustrates the project study area, consisting of three different types of watersheds in Maryland

- Use Class III non-tidal coldwater watersheds
- Hydrologic Unit Code 12 (HUC12) watersheds where brook trout are present
- Hydrologic Unit Code 12 (HUC12) watersheds where naturally reproducing brown trout are present

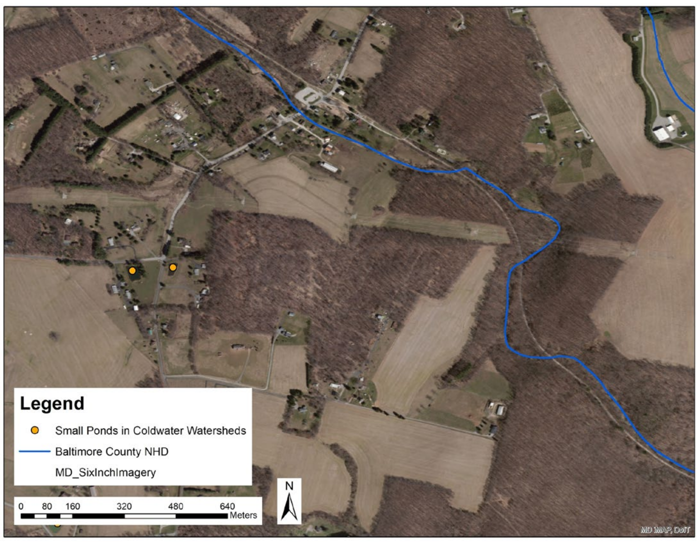
The Maryland Department of Natural Resources Freshwater Fisheries Program and Maryland Biological Stream Survey have completed fish monitoring surveys in upwards of 95% of the HUC12 watersheds in Maryland. With this comprehensive coverage, efforts were focused on identifying ponds in watersheds known to support coldwater resources.

Methods

While the State of Maryland Geographic Information Office and Maryland Department of Natural Resources maintain many GIS layers and databases, none have an inventory of small ponds in the state. To identify these ponds, staff used 6 inch, high resolution aerial imagery in conjunction with 4-band imagery from the Natural Agriculture Imagery Program (NAIP). NAIP data is collected at 1 meter ground sample distance during the growing season. High resolution 4-band imagery is a vast improvement over standard LANDSAT 30 meter remote sensing data. Prior studies evaluating the effectiveness of using LANDSAT data have determined that the large, 30m pixel size can result in missing up to 48 percent of the small ponds the study was interested in. The reason many of these small impoundments were overlooked in previous studies is because many of the ponds in question were often less than a pixel in length and less than a pixel in width.

Along with the higher resolution, this 4-band imagery consists of the three standard visible light bands (Red, Green, and Blue) but also includes reflectance in the near-infrared band which is just outside the visible light spectrum. The advantage of using 4-band data in this application is that it allowed staff to differentiate between water and vegetation in highly forested watersheds. The addition of the near-infrared band allows for transmission through the top layer of canopy and can detect variability in land coverage on the ground. Standard 3-band imagery cannot penetrate the top layer of canopy and could have caused staff to miss the detection of ponds in highly forested watersheds. The combination of aerial imagery and NAIP imagery provided the highest probability that all ponds in the study area were detected.

At the 1:24,000 National Hydrography Dataset (NHD) scale, many of these ponds do not appear closely connected to streams in the watershed. They often appear isolated and a distance away from the nearest 1st order stream. However, when overlaid with a "Zero Order Stream" layer recently developed by the University of Maryland Center for Environmental Science, the connection to the larger stream network becomes more apparent (Figure 2). At this high resolution scale it is possible to see how warmer outflowing water from these small ponds could impact downstream water temperatures.



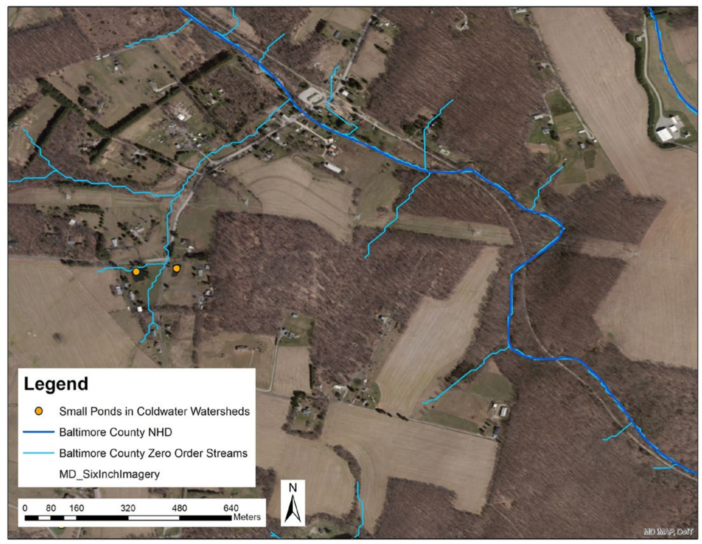


Figure 2. The map on the left shows 2 small, northern Baltimore County farm ponds in relation to the 1:24,000 NHD. The second map on the right tells a different story. Even though these ponds appear to be 550 meters away from the NHD stream, when the zero order streams are added to the map, it becomes evident how connected these ponds are to the entire watershed.

Results

The average number of small ponds per coldwater HUC12 was nearly twice as high in counties in the Piedmont region when compared to counties on the Appalachian Plateau (Table 1). Small pond densities average 30.1 ponds/HUC12 in central Maryland and 16.6 ponds/HUC12 in western MD. With higher pond densities, temperature impacts from small ponds may be more significant in central Maryland. This combined with higher amounts of development and impervious land cover, highlight the multiple thermal stresses that coldwater watersheds are exposed to in the region.

Table 1. Number and densities of small ponds in coldwater HUC12 watersheds by Maryland county and Freshwater Fisheries region.

County	Number of Ponds in Sensitive Watersheds	Average Number of Ponds Per Coldwater HUC12 Watershed	Geographic Region
Allegany	387	19.4	Western
Garrett	801	13.8	Western
Washington	79	7.9	Western
Frederick	510	31.9	Central
Carroll	455	30.3	Central
Baltimore	825	28.4	Central
Harford	418	29.9	Central
Howard	224	28	Central
Montgomery	113	28.3	Central
Cecil	135	33.8	Eastern
Anne Arundel	8	8	Southern

A preliminary model of the impact of pond density to stream water temperature at the 14-digit watershed scale was developed using temperature logger data collected by the Maryland Department of Natural Resources Freshwater Fisheries Program and Maryland Biological Stream Survey (Figure 2). This model was built using only 14-digit watersheds where brook trout are present in central Maryland. Preliminary results show an increasing trend in average daily mean temperature with an increase in pond numbers in a watershed. The results suggest that the addition of an individual pond in a brook trout 14-digit watershed corresponds to a 0.3℃increase in average daily mean stream temperature. For brook trout populations in thermally stressed watersheds, the construction of new ponds could lead to their extirpation as water temperatures increase above their critical thermal threshold. Alternatively, the removal of ponds in brook trout watersheds would potentially result in a decrease in stream water temperatures.

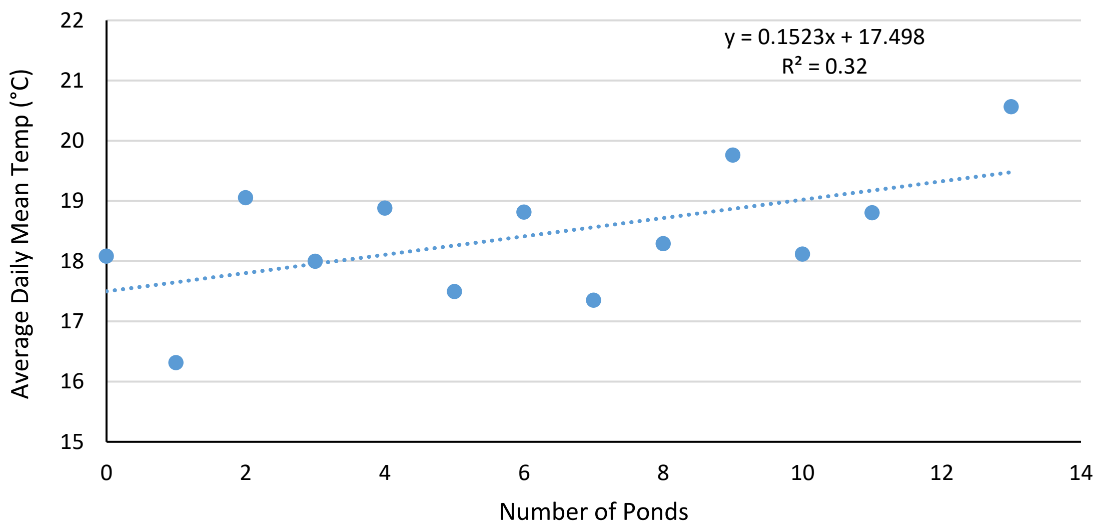


Figure 2. Relationship of average daily mean temperature to number of ponds in Piedmont brook trout watersheds.

Table 2. Small pond counts in Use Class III and trout watersheds in central Maryland.

Watershed Type	Number of Ponds
Small Ponds in Use III or Trout Watersheds	3966
Small Ponds in Trout Watersheds	3170
Small Ponds in Brook Trout Watersheds	2236
Small Ponds in Brook Trout only Watersheds	983
Small Ponds in Brown Trout only Watersheds	929
HUC12 Watersheds Without Ponds	3

2020 Monitoring Plans

To better understand the direct impact that small impoundments have to stream water temperatures, Freshwater Fisheries is planning to monitor the inflow and outflow water temperatures from select individual ponds. This data will help validate initial temperature models and help identify the range of outflow temperatures that a stream is exposed to during the critical summer index period. Additional work will address impacts that increased temperatures in high density pond watersheds may have to trout population numbers.

For any questions about the thermal impacts of small ponds in sensitive watersheds in Maryland, please contact Adam Eshleman (Adam.Eshleman@maryland.gov), Mark Staley (Mark.Staley@maryland.gov), or Michael Kashiwagi (Michael.Kashiwagi@maryland.gov)