HYDROPERIOD OF INTERMITTENT HEADWATER STREAMS IN THE NORTHERN GLACIATED PLAINS

Ross Vander Vorste[1]*, Nels Troelstrup Jr.[2] and Eric Rasmussen[3]
[1]North Carolina Division of Water Quality
Raleigh, NC 27604
[2]Department of Natural Resource Management
South Dakota State University
Brookings, SD 57007
[3]Natural Resources Conservation Service
Redfield, SD 57469
*Corresponding author email. R_vvorste@yahoo.com

ABSTRACT

Intermittent streams comprise 90% of stream and river miles in South Dakota. Hydroperiod (duration of flow) was examined in 60 intermittent headwater streams in the Northern Glaciated Plains ecoregion of eastern South Dakota. HOBO (Onset Inc.) temperature loggers were used to track daily temperature amplitudes and allowed detection of drying dates. Streams began to flow in April following spring snowmelt and 83% of streams were either pooled or dry by early September. The majority of drying occurred in June and July. Streams commonly fluctuated between hydrologic phases and several study sites were re-wetted after initial drying. Level IV ecoregions within the Northern Glaciated Plains showed variability in hydroperiod. All sites studied in the Drift Plains (46i) dried completely during the study period, while only 50% of sites in the Prairie Coteau (46k) dried. Results show that intermittent streams in the Northern Glaciated Plains have seasonal characteristics which create implications for monitoring that are different from perennial streams.

Keywords

Seasonal, prairie, biomonitoring, drought, South Dakota, HOBO

INTRODUCTION

Intermittent headwater streams are globally significant sources of runoff, nutrients, sediment, and biodiversity. These streams comprise 70-80% of catchment area in a watershed and have been shown to influence downstream water quality characteristics (Gomi et al. 2002; Dodds 2006). In South Dakota, intermittent streams comprise 90% of stream and river miles (S.D. DENR 2006). Intermittent streams are characterized by their lack of continuous water flow throughout the year. They undergo a cyclic range of hydrologic conditions as they progress through the hydroperiod. Conditions include flowing, interstitial, pooled and dry. The connection of headwaters with downstream rivers and lakes becomes fragmented during the growing season and in dry years (Matthews 1988; Stanley et al. 1997). These changes create constraints on biota and alter in-stream water chemistry characteristics (Harrel and Dorris 1968; Harris et al. 1999; Dewson et al. 2007; Vander Vorste 2010).

Recent literature has stressed the importance of headwater influence on downstream rivers and the need for more research on headwater drainages (Fritz 2007; Alexander et al. 2007; Dodds and Oakes 2008). Thus, it is important for biologists and managers to know the duration of hydrologic connectivity with downstream reaches. The objective of this study was to describe the hydroperiod of intermittent headwater streams in the Northern Glaciated Plains ecoregion.

METHODS

Sixty intermittent headwater streams were identified from the Northern Glaciated Plains (NGP) ecoregion of eastern South Dakota, an area which constitutes 33% of land area in the state (Figure 1). Landscapes in this region are comprised of flat to gently rolling hills with many seasonal and temporary wetlands. Glacial activity has left fertile soils that developed under mixed and tall grass prairie and are favorable for agricultural production. Climate in the NGP is considered subhumid with the majority of precipitation occurring between April and September (Bryce and Clarke 1996). Study sites were located within seven level IV ecoregions across the NGP (Bryce et al. 1998); the Big Sioux Basin (46m), Drift Plains (46i), Glacial Lake Basins (46c), James River Lowland (46n), Minnesota River Prairie (46o), Prairie Coteau (46k) and Prairie Coteau Escarpment (46l) (Omernik 1995).

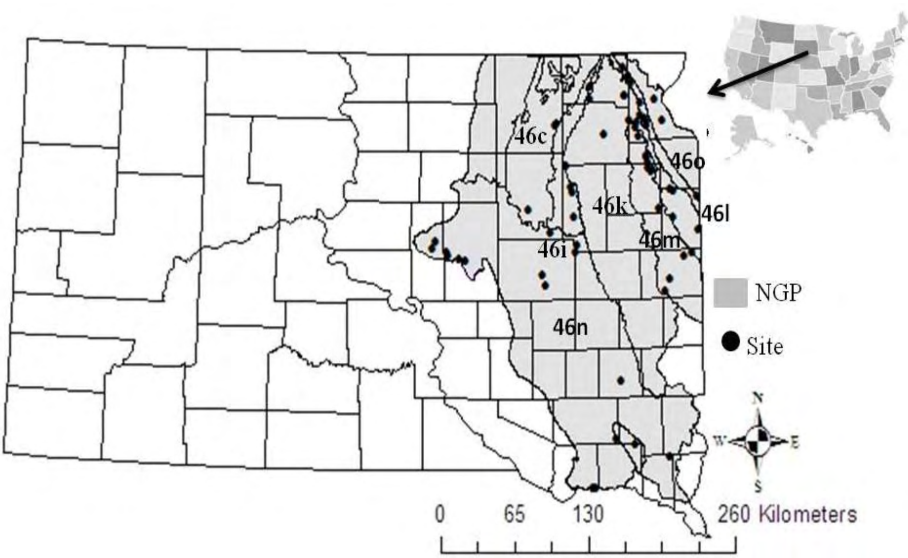

Figure 1. Map of 60 study sites located in the Northern Glaciated Plains ecoregion (46c=Glacial Lake Basins, 46i=Drift Plains, 46k=Prairie Coteau, 46l=Prairie Coteau Escarpment, 46m=Big Sioux Basin, 46n=James River Lowland, 46o=Minnesota River Prairie).

All sites selected for sampling were located completely within the NGP; watershed areas were ≤6 km^2; all streams were assumed 1st to 3rd Strahler order (NHDplus 1st order); all streams had defined channel features (i.e., bed, bank); streams displayed intermittent flow most years; and none of the sites were lake outlets. Validation of intermittency was performed using a modified field protocol for hydrologic permanence (N.C. DWQ 2005). Monthly sampling of sites began on April 1 and ended on September 10, 2008. Stream reaches were classified visually into one of four hydrologic phases. Flowing streams had visible surface flow throughout the stream reach. Sites displaying interstitial flow had surface flow in part of the channel but visible flow was not detectable along the entire reach length. Pooled sites had surface water but no visible flow. Finally, dry sites were those without detectable surface water along the entire reach.

HOBO (Onset Inc.) temperature data loggers were used to determine the hydroperiod (duration of flow) of intermittent streams in this study. Data loggers recorded temperature (°C) at hourly intervals. Data were downloaded to a laptop computer in the field during each visit and then data loggers were placed back in the stream. Loggers were fixed using coated wire and tent stakes driven into the bottom substrate within the thalweg of the stream reach in order to monitor when water was no longer present in the channel.

Standard deviations of hourly temperatures were computed for each day and t-tests were used to compare 5-day blocks of temperature variation. Significant increases or decreases in temperature variation (paired t-test, $P < 0.05$) were used to indicate transition from inundated to dry conditions and vice verse. When loggers were submerged, daily temperature change was buffered by water and fluctuations were smaller compared to dry streams which experienced higher amplitudes. By analyzing data over the entire study period, we were able to categorize hydrologic conditions based on these temperature fluctuations. Hydrologic condition analysis was then validated based on visual observations performed during monthly site sampling. Hydrologic phase was not always clearly defined because some loggers were lost or buried in sediment thus affecting the results.

RESULTS

Several sites (16%) were dry or had snow covering the channel during April sampling (Figure 2). Seventy-five percent of the sites had flowing water and the remaining streams were pooled. Only 30 (50%) streams remained in a flowing phase in May, while 33% of sites were in a pooled or interstitial phase and 16% of sites were dry. During June, 50% of sites were flowing, 43% were interstitial or pooled, and 7% of sites were dry. July observations showed the greatest increase in stream drying with 38% of sites being dry and only 16% flowing. During August, pooling and drying of study reaches did not increase compared to July. In September, visual observations were made and HOBO temperature loggers were removed from streams. Sixty three percent of sites were dry, 16% flowing, and 20% of sites were pooled. We observed 83% of the sites in the NGP had lost their connection with downstream areas by being dry or in a pooled phase.

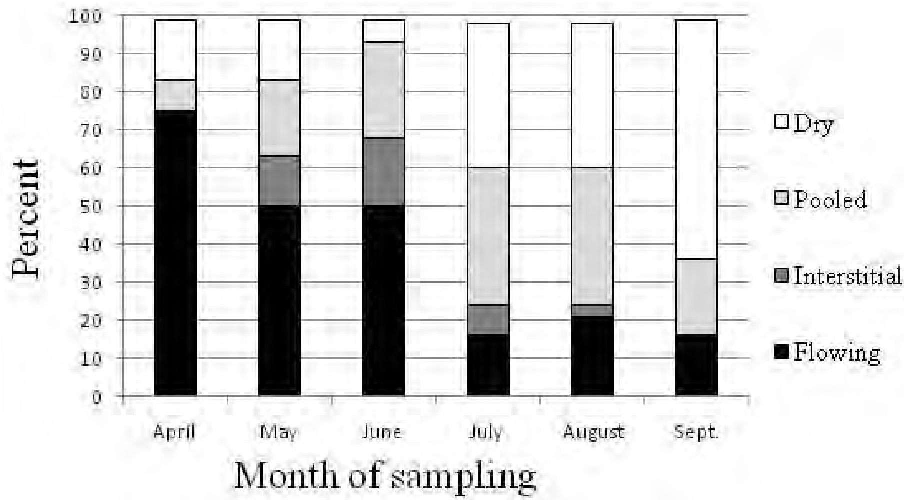

Figure 2. Percentage of stream sites within each hydrologic phase (dry, pooled, interstitial, flowing) throughout the study period in the Northern Glaciated Plains.

Graphs were generated from HOBO outputs and data were analyzed for daily temperature fluctuations. Results from analyzing the hourly temperature data identified a wide and variable range of hydrologic regimes at study sites (Figure 3). It was evident that some study sites shifted hydrologic conditions in response to precipitation events. Several sites (23%) dried and rewetted at least once from April 1st – September 10th, 2008 with at least two sites drying and rewetting more than two times (Figure 3c). Those sites typically rewetted for one week to 30 days after precipitation events. Fifteen percent of study sites progressed from flowing to pooled and dry phases during the study period (Figure 3b). Eleven percent of study sites remained in the flowing phase for the duration of the study period (Figure 3a). Eighty percent of study sites fluctuated between hydrologic phases.

Based on the HOBO data we were able to estimate date of drying at the sixty study sites. Thirty six percent of streams dried between June and the end of July. Twenty three percent of sites dried between August and September 10th, 2008. Sixty three percent of study sites were dry at the end of the study period. It is possible that some study sites dried or rewetted later in the fall after the temperature loggers were removed from the streams.

Spatial change was also evident in the hydroperiod across the seven level IV ecoregions of the NGP. Sites in four level IV ecoregions dried in the eighteen-day period between June 29th and July 17th, 2008. In general, sites located in south and western portions of the NGP dried earlier and more frequently than sites in the northeastern NGP. Glacial Lake Basin (46c), Prairie Coteau (46k) and Prairie Coteau Escarpment (46l) sites either dried later in the summer or not at all.

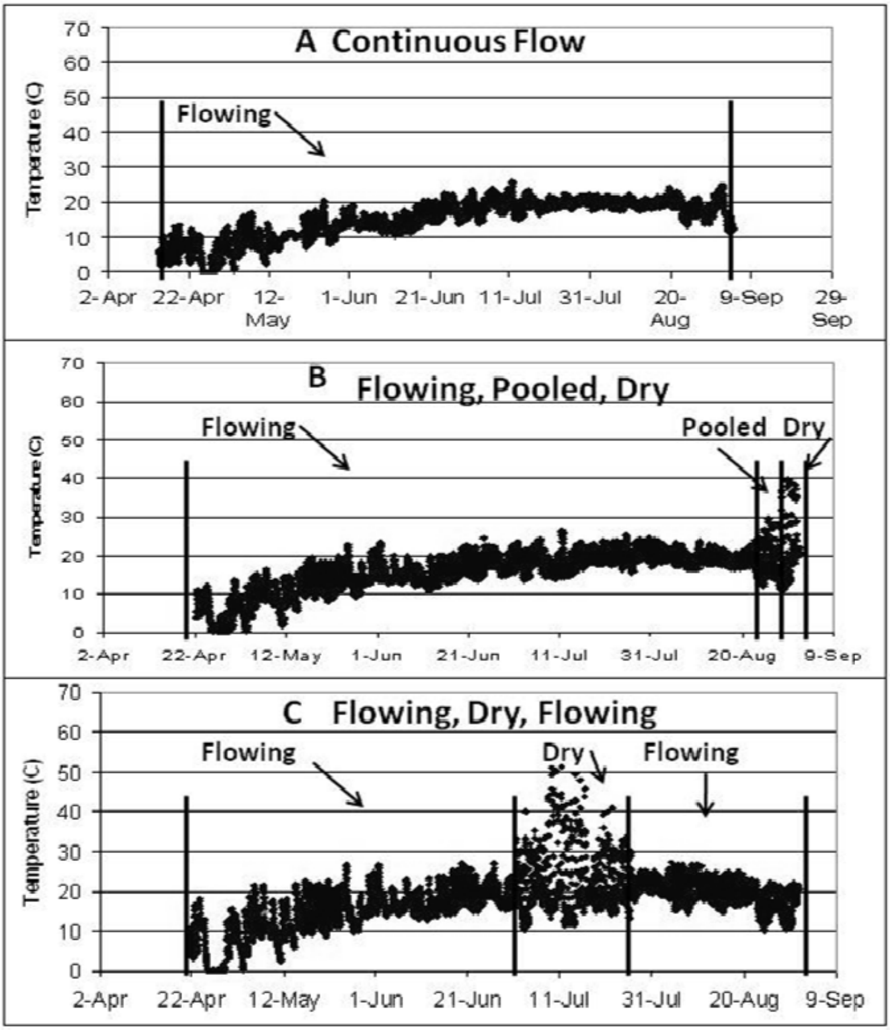

Figure 3. Examples of hydrologic regimes recorded from HOBO (Onset Inc.) hourly temperature loggers during the sampling period at study sites in the Northern Glaciated Plains. A: continuously flowing stream; B: flowing to pooled to dry stream; C: flowing to dry to flowing stream.

DISCUSSION

Recent research on headwater streams in the NGP is lacking. This information is critical to properly assess water quality and biological communities. Study sites in this region typically became inundated in early April and began to dry in June and July. The majority (83%) of reaches had either pooled or dried by early September. These conditions agreed with those found from other intermittent streams. A survey of 110 headwater streams in the Prairie Coteau region of the NGP indicated that by June 30th all but 16 streams were dry and by August 31st only 6 streams remained flowing (McCoy and Hales 1974). Matthews (1988) described the cycle of heavy precipitation and runoff early with mid-summer months experiencing significant drying typical of central and southern prairie streams.

Streams in this region responded to rainfall events during the sampling period by rewetting after their initial drying. Grassland areas are subject to frequent droughts and wet periods depending on month, season, and year (Matthews 1988; Dodds et al. 2004). Greater stream discharge and percentage of flowing streams during April and May appeared to be a response to snowmelt runoff. Average precipitation for April–August in 2008 was 81 mm, higher than the previous five year average of 64 mm but closer to the twenty year average (71 mm) (Menne et al. 2009). The 2008 precipitation totals indicated slightly wetter conditions than normal in the NGP. April–August carried a wide range of monthly totals from 6-131 mm in 2003-2008, exemplifying the dynamic nature of precipitation available to create surface flow. Sites located in the Prairie Coteau (46k) and Glacial Lake Basins (46c) level IV ecoregions had longer hydroperiods and the fewest dry sites. Thus, intermittent headwaters within these regions experience a longer connection with downstream waters and more permanent aquatic habitats. Heavy local precipitation events were likely a cause for extended hydroperiods in these ecoregions. Sites in the Prairie Coteau and Glacial Lake Basins contained deep pools and had the highest frequency of very heavy canopy cover between 0.5 and 5 m above the reach in comparison to other ecoregions (Rasmussen 2010). The percentage of sites that dried per ecoregion was above 50% in all but one level IV ecoregion. Minnesota River Prairie (46o) sites dried first. Two of the three sites in this region resided on flat, grassland/pasture areas exposed to sunlight and heat and contained only shallow glides and pools which dried quickly (Rasmussen 2010). Streams in this ecoregion had at least a 60-day flow period while streams that dried in August had closer to a 120-day flow period. Macroinvertebrates can colonize these streams within 2 weeks and the large number of intermittent streams regionally yields a seasonal pulse of water and nutrients to downstream rivers and lakes (Fritz and Dodds 2004; Dodds et al. 2004).

HOBO temperature loggers placed in stream channels were reliable indicators of stream drying date and identified changes in hydrologic condition based on daily temperature fluctuations. We experienced less than 5% data loss due to burial and disappearance of loggers. We recommend using 1-m-long stakes and insulated wire to secure loggers in loose substrate and marking the stream bank with a small flag to aid in recovery. These loggers made it possible to monitor hydrologic condition and stream temperature at a large number of sites continuously allowing us to track hydroperiod at more streams than would have been possible by using only visual observations.

Results from this study emphasize that a broad-scale biomonitoring effort and water quality assessment in headwater streams must consider the dynamic nature of intermittent streams (see Vander Vorste 2010). Timing of sample collection should be region specific because differences in the hydroperiod were seen among level IV ecoregions. Shifts in macroinvertebrate community structure and function associated with stream drying will affect biomonitoring efforts (Rosenberg and Resh 1993; Williams 1996; Vander Vorste 2010). Streams were responsive to precipitation and many streams contained surface water in flowing or pooled conditions for the majority of summer months. More long-term research will help define the typical hydroperiod of intermittent streams in this region.

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Editor's note: This paper was not presented at the annual meeting.