Tracing Groundwater Inputs into Anacostia Seep Habitats Using Radon

Robyn Winz
University Honors
Dr. Karen Knee, Department of Environmental Sciences
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I. Abstract

Shallow subterranean, or hypotelminorheic, habitats are prevalent in the DC metro area. These persistent wet spots or small pools can be classified as either groundwater-fed seepage springs or surface water-fed vernal pools. Unique fauna, including blind, depigmented arthropod species similar to those found in caves, live in seepage springs and may be threatened by urbanization and development in the surrounding area. In this project, I used radon as a tracer of groundwater input into shallow freshwater pools in the Anacostia watershed in Southeast and Northeast DC. A high radon concentration in a pool indicates recent groundwater input into the habitat.

In collaboration with the National Park Service (NPS), 250-mL samples were collected from pools located on NPS land on a weekly basis and analyzed on a RAD7 detector to measure the concentration of dissolved radon. Other water quality parameters were measured simultaneously, and a sample of aquatic invertebrates was collected in each pool. Statistical analysis was used to explore how radon concentrations related to 1) relevant water quality parameters, and 2) location. This research is important because these pools are home to unique species of troglomorphic (cave-adapted) animals. Characterizing the variability in pool water source is an important step toward understanding and protecting these unique urban habitats. The information and conclusions from this project will help inform NPS policy.

II. Intro

Seepage spring habitat characteristics

Groundwater habitats can be classified into three groups. The two best-known varieties of groundwater habitats are interstitial habitats and caves. A third major category identified by Culver and Pipan includes “shallow subterranean habitats, which occur within a few meters of the ground surface and have variable habitat dimensions."[1] These habitats are the ones evaluated in this paper. They are often identified by the term "seep," but, in US vernacular, this is can be confused with the common label for petroleum oozing out of the ground. To help alleviate the confusion, the term "seepage spring" is often used. Seepage springs are defined as "a diffuse discharge of water, where the flow cannot be immediately observed but the land surface is wet compared to the surrounding area."[2]

Fig. 1 – image of a seepage spring in National Capitol Parks – East

A broader term coined by Mestrov that has been used to categorize these habitats is "hypotelminorheic." This label applies to shallow groundwater habitats that are vertically isolated from the water table. They are made of up of humid soils, contain high levels of organic matter, and are "traversed by moving water."[3] Culver et al. refined this designation, proposing that "hypotelminorheic" be used to describe habitats with the following major features: 1) a location in a slight depression in an area of low to moderate slope; 2) a composition rich in

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[1] Culver, D.C., J.R. Holsinger and D.J. Feller. (2012). The Fauna of Seepage Springs and Other Shallow Subterranean Habitats in the Mid-Atlantic Piedmont and Coastal Plain,. Northeastern Naturalist, 19 (Monograph 9), 1-42.

[2] ibid

[3] ibid

organic matter; 3) a drainage area totaling less than 10,000 square meters; 4) an underlying clay layer from 5 – 50 cm beneath the surface; 5) black in color due to decaying leaves; 6) occurs in a variety of geologic settings.[4]

One important ecological function of these pools is their role in providing habitat to troglomorphic animals or troglobites, which are small animals adapted to living in caves.[5] It can be very difficult to distinguish groundwater-fed pools from surface-fed ones, even though they may be very different ecologically. The pools are especially unique, as no other area in the world outside of some artesian wells in the Edwards Aquifer in Texas boasts as many sympatric subterranean amphipod species[6] (Amphipods are an order of small crustaceans,[7] while sympatry refers to the occurrence of species within the same geographical location[8]). Such species may be threatened by urbanization and development in the surrounding area.

Fig. 2 – Image of an unidentified species of Sygobromus.

Continuing urbanization of the Washington, DC metro area may threaten the quality of the groundwater that sustains hypotelminorheic habitats. Urbanization includes construction of

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[4] Culver, David C. "The Secret World of Seeps" http://www.nps.gov/cue/events/seeps_dec2007/presentation_culver.pdf

[5] Fernanda, Souza and Ferreira, Rodrigo Lopes. (2012) A new highly troglomorphic species of *Eukoenenia* from tropical Brazil. *Journal of Archaeology* 40(2): 151-158.

[6] Culver, D.C., J.R. Holsinger and D.J. Feller. (2012). The Fauna of Seepage Springs and Other Shallow Subterranean Habitats in the Mid-Atlantic Piedmont and Coastal Plain, Northeastern Naturalist, 19 (Monograph 9), pg 1-42

[7] "Amphipod." Merriam-Webster Free Online Dictionary. Encyclopedia Britannica. Web. 9 April 2013.

[8] Mallet, James. (2003) "Perspectives Poulton, Wallace and Jordan: how discoveries in *Papilio* butterflies led to a new species concept 100 years ago." *Systematics and Biodiversity* 1(4): 441-452.

roofs and paved areas, such as highways and roads, airport aprons, etc. Such development can cause major changes in frequency, volume, and quality of groundwater recharge. Urbanization consistently results in paving significant portions of land surface with impermeable materials and the importing of large quantities of water from beyond urban limits. Additionally, urbanization can affect groundwater quality if sewage, domestic or industrial chemicals, lawn fertilizers or other pollutants resulting from human activities infiltrate the aquifer. These changes, in the long term, can impact groundwater levels, resources and quality in underlying aquifers. The severity of these changes depends to some degree upon pre-existing land-use and other factors.[9]

Using radon as a groundwater tracer

Groundwater discharge can be very difficult to measure. One potential method of determining groundwater discharge is the use of natural tracers.[10] In this study, radon is used as a tracer for groundwater. A high concentration of radon in a pool indicates recent groundwater seepage, discharge, or input into the habitat. Radon (^{222}Rn) is naturally present in groundwater at concentrations 2-3 orders of magnitude higher than in surface water, and it has a short half-life. (3.8 d)[11] Furthermore, it is unreactive.[12] Radon gets into groundwater as a result of the radioactive decay of ^{226}Rn, a product of the ^{238}U decay chain. ^{238}U occurs naturally in trace amounts in almost all soils and rocks. Radon is rarely found in significant concentrations in

[9] Foster, S.S.D. (1990) Impacts of urbanization on groundwater. *Hydrological Processes and Water Management in Urban Areas* 198:187-208.

[10] Burnett, William C., Dulaiova, Henrieta. (2003) Estimating the dynamics of groundwater input into the coastal zone via continuous radon-222 measurements. *Journal of Environmental Radioactivity* 69(1-2): 21-35.

[11] Dimova, N. and W. C. Burnett. (2011) Evaluation of groundwater discharge into small lakes based on the temporal distribution of radon-222. *Limnology and Oceanography* 56(2): 486-494.

[12] Burnett, William C., Dulaiova, Henrieta. (2003) Estimating the dynamics of groundwater input into the coastal zone via continuous radon-222 measurements. *Journal of Environmental Radioactivity* 69(1-2): 21-35.

surface water, as it disperses into the atmosphere quite rapidly.[13] The SI unit for measuring radon activity, and the unit used here, is Becquerels per cubic meter (Bq/m^3).[14] A Becquerel is equivalent to one radioactive decay per second, and the activity in Bq is proportional to the mass of Rn present.

Other water quality characteristics

This study incorporates data concerning other water quality characteristics – in particular, dissolved oxygen and pH. Dissolved oxygen (D.O.) enters fast-moving streams through aeration as it churns over an uneven streambed. In slower waters, oxygen can only enter the top layer, while deeper layers are low in D.O. Groundwater usually has low D.O. concentrations. D.O. concentration performs an important function in groundwater by regulating the valence state of trace metals and by limiting the bacterial metabolism of dissolved organic species. O_2 has generally been assumed absent below the water table.[15]

There is a documented moderate relationship between ^{222}Rn to pH. One study of water quality characteristics conducted in the Chattanooga Shale area in Tennessee found that concentration of this isotope of radon is inversely related to pH of the water in the Highland Rim aquifer system, one of the few pairings of concentrations of radionuclides with key indicators of water chemistry to demonstrate any relationship. The authors of this study attributed the correlation between ^{222}Rn and pH to the hydrogeochemical environments in the aquifer system[16]

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[13] RAD H2O User Manual: Radon in Water Accessory. DURRIDGE Company, Boston (2011).

[14] Brill, A.B. et al. (1994) Radon update: facts concerning environmental radon: levels, mitigation strategies, dosimetry, effects and guidelines. *Journal of Nuclear Medicine* 35(2)

[15] Rose, Seth and Long, Austin. (1988) Monitoring Dissolved Oxygen in Groundwater: Some Basic Considerations. *Groundwater Monitoring and Remediation* 93-97.

[16] Hileman, Gregg E. and Lee, Roger W. (1993) Geochemistry of and Radioactivity in Ground Water of the Highland Rim and Central Basin Aquifer Systems, Hickman and Maury Counties, Tennessee. *Water Resources Investigation Report 92-4092*. U.S. Geological Survey and Tennessee Department of Environment and Conservation.

Sampling region

Samples were collected from shallow pools within the National Capital Parks-East (NACE) in January-April 2013. NACE is made up of 14 different sites in and around Washington, DC, encompassing over 8,000 acres.[17] This study took place mainly on the grounds of the Fort Dupont Park and Langston Golf Course sites of the National Capital Parks-East.

III. Methods

The study area was divided into transects, and samplers walked along each transect searching for seeps. Once a seep was located, a 250 ml water sample was collected, either by submerging the bottle into the water, or by using a small submersible pump. Other water quality parameters and ancillary data, including temperature, dissolved oxygen, atmospheric pressure, conductivity, and pH, were measured in the field using a YSI Professional Plus hand held instrument. Aquatic invertebrates were collected using a small hand net and preserved in a small glass vial full of ethanol for later identification and study.

Fig. 3 – Gathering samples from a seepage spring in 250ml bottles. Samples were collected either by submerging the bottle (shown), or by using a small submersible pump.

[17] "National Capital Parks-East." National Park Service. U.S. Department of the Interior. Web. 9 April 2013.

The radon activity of each sample was measured using a RAD-7 radon detector with RAD-H_2O accessory (Durridge Co., Inc.). The RAD H_2O attached to the RAD-7 aerated the sample for 5 minutes, removing approximately 95% of the dissolved Rn from the 250ml sample before measuring it in four 5-minute cycles. The radon concentrations (Bq/m^3) and the uncertainty associated with it are reported for each cycle. Data from the four cycles associated with each sample were averaged together and correlations with other water quality characteristics were investigated.

IV. Results & Discussion

Radon activities less than 400 Bq/m^3 were judged to be not significantly different from 0, because the uncertainty associated with each measurement was higher than the magnitude of the measurement. The variables of conductivity, salinity, and temperature appeared to be unrelated to the amount of radon present in the water. The following charts illustrate the two factors that did appear to have a correlation – dissolved oxygen and pH.

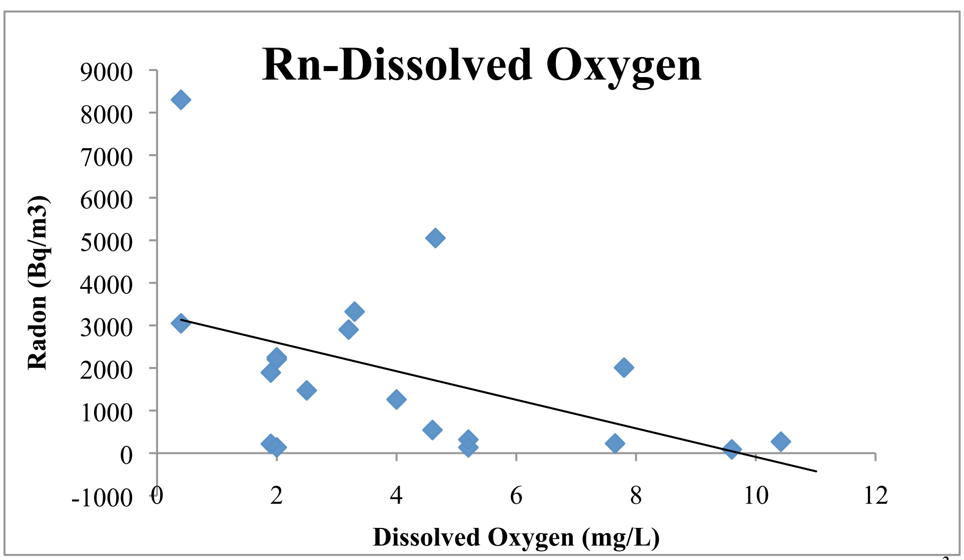

Fig 4 – This plot compares dissolved oxygen (mg/L) against radon (Bq/m^3).

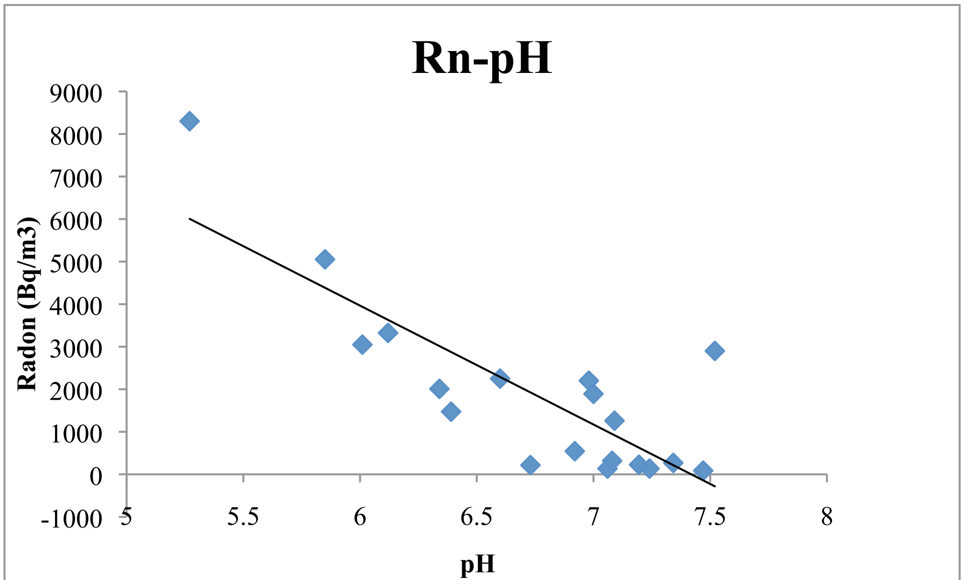

Fig. 5 – This plot compares pH to radon (Bq/m^3).

There appears to be an inverse relationship between radon levels and the amount of dissolved oxygen in the water based on Figure 4. This makes sense, as water confined underground contains more radon and less oxygen than surface water. However, since cold groundwater inputs may lower the temperature of the receiving surface water body and increase solubility of oxygen as a result, D.O. may not be the best mechanism for monitoring groundwater input into seepage springs.

Fig. 5 demonstrates, first of all, that groundwater in this area is more acidic than surface water, and that surface water is likely poorly buffered. It also indicates that there is a strong correlation between pH levels and radon. This relationship is similar to the inverse correlation that was demonstrated by Hileman and Lee.

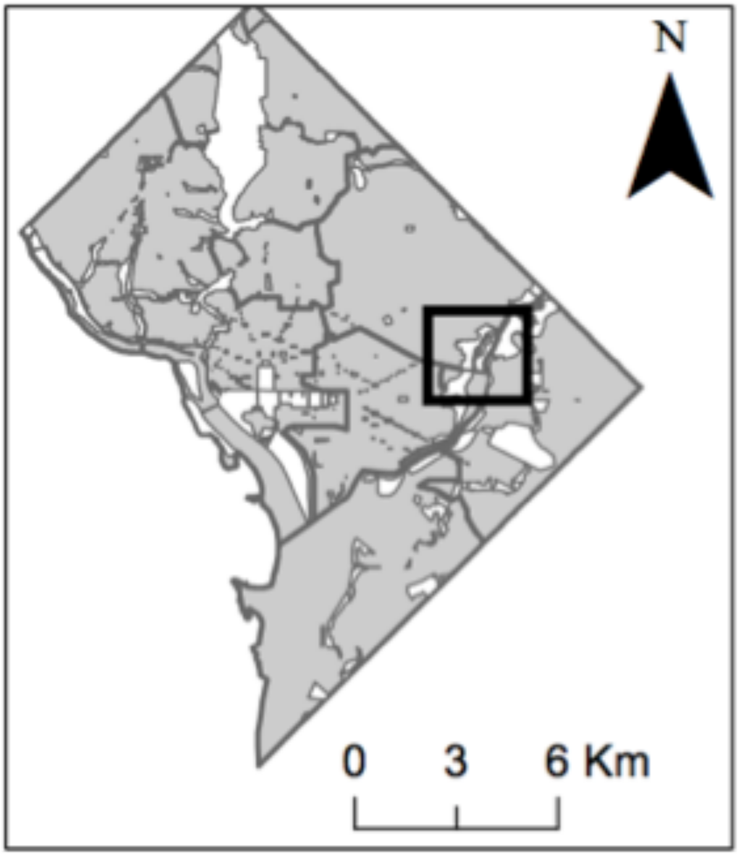

Fig. 6 – The thick black box indicates Langston Golf Course, part of the sampling region in North Capitol Parks – East. The other sampling region, Fort Dupont Park, is the large white section to the lower left of the black box. However, no geographical data was obtained for Fort Dupont Park to cross-reference with water quality characteristics.

Geographical data was obtained for a portion of the sampling sites within Langston Golf Course. The next section includes maps of the area in question overlaid with data concerning pH, Rn, and conductivity.

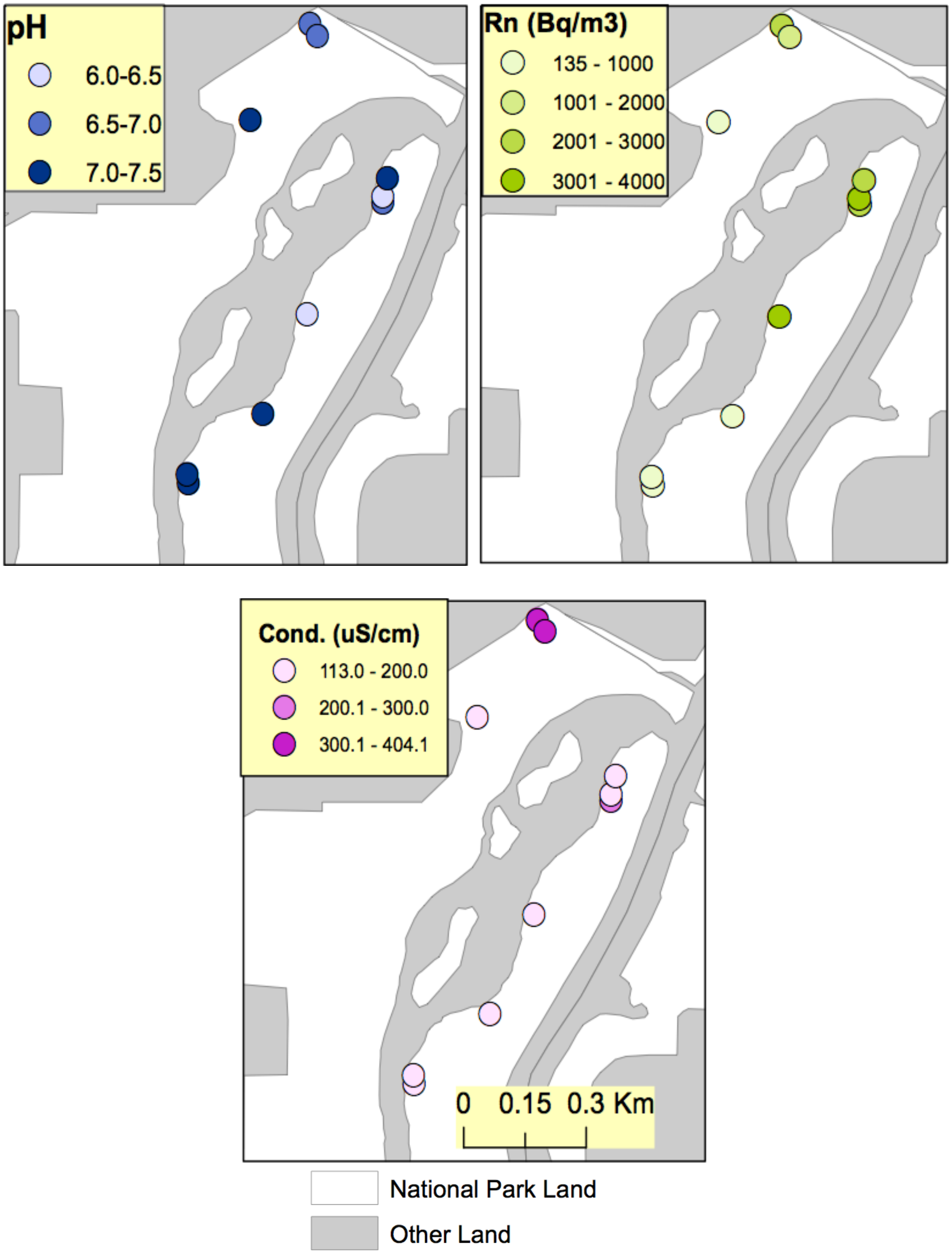

Fig. 7 – These diagrams show, respectively, pH, radon activity (Bq/m3) and conductivity (μS/cm) at each seepage spring within Fort Langston Golf Course.

V. Conclusion & future of the project

This work is relevant to environmental management and conservation, because these National Park lands are home to unique species of troglomorphic organisms. Information about their habitat's characteristics and qualities will help the National Park Service implement measures to protect them. One of the main goals of this project is to determine how abundance and diversity of the troglomorphic invertebrates native to the National Capitol-East area is related to water quality characteristics including radon. This final conclusive step will be taken once the organisms have been identified. Further study is needed on the nature of these seep habitats in the National Capitol-East area in order to determine how these water quality characteristics correspond to troglobite abundance. Based on such data, the National Park Service can develop and implement measures to protect these unique species and the quality of the groundwater that sustains their habitats.

VI. References

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