LIDAR-based Fish Passage Assessment of 350 Road-Stream Crossings in Nine Lower Delaware Wild and Scenic River Municipalities

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December 2020

SUMMARY

Roads cross streams at ~40,000 locations in the Delaware River Basin. Where these crossings are not properly designed for the streams they carry, aquatic and terrestrial organism passage can be blocked, roads may flood, and erosion rates likely increase. Therefore, identifying and upgrading problem crossings can benefit both fish and wildlife and human communities. However, field-assessing road-stream crossings for fish passage and flood resiliency, while very valuable, can be costly and time-consuming in the initial phase of project development. For this Lower Delaware Wild and Scenic (LDWS) grant project, Trout Unlimited evaluated a computer-based approach (high resolution LIDAR) to increase the efficiency of initial road-stream crossing assessment for fish passage. We remotely estimated a common surrogate of fish passage—stream elevation drop from above to below the road-stream crossing— at 76 crossings in northwest New Jersey where we also had field-measured estimates of fish passage. We then applied this method to 350 crossings in nine New Jersey municipalities in the LDWS region. When tested against field assessments the computer-based approach correctly identified 100% of significant and severe barriers to fish passage as ranked by the North Atlantic Aquatic Connectivity Collaborative's scoring system. LIDAR-measured elevation drop explained significant variation in field-measured elevation drop ($R^2 = 0.85$; $F_{(1,64)} = 364.5$; $p < 0.001$), and computer and field measures differed by a mean of 0.22 feet. Moreover, we estimated that this method saved approximately $24,255 (87% savings) relative to traditional field assessments when applied in the LDWS, even when budgeting for final field surveys of computer-identified barriers to fish passage. The accuracy and cost of this approach strike a balance between those of field surveys and coarse landscape-based computer models and are likely acceptable for many ecological applications. However, the method should be tested against field data when applied in new geographic regions or with new digital elevation datasets. Of the 350 crossings evaluated in the LDWS, 107 were identified as potential barriers to fish passage, 62 of these were in wild trout waters where our organization prioritizes its work, and 34 are potentially ecologically significant given their position in the stream network. We recommend more detailed field assessments of condition, fish passage, terrestrial wildlife passage, and flood resiliency at these 34 crossings. Replacing some of these structures with fish-friendly designs either proactively or when road managers determine maintenance costs outweigh the replacement cost of a given structure will likely benefit people, wildlife, and fish populations.

INTRODUCTION

In the past three decades fisheries ecologists have emphasized that conserving fish populations requires a watershed-scale perspective on processes influencing their life history (Schlosser 1991; Fausch et al. 2002). In this model of fish conservation, the ability of fish to move freely among habitat types (e.g., spawning, foraging, thermal refuge, and overwintering habitat) is critical for their persistence. The importance of this watershed ‘connectivity’ extends to our understanding and management of physical river processes like flow and sediment transport (Wohl 2017). Therefore, identifying and restoring barriers to the movement of biological organisms, flows, sediment, and nutrients has become a paramount component of river restoration (Wohl, Lane, and Wilcox 2015).

While our river networks have been severely fragmented by barriers like dams and poorly designed road-stream crossings, we often lack an understanding of where these potential barriers are and the extent to which they are actual barriers to fish movement (Januchowski-Hartley et al. 2013). We generally know much less about the ability for fish to pass individual road-stream crossings than dams, yet road-stream crossings far outnumber dams in most watersheds. For example, Januchowski-Hartley et al. (2013) estimated that road-stream crossings outnumbered dams in the Great Lakes Basin by 38 times, and that about 36% of these crossings were probably barriers to fish movement. While road-stream crossings like large bridges have little to no impact on fish passage, undersized, geomorphically incompatible culverts can accelerate streamflow and form downstream outlet drops that serve as velocity and height barriers to upstream fish movement. Planning restoration at scales relevant to local fish populations requires that we know where these poorly-designed crossings are and how severely individual crossings impede fish movement.

In the northeastern United States, Trout Unlimited (TU) has focused on road-stream crossing assessment and restoration to improve wild trout populations and their recreational fisheries. TU is increasingly taking a watershed-based approach to developing and executing restoration plans for wild brook trout, and a road-stream crossing assessment that identifies fragmented patches of wild trout serves as the foundation of these plans (Rummel and Fesenmyer 2019). Traditional field assessment of road-stream crossings following a standard protocol developed by the North Atlantic Aquatic Connectivity Collaborative (NAACC) has allowed TU and other organizations to rank individual road-stream crossings as barriers to fish passage both quantitatively and qualitatively, from ‘insignificant’ to ‘severe’.

These field assessments provide critical information to watershed managers, but they can be costly and time-consuming (and occasionally dangerous) in the early phases of restoration planning. For example, TU experience suggests that field assessment costs about $80 and takes about 0.67 hours per road-stream crossing. At these rates, assessing the approximately 40,000 crossings in the Delaware River Basin would cost $3.2 million over 3,350 full workdays. Given that road-stream crossing assessment is just one component of the restoration planning process, more efficient methods are needed to scale up restoration work across multiple watersheds.

Scientists have attempted to increase this efficiency by using broad landscape features like catchment elevation, area, and slope to predict road-stream crossing barrier severity (Januchowski-Hartley et al. 2014; McGarigal et al. 2017). These models are helpful in comparing predicted average barrier severity among watersheds to determine where detailed crossing assessment programs would be most useful, but they often have low explanatory power at the individual crossing level when tested against field data (e.g., $R^2 = 0.23$; McGarigal et al. 2017) and are therefore less useful in developing local watershed restoration plans.

By contrast, increasingly high-resolution digital elevation data collected via light detection and ranging (LIDAR) technology has many promising applications in watershed science and restoration, including road-stream crossing assessment. LIDAR elevation data with sub-foot vertical resolution provide an opportunity to identify crossings with outlet drops or steep slopes using a computer-based geographic information system. Winston and Diebel (2015) tested such a LIDAR-based method of coarse fish passage assessment against field-based passage assessments, found good concordance between the approaches, and subsequently applied this method in Wisconsin to assess fish passage across thousands of road-stream crossings at a scale and efficiency not possible with a traditional field approach. However, differences in geography and data quality may not make this approach applicable in all areas. In this project we sought to 1) test the accuracy and cost savings of a LIDAR-based method of rapid road-stream crossing assessment in northwestern NJ, 2) apply this method to assess potential fish passage at 350 identified road-stream crossings in NJ LDWS municipalities, and 3) use these assessments to identify a subset of crossings where upgrade projects may benefit wild trout populations.

Trout Unlimited focuses its work in northwestern New Jersey where land use and stream temperatures still allow for the persistence of wild trout populations and fisheries. Major focal watersheds of TU's current work include the Flatbrook, Paulinskill, Lopatcong, Musconetcong, and Pohatcong, most of which join the Delaware River within the Lower Delaware Wild and Scenic River corridor. Within nine LDWS municipalities, at least 18 tributaries of varying size drain directly to the Delaware north of, and including, the Musconetcong River. Many of these waters are wild-trout producing as well as accessible to anadromous species inhabiting the Delaware River watershed. Ensuring that these fish have access to critical habitats by removing barriers to their movement will contribute to the LDWS management goals of both protecting important animal species in tributaries and improving and encouraging use of recreational fisheries (LDWSR Task Force and NPS 1997). Moreover, identifying and improving problem culverts for fish passage can reduce local erosion and enhance the flood resiliency of road infrastructure.

METHODS

General LIDAR Assessment Approach

In 2018 LIDAR data with a 0.5 ft vertical resolution and 2.0 ft horizontal cell size were collected, ground-truthed, and processed into a bare-earth digital elevation model by the Sanborn Mapping Company, Inc. for the New Jersey Highlands following U.S. Geological Survey National Geospatial Program Base Lidar Specification, Version 1.3. This bare earth digital elevation model is publicly available as an image service through the NJ Office of GIS. We extracted the point locations of all 350 public road-stream crossings within the nine LDWS municipalities using the North Atlantic Aquatic Connectivity Collaborative's Data Center, and we used publicly available 2015 leaf-off aerial imagery with 1 ft pixel resolution to aid in crossing interpretation.

We analyzed the digital elevation model within the ArcGIS Desktop 10.7.1 environment at each road-stream crossing to 1) classify the crossing as a true crossing or not, depending on observable features of both the stream and road at the potential crossing (e.g., does a road exist at this location and is a stream channel apparent on both side of the road?; see Winston and Diebel 2015 for complete details), 2) classify true crossings as a bridge or culvert, depending on whether the digital elevation model creators fully breached the crossing based on given knowledge of bridge locations, and 3) estimate the elevation drop of the water surface between the upstream and downstream side of the crossing as a surrogate metric of fish passage.

Elevation drop was estimated by digitizing a longitudinal stream elevation profile using the ArcGIS 3D Analyst extension. At a 1:500 map scale, a line was manually interpolated along the middle of the stream channel (i.e., following the lowest local elevation) from approximately two crossing widths above to two crossing widths below the road-stream crossing. A profile graph was generated from this digitized stream line, which generally showed a clear, abrupt elevation change at the road-stream crossing (Fig. 1). Elevation drop was estimated from this profile graph as the elevation difference just upstream to just downstream of the road-stream crossing influence. We acknowledge potential error in locating the start of the downstream water elevation surface at some crossings; however, we attempted to consistently locate downstream measurements immediately below the first visually significant change in slope after the crossing. Vertical measurement precision in elevation drop varied with the elevation range of the automatically generated profile graph (median precision = 0.25 ft, range = 0.05 – 1.0 ft, n = 50 randomly sampled crossings).

A crossing was identified as a potential barrier to fish passage if its elevation drop was ≥ 1 ft. In another LIDAR-based screening of fish passage, crossings with ≥ 1 ft elevation drop generally had an outlet drop > 0 (Winston and Diebel 2015), a major determinant of reduced fish passage in the NAACC scoring system (NAACC 2015). This elevation threshold can be revised after testing against NJ-specific field data.

Field Test

In 2019, trained TU staff field-assessed 189 road-stream crossing structures in the Flatbrook watershed, a Delaware River tributary just north of the LDWS corridor, following the NAACC aquatic connectivity protocol (NAACC 2015). The NAACC protocol generates quantitative and qualitative barrier severity ranks for each field-assessed crossing, from insignificant to severe barrier to fish passage. TU also collected supplemental longitudinal profile data to model the hydraulic vulnerability of each crossing.

We independently estimated elevation drop at Flatbrook crossings identified as culverts using the LIDAR-based approach described above. We then calculated the field-based equivalent elevation drop by adding the outlet drop measured in the NAACC assessment to the crossing inlet-outlet elevation difference measured in the supplemental longitudinal profile.

We compared the estimates of field- and computer-based assessments in two ways. First, we determined whether computer-estimated elevation drop was a significant predictor of field-measured elevation drop using linear regression. This comparison indicates whether the computer-based evaluation accurately reflects actual crossing characteristics, but it does not indicate whether this method reliably identifies potential barriers to fish passage.

Second, we calculated the percentage of crossings in each field-estimated NAACC barrier severity category that were flagged as a potential barrier to fish passage using LIDAR-based elevation drop thresholds (1 ft and 2 ft). *A priori*, we would consider the LIDAR-based method useful if it correctly flagged a high percentage of crossings in the more severe barrier categories while limiting the number of flagged crossings in low-severity crossings.

LDWS Barrier and Ecological Importance Assessment

We evaluated all 350 NAACC-identified LDWS road-stream crossings north of and including the Musconetcong watershed using the LIDAR approach described above, using the 1 ft elevation drop threshold to identify potential barriers to fish passage. We summarized potential crossings, true crossings, and potential barriers to fish passage by municipality.

For all potential barriers to fish passage, we followed a series of decision rules to determine which may be beneficial restoration projects for wild trout populations. This is just one rapid, trout-focused approach to ecological prioritization; potential barriers not identified for further study here *should not* be assumed to be of no ecological significance to other fish and wildlife species. First, we removed crossings not located in Trout Production waters as classified by the NJ Department of Environmental Protection’s Surface Water Quality Standards (NJDEP 2020).

We then removed crossings that 1) were in small agricultural- or urban-dominated catchments with many other likely habitat quality issues, 2) were immediately adjacent to other known barriers to fish movement (e.g., natural waterfalls, dams, flagged crossings at highway or railroads), or 3) were high in tributary headwaters with little stream habitat above the crossing. We classified the remaining potential barriers as ecologically significant because they were 1) centrally located in a stream’s mainstem, preventing fish movement through the watershed, 2) located near a tributary’s mouth to a larger mainstem, foreseeably blocking mainstem fish use of complementary coldwater refuge, spawning, and nursery tributary habitat, or 3) located in forested headwater reaches with significant upstream habitat above the barrier to either serve as climate-resilient brook trout refuge from non-native species in sympatric watersheds or to be reconnected to expand brook trout population size in allopatric watersheds. For this grant TU staff used their best judgment to estimate the ecological relevance of potential barriers as described above. Alternative quantitative approaches to project prioritization may certainly be warranted at this stage of road-stream crossing assessment depending on project goals and organizational capacity.

Cost and Time Savings Estimate

We estimated the cost and time savings of a LIDAR-based approach to road-stream crossing assessment by comparing our observed costs in the LDWS assessment with our estimated costs of field assessment based on previous experience. We assumed that any LIDAR-based approach would be followed by field assessments of flagged crossings and included these field costs in the LIDAR project budget accordingly. For LIDAR assessments, we assumed 1 coordinator completed 15 crossings per hour (as found when performing our LDWS assessment) and estimated total project cost including salary, benefits, and overhead based on this hourly rate. Based on our organization's experience, we assumed a field-based evaluation rate of 1.5 crossings per hour. Using recent expenditures from a field-assessment of ~750 road-stream crossings in the Delaware basin, we calculated a field assessment cost rate of $80 per crossing including labor and travel costs (Amy Wolfe, TU Northeast Coldwater Habitat Program Director, personal communication). We used these assumptions to calculate total project cost and time to assess all 350 LDWS crossings using a traditional field-based approach, a LIDAR only approach, and a LIDAR approach supplemented by field assessments of 1) all potential barriers and 2) only barriers with potential ecological relevance to trout. We then calculated time and cost savings of all LIDAR-based approaches relative to a field-only approach as:

$$\%\ savings = \frac{Cost(Time)_{Field} - Cost(Time)_{LIDAR}}{Cost(Time)_{Field}} \times 100$$

RESULTS

Field Test

84 Flatbrook crossings were identified as culverts, 76 were assigned a NAACC barrier severity score, and 66 had supplemental longitudinal data to permit comparison to LIDAR-estimated elevation drop. LIDAR-measured elevation drops explained significant variation in field-measured elevation drops ($R^2 = 0.85$; $F_{(1,64)} = 364.5$; $p < 0.001$; Fig. 2). A 1ft LIDAR-based elevation drop threshold correctly identified 100% of significant and severe crossings in the Flatbrook watershed, but also flagged a combined 42.3% of insignificant and minor crossings as potential barriers (Table 1). A 2 ft drop threshold still identified 100% of significant and severe crossings but flagged many fewer insignificant and minor crossings (combined 9.6% flagged; Table 2).

LDWS Barrier and Ecological Importance Assessment

Of the 350 potential crossings assessed, 266 were identified as true crossings, 107 were flagged as potential barriers to fish passage, 62 of these were located in wild trout waters, and 34 of these are recommended for further study on their potential effects on wild trout populations and restoration benefits (Table 2; Fig. 3). Knowlton and White townships had the most actual crossings and potential barriers to fish passage (Table 2). Potentially beneficial restoration projects were located across 11 wild trout watersheds, including 7 crossings located in two wild trout-managed fisheries (Lopatcong and Pophandusing Creeks; Table 3).

Most potential barriers in wild trout waters that were not included for further study were excluded because little functional habitat existed upstream of the crossing (19/28 [67.9%]; Table 4). Ecologically significant barriers warranting further study were split across those that were located centrally on a mainstem stream (10/34 [29.4%]), near tributary mouths (10/34 [29.4%]), or in forested headwaters with significant upstream habitat (14/34 [41.1%]) (Table 4).

Cost and Time Savings Estimate
After an initial practice period, we found that TU staff could retrieve and organize LIDAR and NAACC data, evaluate crossings in ArcGIS, and enter, manage, and analyze these data at a rate of approximately 15 crossings per hour. Therefore, LIDAR-based approaches saved significant time and money over a traditional field-based approach, even when performing follow up field assessments on LIDAR-flagged potential barriers (Table 5). A likely assessment approach for TU (LIDAR assessment + follow up field assessment on potential trout-benefitting projects) cost $24,255 less (87% savings) and required 187 fewer labor hours (80% savings) than a traditional field approach.

DISCUSSION

We found that LIDAR-based road-stream crossing assessments are likely a cost- and time-efficient and accurate way to identify potential barriers to fish passage in northwestern NJ. LIDAR-based measures of road-stream crossing elevation drop explained significant variation in field-measured conditions (Fig. 2), as did the only other study of this kind that we are aware of ($R^2 = 0.85$; Winston and Diebel 2015). Moreover, flagging likely barriers based on elevation drop correctly identified 100% of significant and severe barriers whether we used a threshold drop of 1 or 2 ft (Table 1).

However, using a 1 ft threshold included many potential false positives in which actual insignificant and minor barriers were flagged as potential barriers. A 2 ft threshold greatly reduced this potential misclassification rate at the expense of a reduced rate of flagging moderate barriers (Table 1). High false positivity rates may significantly increase subsequent field costs and time if project managers use the LIDAR assessment to prioritize more detailed field assessment. Likewise, false positives may generate significantly higher estimates of watershed fragmentation and connectivity concerns if these data are used for conservation planning. By contrast, reducing this false positivity rate will also reduce moderate barrier identification, which may particularly affect weaker-swimming species or early life stages.

Selecting an elevation drop threshold should take these concerns into account given the species, goals, and geography of a project. We choose to keep a conservative 1ft threshold for our LDWS analysis because 1) so few trout-relevant crossings were prioritized to begin with (34 vs. 21 with a 2 ft threshold) and 2) slight differences in landscape characteristics between the Flatbrook and LDWS regions may lead to slightly different relationships between threshold drop and barrier severity. Ideally, field assessments would be performed on a subset of crossings in the focal watershed of the LIDAR assessment to ensure the method remains reliable across geographies.

Our LIDAR assessment greatly reduced the number of potential crossings acting as barriers in the LDWS from 350 to 107, and further to 34 when only considering ecologically significant crossings in trout waters. In theory, this approach saved us at least $24,255 in labor and travel costs (Table 5). Unsurprisingly, townships with more stream miles like Knowlton and White had more surveyed crossings and more crossings identified as potential barriers to wild trout (Table 2). Potential barriers were located within 10 wild trout watersheds (Table 3), and their restoration may have different functional benefits to trout populations depending on their location within the stream network (Table 5). Further examination of these watersheds in partnership with the NJ Bureau of Freshwater Fisheries would further narrow candidate projects to those crossings most likely to meet the conservation goals of both TU and NJBFF. Knowing which streams have predicted temperatures suitable for wild trout occupancy in the future will be important in prioritizing our work. All else equal, TU and NJBFF may first prioritize brook trout only watersheds (Buckhorn Creek), then wild trout fisheries of any kind (Lopatcong and Pophandusing Creeks), then wild brown only watersheds, then mixed brook and brown watersheds when planning crossing upgrade projects.

Road-stream crossing upgrades may bring many benefits to the watershed community beyond trout enhancement. Road infrastructure resilience in the face of increasing floods is a key concern of municipal, county, and state managers, and undersized crossings that disrupt fish passage also often disrupt streamflow and increase the probability of crossing failure during high waters. Many resident and anadromous non-game fish species are also mobile and benefit from restoring watershed connectivity, while terrestrial wildlife like salamanders, turtles, and even small mammals also benefit from properly designed road-stream crossings (NJDFW 2019). Straightforward protocols exist to assess the condition, flood resilience, and terrestrial wildlife passage of road-stream crossings in the field. Adding these assessments to the traditional aquatic connectivity protocol would approximately double the field time required per crossing. However, restricting field assessments to those crossings that have already been flagged as a fish passage barrier via LIDAR assessment will still keep total project costs relatively low (Table 5) while greatly enhancing opportunities to find win-win upgrade projects for fish, wildlife, and people. TU is excited to share the findings of this project with municipal, state, and non-profit partners to identify beneficial restoration projects in the LDWS and adjacent watersheds.

ACKNOWLEDGMENTS

Aspects of this work was funded by the Lower Delaware Wild and Scenic River Management Council 2020 mini-grant program, the National Fish and Wildlife Foundation’s Delaware Watershed Conservation Fund, and the F.M. Kirby Foundation. We appreciate guidance from Matt Diebel of the Dane County (Wisconsin) Land and Water Resources Department who developed methods of LIDAR-based fish passage assessment at road-stream crossings across Wisconsin.

DATA AVAILABILITY

Trout Unlimited will share LDWS crossing evaluation data with any interested party. Contact keith.fritschie@tu.org for a .csv or shapefile.

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FIGURES

Figure 1. Example profile graph of a digitized stream longitudinal profile centered on a road-stream crossing. Elevation drop (stream surface elevation difference above vs. below the road-stream crossing) is a major determinant of fish passage and was estimated manually from the profile graph generated in ArcGIS 3D Analyst

extension.

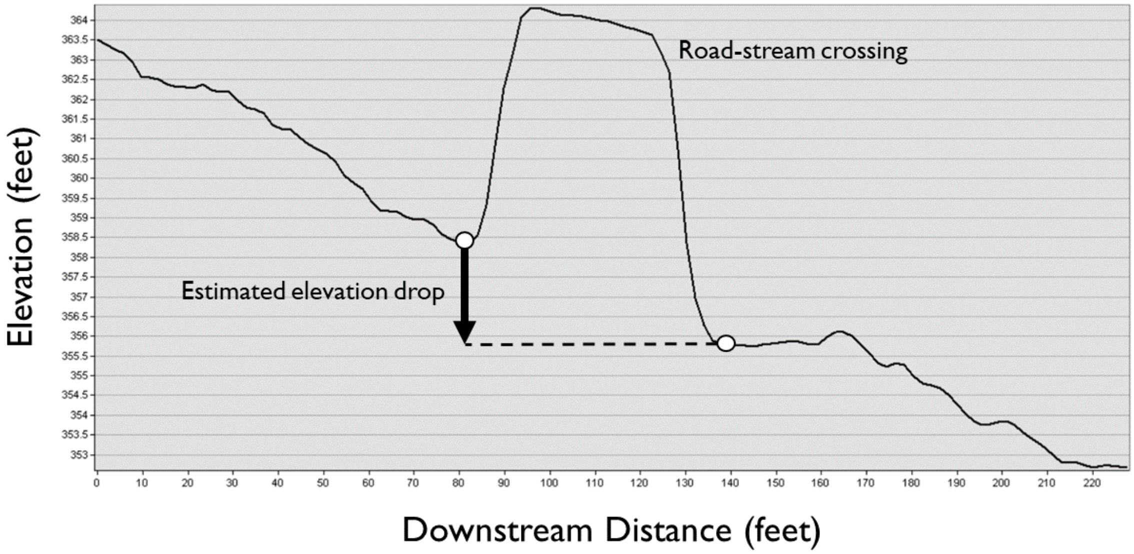


Figure 2. LIDAR-measured elevation drops from upstream to downstream of road-stream stream crossings explained significant variation in field-measured elevation drops in the Flatbrook watershed. We flagged LIDAR-measured drops > 1 ft as potential barriers to fish passage (right of dotted vertical line). Points are colored by their evaluated severity according to the NAACC scoring system. Not all NAACC-assessed barriers had supplemental data needed to measure elevation drop in the field.

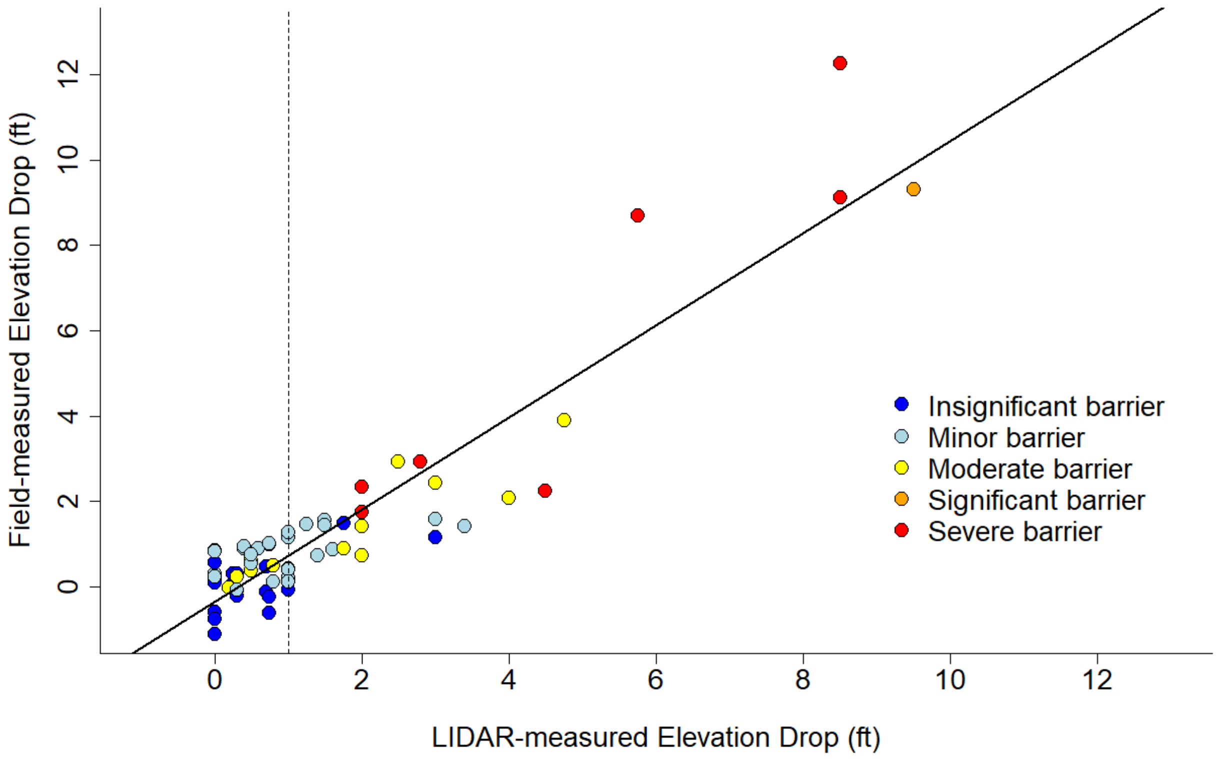
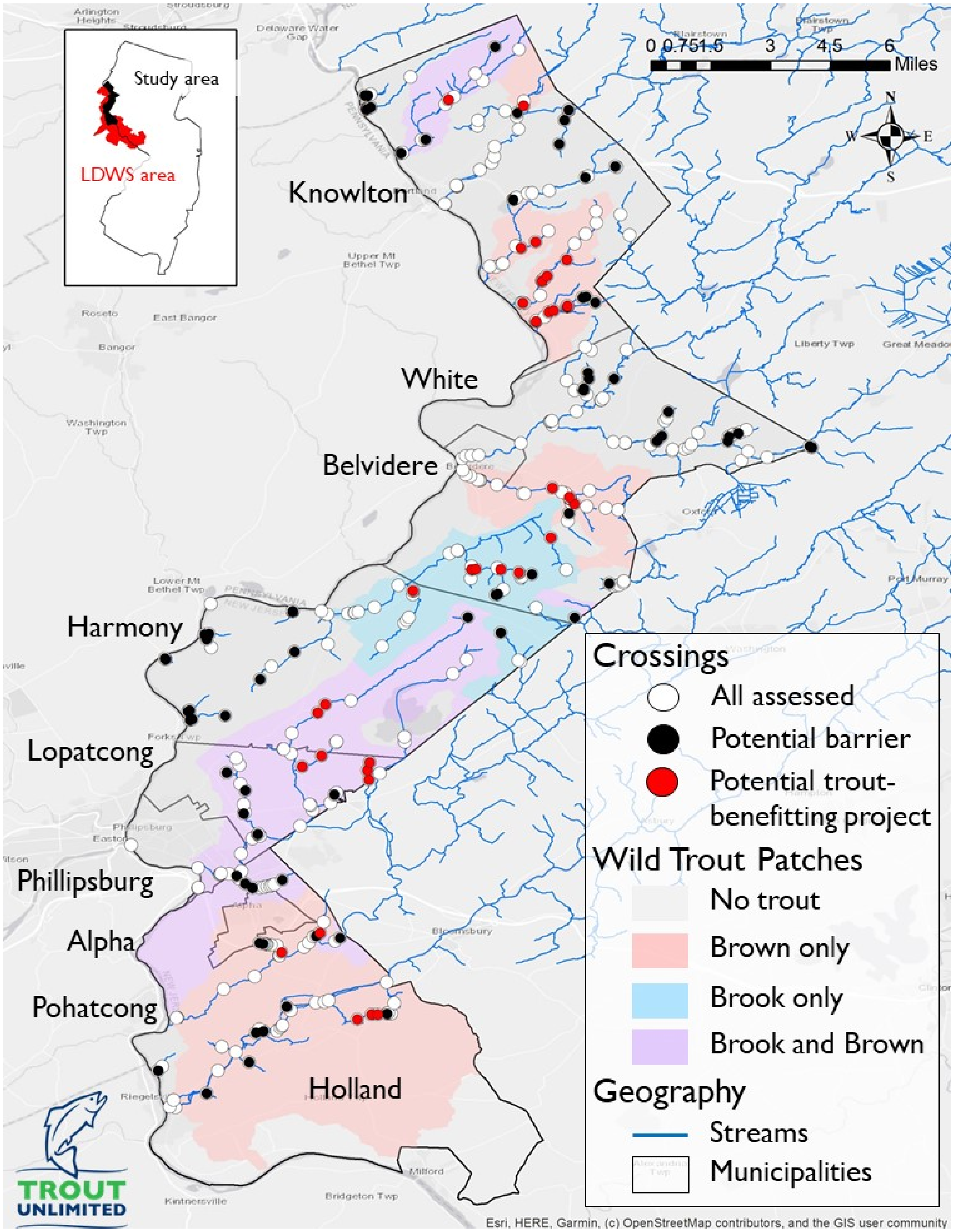


Figure 3. Computer-based assessments of fish passage at road-stream crossings identified 107 potential barriers to fish passage (black points) in 9 LDWS municipalities. 62 of these potential barriers were in wild trout waters, and TU staff's initial review identified 34 potential barriers to study further for their potential benefit to wild trout populations (red points).



TABLES

Table 1. Counts of Flatbrook, NJ road-stream crossings classified by field-estimated barrier severity and the number and percent of these crossings flagged as potential barriers using a LIDAR approach at two elevation drop thresholds.

NAACC Barrier Evaluation	Count	# (%) LIDAR-flagged as Potential Barrier at 1ft	# (%) LIDAR-flagged as Potential Barrier at 2ft
Insignificant	20	4 (20%)	1 (5%)
Minor	32	18 (56.3%)	4 (12.5%)
Moderate	14	9 (64.2%)	6 (42.9%)
Significant	3	3 (100%)	3 (100%)
Severe	7	7 (100%)	7 (100%)
All categories	*76*	*41 (53.9%)*	*21 (27.6%)*

Table 2. LIDAR-assessed crossings and their status in 9 LWDS municipalities

Municipality	Assessed Crossings	True Crossings	Potential Barriers	Potential Trout-Benefitting Projects
Alpha	1	1	1	0
Belvidere	10	7	0	0
Harmony	50	39	19	3
Holland	23	14	8	3
Knowlton	95	68	30	13
Lopatcong	29	26	10	5
Phillipsburg	8	8	0	0
Pohatcong	42	35	11	2
White	92	68	28	8

Table 3. Potential trout-benefitting projects in wild trout waters according to LIDAR assessment

Watershed	Municipality	Wild Trout Community	Potential Trout-Benefitting Projects
Buckhorn Creek	Harmony/White	Brook only	6
Delawanna Creek	Knowlton	Brown only	2
Knowlton Brook	Knowlton	Brown only	4
Lopatcong Creek*	Harmony/Lopatcong	Brook/Brown	4
Merrill Creek	Lopatcong	Brook/Brown	3
Pophandusing Brook*	White	Brown only	3
Pohatcong Creek Tributary	Pohatcong	Brown only	2
Scout Run (Musconetcong)	Holland	Brown only	3
Stony Brook	Knowlton	Brook/Brown	1
Unnamed Delaware R. Tributary	Knowlton	Brown only	5
Yards Creek	Knowlton	Brown only	1

*Managed as wild trout fisheries by NJDFW

Table 4. Rapid ecological benefit assessment of potential barriers in wild trout waters

Category	Ecologically Significant?	Barrier Count	Rationale
Land use	No	5	Catchment land use is prohibitive (e.g., 100% agriculture)
Other barriers	No	4	Crossing adjacent to other unrestorable barriers (e.g., highways)

High in headwater	No	19	Little functional habitat upstream
Mainstem	Yes	10	Barrier to movement in central watershed location
Near trib. mouth	Yes	10	Isolates complementary mainstem and tributary habitat
Brook trout refugia	Yes	14	In multi-species watersheds, barrier may maintain brook trout population isolated from brown trout; in brook trout-only watersheds, barrier removal may expand headwater climate refuge habitat for brook trout

Table 5. Estimated cost and time investment of each potential road-stream crossing assessment method and percent savings of each relative to traditional field-based assessments for all 350 crossings in the LDWS

Assessment Method	**Total Cost ($)**	**Cost Savings (%)**	**Total Time (hrs)**	**Time Savings (%)**
Field only (350 crossings)	28,000	0	233	0
LIDAR (350 crossings) + Field (107 potential barriers)	9,585	66	95	59
LIDAR (350 crossings) + Field (34 wild trout barriers)	3,745	87	46	80
LIDAR only (350 crossings)	1,025	96	23	90