Aquatic and Terrestrial Connectivity at Select Road-Stream Crossings in the North and South Branch Raritan Watershed Region (WMA8) of New Jersey, USA

A project report from
Raritan Headwaters Association
Submitted to NJ Division of Fish and Wildlife,
Endangered and Nongame Species Program
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Mission of Raritan Headwaters

Raritan Headwaters (RHA) is a 501(c)3 non-profit conservation organization, formed by the 2011 merger of Upper Raritan and South Branch watershed associations (URWA and SBWA), both founded in 1959 to engage New Jersey residents in safeguarding water and natural ecosystems. As one of the oldest watershed associations in New Jersey, Raritan Headwaters protects, preserves and improves water quality and other natural resources of the Raritan River headwaters region through science, education, advocacy, land preservation and stewardship. Our combined organization is a strong voice in advocating for sound land use policies that protect critical water resources in the region. We are based in Bedminster, NJ with a satellite office in Flemington. Major RHA programs include water monitoring, ecological research, habitat restoration, land preservation and stewardship, policy and advocacy as well as extensive public education and outreach. Through our long-established Well Testing and Stream Monitoring programs, we have become a trusted source of data on the health of ground and surface water. We work to identify stressors on water quality including pollutants, land use practices, and factors associated with climate change. We monitor the effectiveness of various restoration practices for improving water quality as well as insuring resilience of these systems into the future as the impacts of climate change become more pronounced. We preserve land to protect water quality including properties we own and manage (11 wildlife preserves encompassing 450 acres, plus 32 conservation easements protecting 880 acres). Our stewardship efforts include riparian restoration, invasive plant removal and forest management. Our work engages community residents, including more than 3,200 volunteers and citizen scientists annually, in efforts to protect land, water and natural habitat in our region. To learn more visit www.raritanheadwaters.org or contact kmacdonald@raritanheadwaters.org.

Acknowledgements

Funding for this project was provided by the NJ Division of Fish and Wildlife, Endangered and Nongame Species Program (ENSP) to support their Connecting Habitat Across New Jersey (CHANJ) initiative. A special note of thanks goes to Rita Matos, RHA's former Stream Connectivity Coordinator and North Atlantic Aquatic Connectivity Collaborative (NAACC) Lead Observer, for her hard work and dedication in managing the program. Her expertise in GIS and conducting culvert assessments, her work in certifying new trainees through this project, and her meticulous data management were key to the success of this project. RHA volunteers Raymond Croot and Brian Lynch and RHA interns Shannen Higgins and Madison Purguy devoted many hours to training in NAACC protocols and assisting in data collection. Rita Matos is the primary author of this report and Kristi MacDonald, PhD, RHA Science Director, provided extensive input and edits. Melissa Mitchell Thomas, RHA GIS Director, and Rita created all the maps in this report. Project guidance and GIS data for the culvert and CHANJ mapping was provided by ENSP biologists MacKenzie Hall, Gretchen Fowles, and Brian Zarate. In addition to the summary of data and maps in this report, connectivity data for these sites and many others are available at https://naacc.org/naacc_data_center_home.cfm.

Cover photo Crossing Structure on the South Branch Raritan River in Hillsborough, NJ.

Introduction

In summer and fall 2021, RHA assessed 150 road-stream crossing structures (e.g., culverts and bridges) within core and corridor wildlife habitat mapped as part of the Connecting Habitat Across New Jersey (CHANJ) program in the North and South Branch Raritan Watershed Region (WMA8) of New Jersey to determine their barrier severity for aquatic and terrestrial organisms who may use such crossings to move within streams and to safely cross under roadways, respectively. We used the North Atlantic Aquatic Connectivity Collaborative's (NAACC) protocols for assessing nontidal streams and dry passage through crossing structures (Abbott and Jackson 2019). The goal of the project was to identify road-stream crossings where aquatic and/or terrestrial connectivity exist, where facilitation of under-road crossing for terrestrial wildlife may be installed (e.g., drift fencing) and where aquatic and terrestrial connectivity are impaired making the structures targets for future retrofitting to improve passage.

Key questions of the project were as follows:

1) Overall, for all 150 selected structures:
    a. What is the barrier level severity for aquatic passage?
    b. What is the barrier level severity for terrestrial passage?

2) With respect to CHANJ habitat (core or corridor):
    a. What is the barrier level severity for aquatic passage?
    b. What is the barrier level severity for terrestrial passage?

3) With respect to levels of traffic volume:
    a. What is the barrier level severity for aquatic passage?
    b. What is the barrier level severity for terrestrial passage?

4) With respect to CHANJ habitat X traffic volume:
    a. What is the barrier level by habitat for aquatic passage?
    b. What is the barrier level by habitat for terrestrial passage?

Methods

Study area:

The North and South Branch Raritan Watershed Region (WMA8; Figure 1) is the largest watershed within the Raritan River Basin and is part of the New Jersey Highlands Region. The 470 mile^2 (1,217 km^2) watershed, which comprises the Raritan Headwaters region or Upper Raritan, provides drinking water to 300,000 watershed residents of 38 municipalities in Hunterdon, Morris and Somerset counties and drinking water to more than 1.5 million residents that live beyond our watershed, in the state's more urban areas. The South Branch Raritan River is 51 miles long, from its source in Budd Lake to its confluence with the North Branch Raritan River. The North Branch originates as a spring-fed stream in Morris County and flows south approximately 23 miles to meet the South Branch meet in Branchburg at the confluence with the Lower Raritan and the river eventually flows into Raritan Bay and the Atlantic Ocean. The watershed holds a rich variety of flora and fauna and contains some 1,400 miles of stream, including many that are classified as supporting wild trout production. Two large reservoirs, Spruce Run and Round Valley, and a variety of large protected public lands including Ken Lockwood

Gorge, Hacklebarney State Park, the Black River Wildlife Management Area, and the Sourland Mountains are all within the Raritan Headwaters region. Under the surface, are the fractured-rock aquifers of the Newark Basin including mainly the Brunswick aquifer, Lockatong and Stockton formations, along with some limestone aquifers and buried valley aquifers where glaciers deposited sand, gravel and clay materials. These resources are threatened by continued degradation caused by numerous stressors associated with human activities.

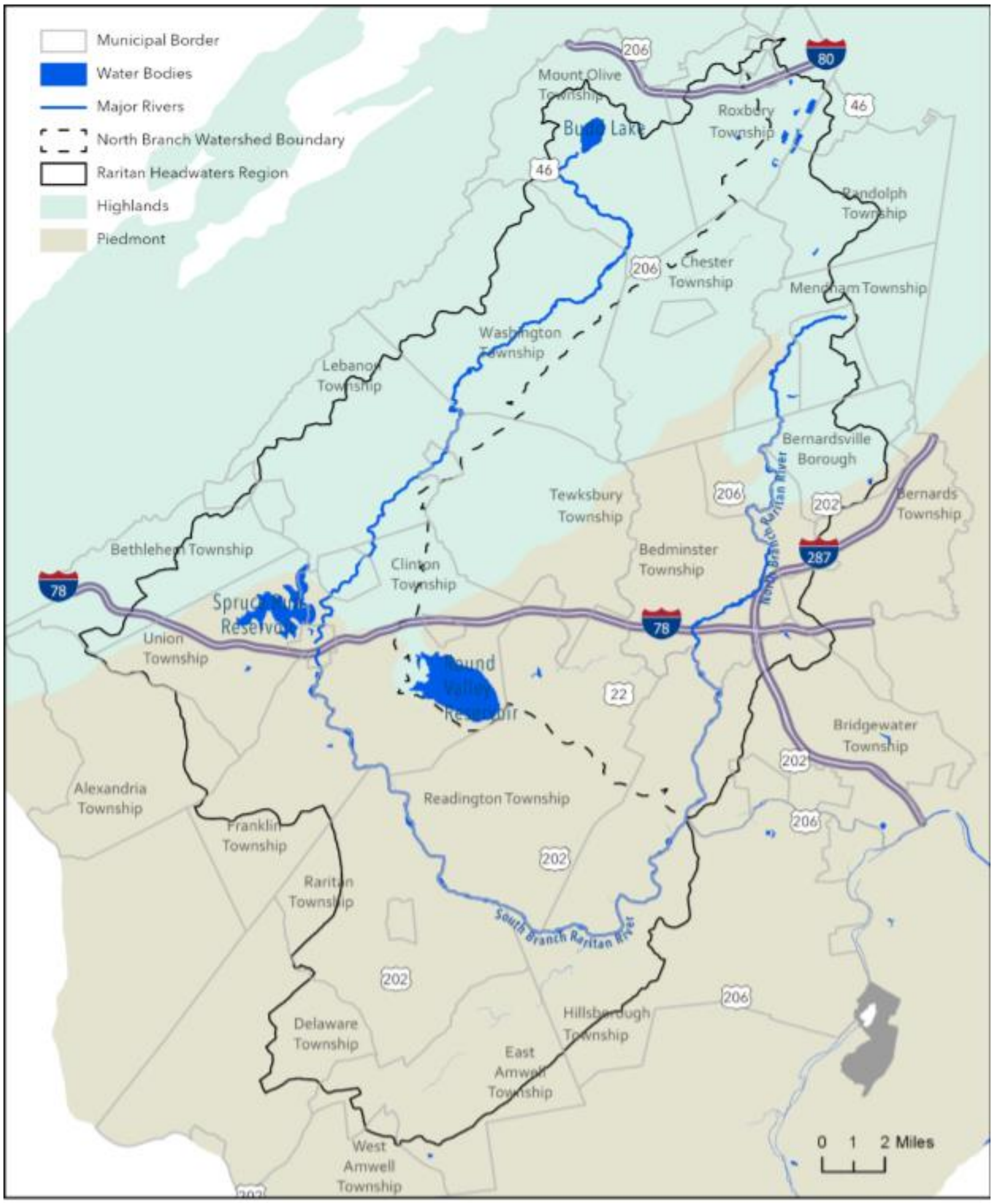

Figure 1. Map of the North and South Branch Raritan Watershed Region (WMA8) depicting major waterbodies, waterways, roads, and the Highlands and Piedmont physiographic provinces.

Land use – land cover conditions and trends:

Figure 2 is a map of 2012 land use and land cover in the watershed (NJDEP, Bureau of GIS). Land use-land cover and other trends are described in Table 1. There have been great changes in land use in the watershed over the past two decades, which included an increase in urban/suburban land use replacing farmland and forestland. Protection of remaining forest and wetlands in this headwater region is critical to maintaining surface and groundwater quality.

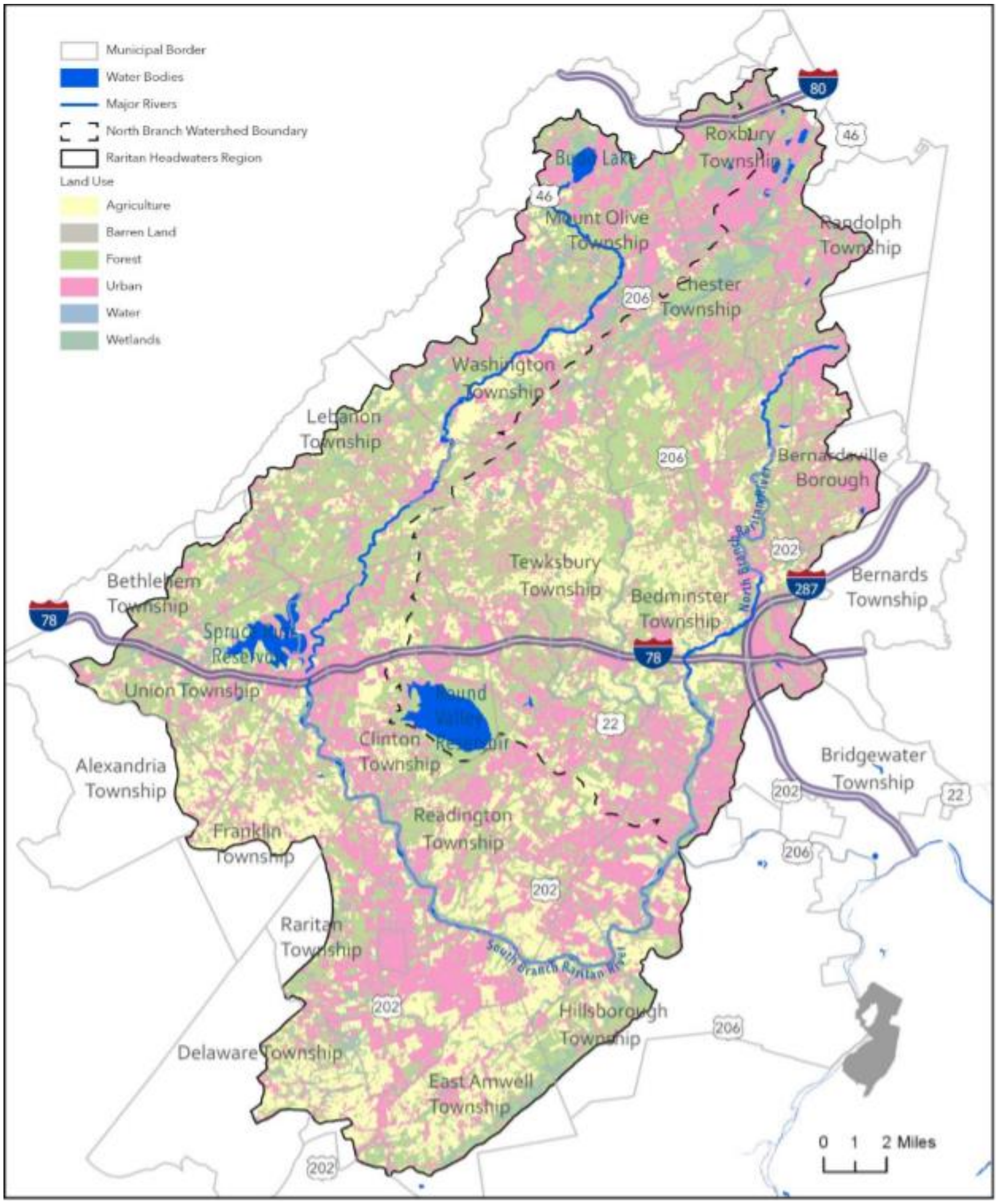

Figure 2. Land use and land cover in the North and South Branch Raritan Watershed Region (WMA8) based on NJDEP analysis of 2012 satellite imagery.

Culvert Selection Criteria:

The project utilizes stream connectivity assessment protocols (Abbot and Jackson 2019) and terrestrial passage assessment protocols (Fadden and Marx 2019) developed by NAACC and CHANJ (www.naacc.org; https://www.nj.gov/dep/fgw/ensp/chanj.htm)

ENSP provided RHA with an initial GIS map that contained a clip of 477 culverts located in WMA8, overlapped with CHANJ core or corridor wildlife habitat, and indicated the traffic volume grade associated with the roadway (severe_hv, severe, moderate; Figure 3). Traffic volume levels were defined based on number of vehicles/day (based on AADT levels from DOT records) and referenced in the CHANJ Guidance Document (ENSP 2019). The 3 categories were: 1) local (moderate traffic volume grade), 2) county, highways, and interstates with <10,000 vehicles/day (severe traffic volume grade), and 3) county, highways, and interstates with >10,000 vehicles/day (severe_hv – high volume - traffic volume grade; ENSP 2019). Additional data on core and corridor habitats along with vernal pool sites in WMA8 were obtained from NJDEP (Bureau of GIS; Figure 4).

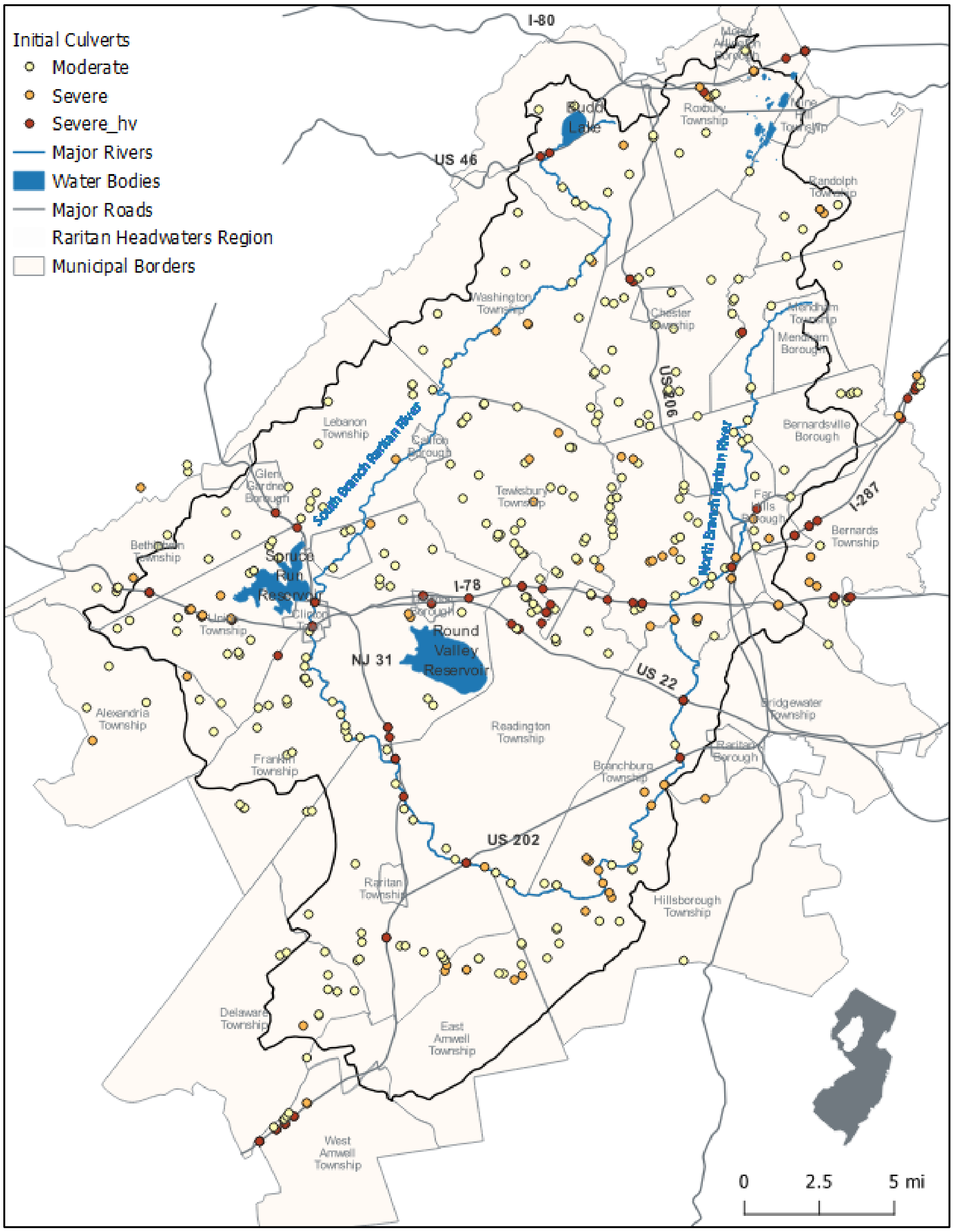

Figure 3. Map of 477 stream-road crossings overlapping with CHANJ core and corridor wildlife habitat in the North and South Branch Raritan Watershed Region (WMA8).

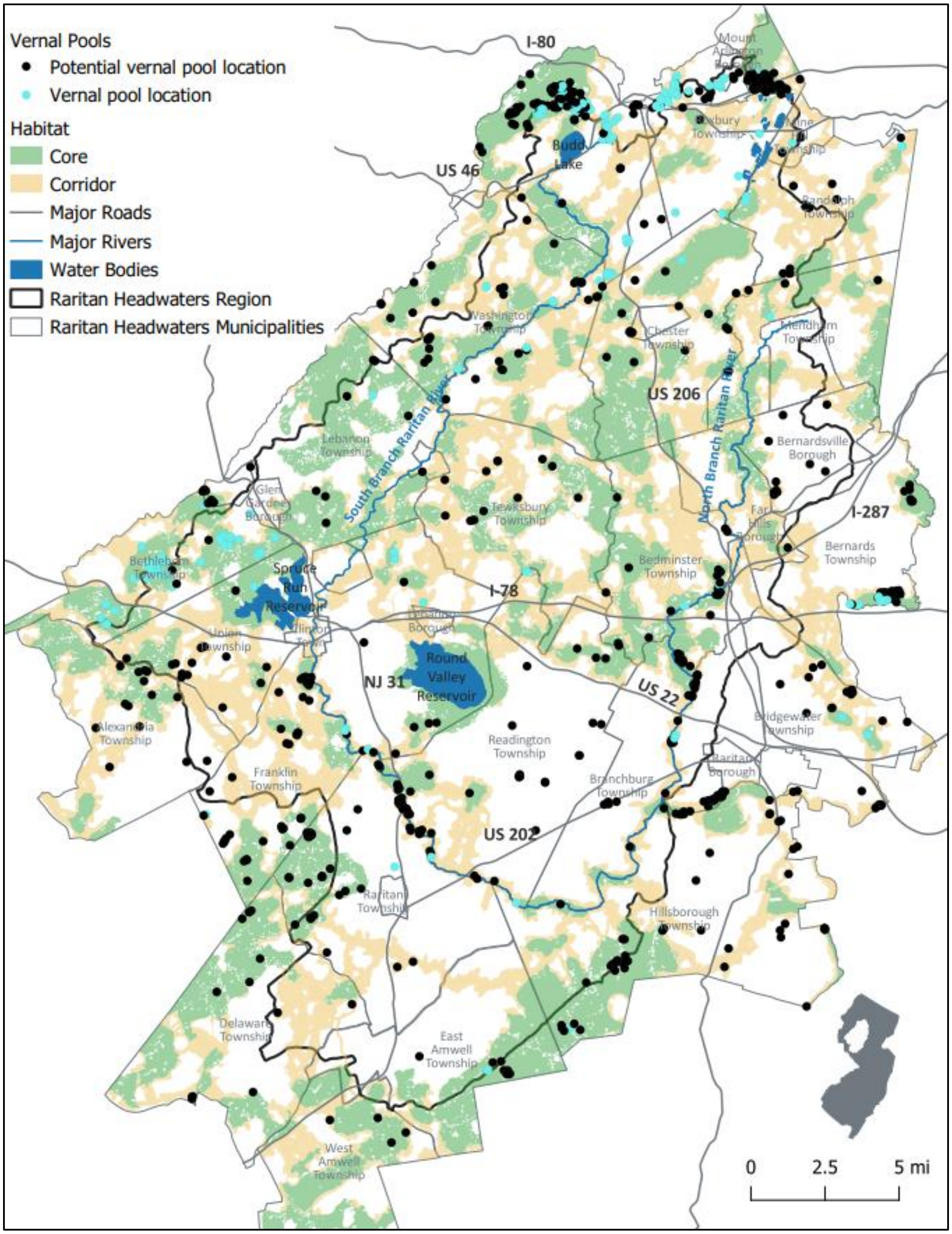

Figure 4: Map of North and South Branch Watershed region (WMA8) depicting major waterbodies, waterways, roads, core and corridor habitats, and vernal pool sites.

From the initial map of 477 stream-road crossings 150 were selected as top priorities for assessment in WMA8 based on four criteria:

1) It was located in a CHANJ core or corridor habitat
2) It contained forest or wetland on both sides of the road-stream crossing

3) The traffic volume was moderate (lowest rank), severe, severe_hv (highest rank);
4) A vernal pool was located nearby

Each culvert was given a priority level based on the four criteria above with 1=highest (meeting all four criteria above), 2=moderate (fulfilling 3 of the 4 criteria above) and 3=low priority (meeting only 2 criteria or less above). All stream-road crossing structures chosen were of highest priority level (1) for assessment.

Data Collection:

All 150 priority sites were visited between August and November 2021. Data were collected at suitable road-stream crossings using the NAACC stream connectivity and terrestrial passage assessment protocols. Data sheets were provided by NAACC via their documents webpage (https://streamcontinuity.org/naacc/assessments/documents). NAACC protocols suggest culvert assessments should be conducted during typical low-flow conditions to ensure homogeneity in baseline data collection, thus all data was collected during typical low-flow conditions. If a rain event occurred, 48 hours elapsed before data were collected at a site. Two RHA volunteers and two interns were trained and assisted in data collection. Of these, 3 successfully received NAACC Aquatic and Terrestrial Assessment certifications and may now conduct assessments without the supervision of a NAACC Lead Observer in the field (Figure 5).

Figure 5. Image of Stream Connectivity Coordinator (Rita Matos), Stream Connectivity Intern (Shannen Higgins), and RHA volunteer (Brian Lynch) conducting culvert assessment training/shadowing to receive NAACC certification.

Aquatic and Terrestrial Criteria:

Data was entered into the NAACC Data Center portal (www.naacc.org). Final aquatic and terrestrial Passibility scores were calculated based off the metrics and weighted composite scores developed by NAACC (NAACC 2015 and NAACC 2018).

The 5 categories of Passibility scores were: no barrier, minor barrier, insignificant barrier, moderate barrier, significant barrier, or severe barrier.

Results

CHANJ Habitat and Accessibility:

One of the criteria for selection of culverts was whether there was forested area on both sides of the road and if they were on core or corridor habitats. Out of the 150 culverts that were chosen for this project, 40 (27%) of the culverts were on core habitats; 36 were completed, 3 were inaccessible and 1 had a ‘no crossing’ score. 110 (73%) culverts were on corridor habitats of which 80 were completed, 29 were inaccessible, and 1 was given a ‘no crossing’ score.

Overall Culvert Accessibility:

All 150 road-stream crossing sites were visited by Rita Matos and at least one assistant. Out of the 150 crossings, 119 crossings (79%) were successfully completed where we conducted full assessments on the structures. 29 crossings (19%) were inaccessible either due to weather destroying culverts (e.g., Hurricane Ida,) extremely deep waters or impassable thick brush, or unsafe pull off zones on the roadway. Two crossings (1%; one in corridor and one in core habitat) were listed as ‘no crossing’ due to there being no structure present or no visible water flowing.

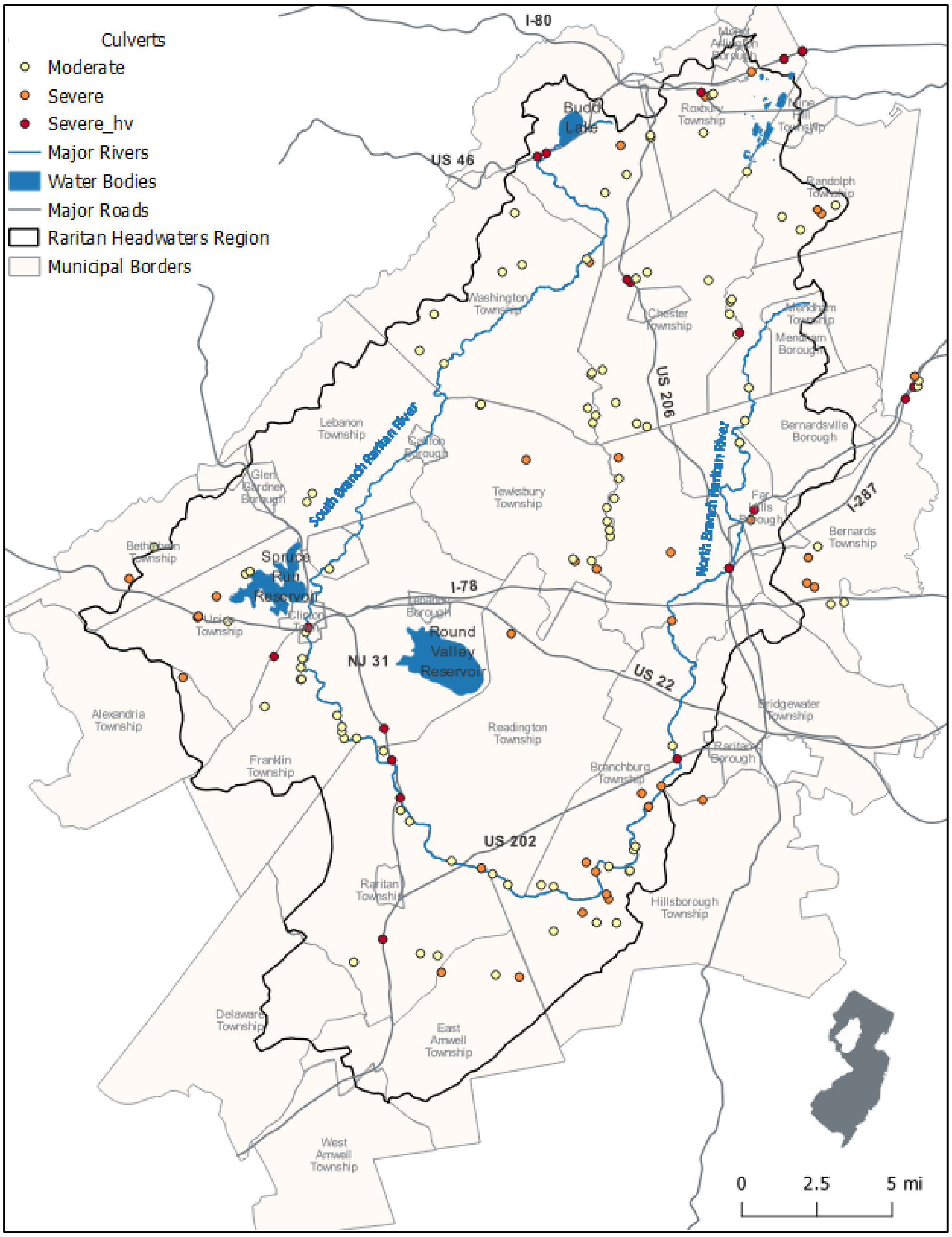

Figure 5: Map of the North and South Branch Raritan Watershed Region (WMA8) depicting the 150 priority culverts with traffic volume categories, major waterbodies, waterways, major roads and municipalities.

Overall Aquatic and Terrestrial Passibility Scores:

Overall Aquatic Passibility:

Of the 119 crossings successfully surveyed, 12 crossings (10%) presented ‘no barrier’, 72 (61%) were scored as ‘insignificant’, 21 crossings (18%) had ‘minor barriers’, 3 (3%) had ‘significant barrier’ scores, 7 (6%) had ‘moderate’ barrier scores, and 4 crossings (3%) received a ‘severe barrier’ score (Figure 6).

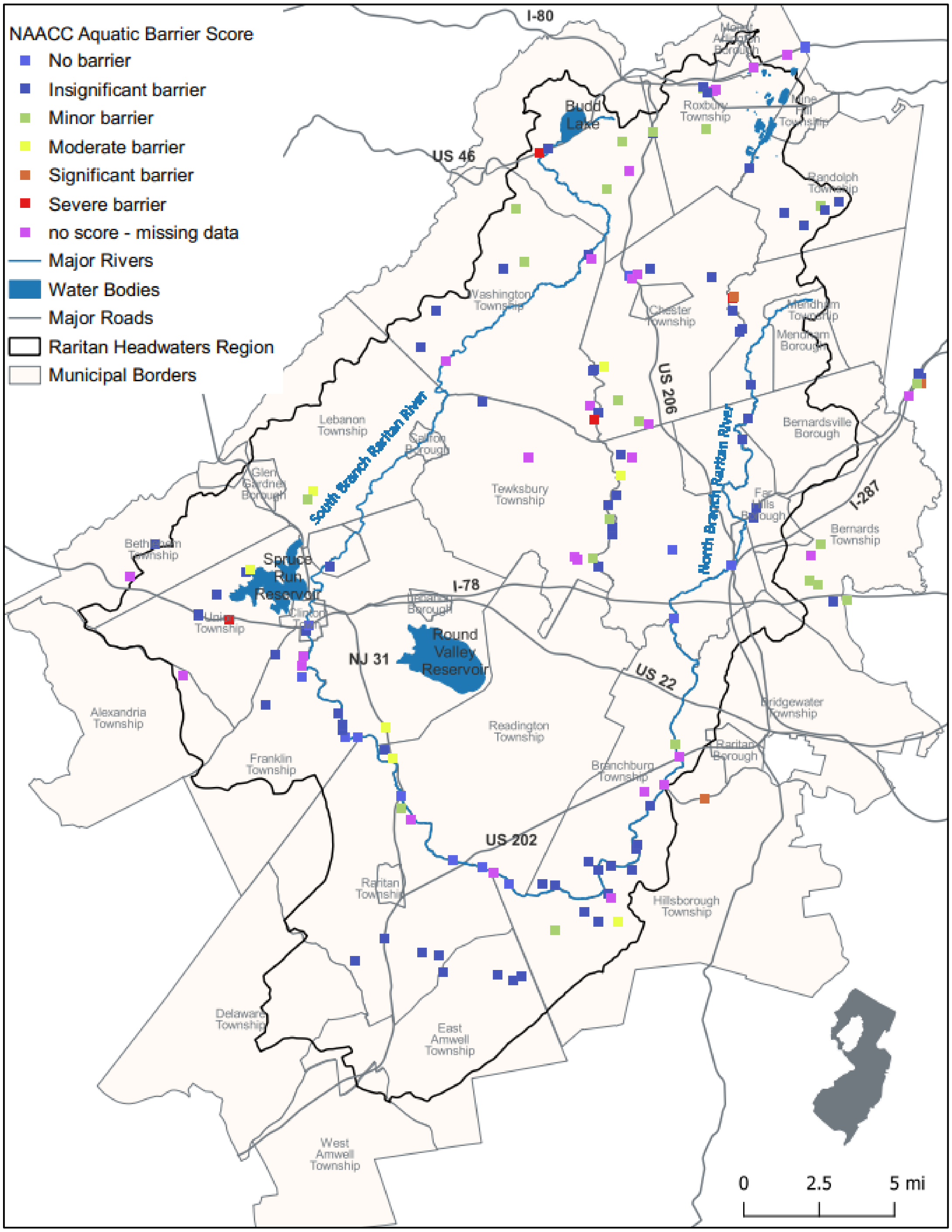

Figure 6. Map of the North and South Branch Watershed Region (WMA8) depicting the NAACC Barrier passibility scores for aquatic passage for 150 stream-road crossings, major waterbodies, waterways, major roads and municipalities.

Overall Terrestrial Passibility:

Of the 116 crossings successfully assessed for terrestrial connectivity, 5 (4%) of the structures presented 'no barrier', 11 (9%) presented 'insignificant barriers', 6 (5%) had 'minor barriers', 20 (17%) had 'significant barriers', 14 (12%) were 'moderate barriers', and 60 (52%) structures had 'severe barriers' (Figure 7). 34 crossings out of the original 150 were either inaccessible or no crossing existed at the time the site was visited.

Note there were 119 completely assessed for aquatic connectivity and 116 for terrestrial because there were more sites with 'no score-missing data' for terrestrial than there were for aquatic. If we came across a large bridge on the North Branch for example, there is no barrier for aquatic organisms, but because the sites were deep and we could not fully measure the bridge to completion 'NAACC' gives that a 'missing data score' for terrestrial and a 'no barrier' score when the bridge is large enough. No further measurements are required.

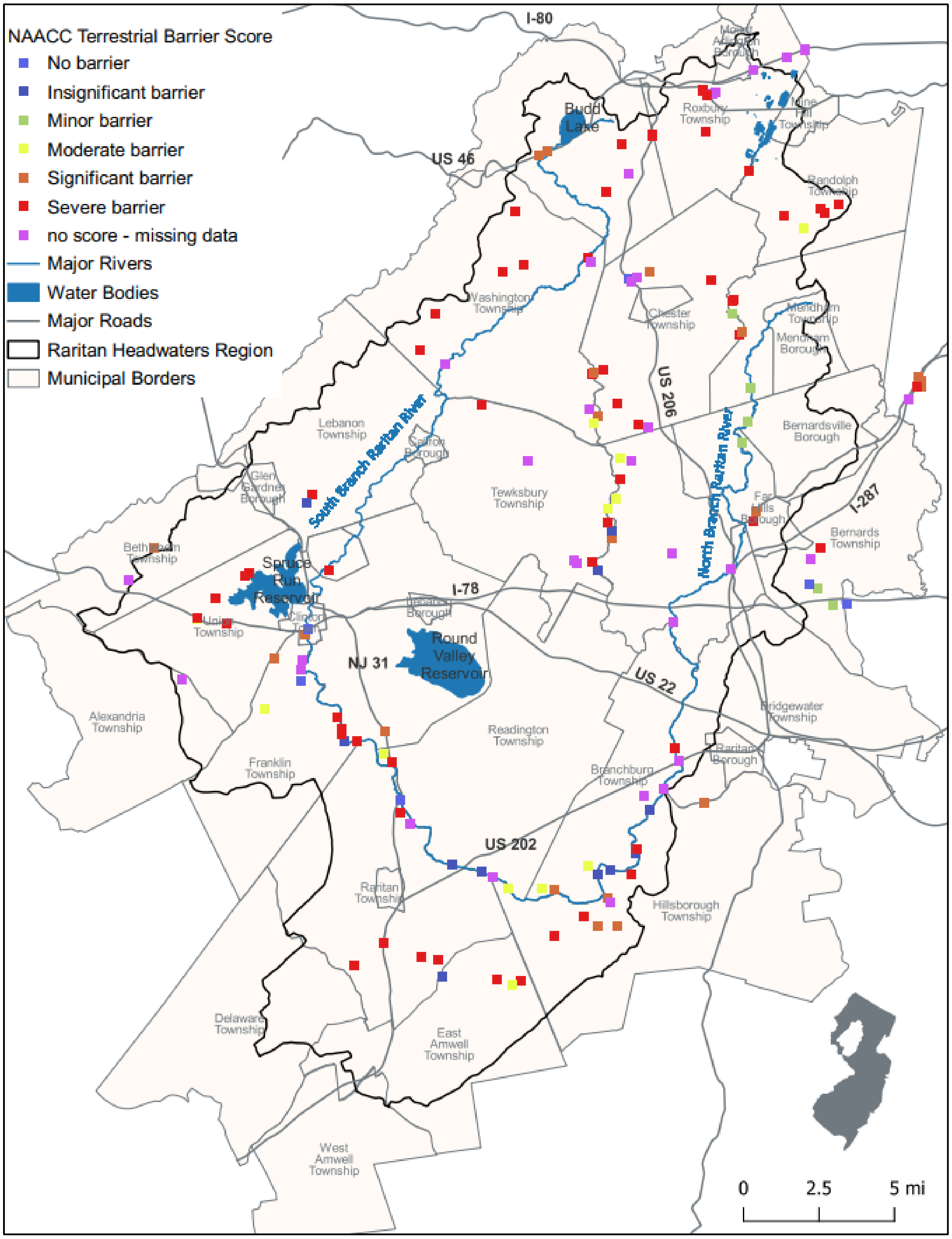

Figure 7. Map of the North and South Branch Watershed Region (WMA8) depicting the NAACC Barrier passibility scores for terrestrial passage for 150 road-stream crossings, major waterbodies, waterways, major roads and municipalities.

CHANJ Habitat (Core or Corridor):

CHANJ Habitat and Accessibility:

The 40 culverts that were located in core habitats were found only on moderate traffic volume roadways. Out of the 110 culverts located in corridor habitats, 24 (22%) were on severe_hv roadways, 33 (30%) were found on severe roadways, and 53 (48%) culverts were found on moderate roadways (Table 1).

Habitat	Road Threat		
	Severe_hv	Severe	Moderate
Core	0	0	40
Corridor	24	33	53
Total	**24**	**33**	**93**

Table 1. Distribution of 150 culverts with respect to habitat type and traffic volume.

Aquatic Passibility by CHANJ Habitat:

Of the sites successfully assessed for aquatic passibility in core habitats (N=36), we found 1 (2%) crossing presented 'no barrier', 21 (58%) were 'insignificant barriers', 8 (22%) were 'minor barriers', 3 (8%) were 'moderate barriers', 1 (2%) crossing presented a 'significant barrier', and 2 (5%) crossings presented 'severe barriers' (Table 2). 4 crossings had data missing due to inaccessibility or no crossing being present.

Of the sites successfully assessed for aquatic passibility in corridor habitats (N=85), we found 13 (15%) presented as 'no barriers', 51 (60%) were 'insignificant barriers', 13 (15%) were 'minor barriers', 4 (5%) were 'moderate barriers', 2 (2%) were 'significant barriers', and 2 (2%) were 'severe barriers' (Table 2). 25 crossings were inaccessible or there was no crossing present.

Terrestrial Passibility by CHANJ Habitat:

Of the sites successfully assessed for terrestrial passibility in core areas (N=36), there was some sort of barrier present at every crossing; none of the assessed crossings were a 'no barrier' score. 4 (11%) of the crossings presented an 'insignificant barrier', 3 (8%) presented 'minor barriers', 5 (13%) were 'moderate barriers', 4 (12%) were 'significant barriers', and 20 (55%) were 'severe barriers' to wildlife in core habitats (Table 2). 4 crossings were given a 'no score-missing data' or 'no crossing' due to lack of access to the site or no crossing present.

Of the sites successfully assessed for terrestrial passibility in corridor habitats (N=80), 5 (6%) presented as 'no barriers', 7 (8%) were 'insignificant barriers', 3 (3%) were 'minor barriers', 9 (11%) presented 'moderate barriers', 16 (20%) were 'significant barriers', and 40 (50%) were 'severe barriers' for wildlife in corridor habitats (Table 2). Note 30 of the original 110 corridor habitats received a 'no score-missing data' or 'no crossing' due to inaccessibility to collecting terrestrial data.

Barrier Score	Habitat Connectivity			
	Aquatic		Terrestrial	
	Core	Corridor	Core	Corridor
No barrier	1	13	0	5
Insignificant	21	51	4	7
Minor	8	13	3	3
Moderate	3	4	5	9
Significant	1	2	4	16
Severe	2	2	20	40
No crossing	1	1	1	1
no score-missing data	3	24	3	29
Total	**40**	**110**	**40**	**110**

Table 2. Passibility scores for aquatic and terrestrial connectivity based on habitat type.

Traffic Volume and Accessibility:

Culverts were selected based on their priority levels and traffic volumes. All 150 culverts were of highest priority level (1) for WMA8. Of the 150, 24 culverts (16%) were assessed on severe_hv roadways such as interstates, US highways, and state highways. Out of those 24, 20 passageways (83%) were fully assessed and 4 were inaccessible (17%) due to high traffic volumes or unsafe conditions to pullover. Thirty-three culverts (22%) were assessed on severe roadways such as county roads or US highways. Of those 33, 21 culverts (64%) were successfully assessed and 12 culverts (35%) were inaccessible due to high traffic volumes, lack of shoulders, or unsafe conditions to pullover. 93 culverts (61.3%) were assessed on moderate roadways such as local roads, private roads, or county roads. Of those 93 culverts assessed on moderate roadways, 78 culverts (84%) were fully assessed. 13 of the 93 were inaccessible (14%) due to private property boundaries, lack of shoulder, or unsafe conditions to pull over and 2 were ‘no crossings’ (2%) where we could not locate the structure or visible water flowing. Table 3 summarizes these data.

Accessibility	Road Threat		
	Severe_hv	Severe	Moderate
Completed	20	21	78
Inaccessible	4	12	13
No-crossing score	0	0	2
Total	**24**	**33**	**93**

Table 3. The number of culverts assessed by traffic volume.

Aquatic Passibility by Road Severity:

24 road-stream crossings were successfully assessed in severe_hv roadways. Of these 24, 7 (29%) presented as 'no barrier' to aquatic connectivity, 8 (33%) were an 'insignificant barrier', 2 (8%) were a 'minor barrier', 2 (8%) were a 'moderate barrier', and 1 (4%) was a 'severe barrier.' Four crossings were inaccessible and received a 'no score-missing data'. 33 culverts were successfully assessed on severe roadways. Of these 33 culverts, 3 (9%) had a score of 'no barrier', 15 (45%) were a 'insignificant barrier,' 4 (12%) were a 'minor barrier', and 1 (1%) were a 'significant barrier' for aquatic passibility. 10 were inaccessible. There were no severe barrier scores for severe traffic volume roadways. 93 culverts were successfully assessed on moderate roadways. Of those 93 culverts, 4 (4%) were 'no barrier', 49 (52%) were 'insignificant barriers', 15 (16%) were 'minor barrier', 2 (32%) were 'significant barriers', 5 (5%) were 'moderate barriers, and 3 (3%) were 'severe barriers' for aquatic passibility (Table 4). 15 were inaccessible or no crossing was present.

Barrier Score Aquatic	Road Threat		
	Severe_hv	Severe	Moderate
No barrier	7	3	4
Insignificant	8	15	49
Minor	2	4	15
Moderate	2	0	5
Significant	0	1	2
Severe	1	0	3
no score-missing data	4	10	15
Total	**24**	**33**	**93**

Table 4. Aquatic Passibility score by traffic volume.

Terrestrial Passibility by Road Severity:

Of the 24 road-stream crossings assessed for terrestrial passibility along severe_hv roadways, 4 (16%) presented as 'no barrier', 6 (25%) were 'significant barriers', 1 (4%) was a 'moderate barrier', 6 (25%) were 'severe barriers', and 4 (16%) were 'no score-missing data' due to inaccessibility to dry passage either because of a large bridge, steep embankments, or fencing. Of the 33 culverts assessed for terrestrial passibility along severe roadways, 1 (3%) crossing presented as ‘no barrier’, 5 (15%) were ‘insignificant barriers’, 1 (3%) was a ‘minor barrier’, 3 (9%) were ‘significant barriers’, 3 (9%) were ‘moderate barriers’, and 8 (24%) were ‘severe barriers’. 12 were inaccessible. Lastly, for the 93 culverts that were assessed for terrestrial passibility along moderate roadways, every culvert presented some form of barrier with there being none with a ‘no barrier’ score. 6 (6%) were ‘insignificant barriers’, 5 (5%) were ‘minor barriers’, 11 (11%) were ‘significant barriers’, 10 (10%) were ‘moderate barriers’, and 46 (49%) were ‘severe barriers’ for terrestrial wildlife on moderate traffic volume roadways (Table 5). 15 were inaccessible or there was no crossing present.

Barrier Score Terrestrial	Road Threat		
	Severe_hv	Severe	Moderate
No barrier	4	1	0
Insignificant	0	5	6
Minor	0	1	5
Moderate	1	3	10
Significant	6	3	11
Severe	6	8	46
no score-missing data	4	12	15
Total	**24**	**33**	**93**

Table 5. Terrestrial Passibility score by traffic volume.

Summary and Conclusions:

The assessment of stream-road crossings completed by RHA will provide valuable information to NJ Fish and Wildlife, Endangered and Nongame Species Program for targeting areas that provide safe passage across roadways in core and corridor habitat as part of CHANJ. In addition, the data will provide useful data on aquatic connectivity retrofits needed to improve connectivity for stream and wetland fish and wildlife, address flooding, and protect streams from extreme storms and heavy precipitation events due to climate change. One major finding from this study is that many road-stream crossings are not connected on both sides, for aquatic and/or terrestrial organisms. Many more culverts did not meet the terrestrial connectivity standards as compared to aquatic connectivity. Road-stream crossings provide an opportunity for safe road crossings for terrestrial wildlife. The data from this assessment of 150 road-stream crossings and the scores for each of these crossings are available at the NAACC Data Center portal (www.naacc.org).

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