Using Trail Cameras to Assess Recreation in Hellbender Streams of North Carolina National Forests

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Abstract: Each year the number of recreational visitors to southeastern national forests increases which brings new challenges for wildlife managers related to visitor activity and their potential effects of visitors on natural resources. This increasing visitation and recreation may affect species inhabiting streams if these habitats are modified by visitors. North Carolina includes some of the last stable populations of a fully aquatic salamander, the eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*). Few studies have assessed instream recreation (e.g., fishing, tubing, swimming) and related habitat alteration in watersheds known to contain protected aquatic species. From 2017–2018, we deployed trail cameras at local day-use access points within tributaries of the French Broad River, Pisgah National Forest, North Carolina (six stations across three streams) during potential high visitation holiday periods (Memorial Day, 4th of July, and Labor Day). In addition, we tracked habitat modification of streams within this watershed by enumerating any altered habitat (evidence of rock movement, dams, or cairns within 100 m of view of the camera stations). The highest number of recreational visitors per image across sites occurred during the 4th of July time period (average = 20.1, minimum = 1, maximum = 55). The most frequent recreational activity documented by percentage of observations across from trail cameras included visitors standing on banks (32.2%), wading (30.2%) and swimming (14.6%), followed by tubing (9.0%), taking photos (4.9%), and fishing (2.7%). The majority of observations in our study showed visitors recreating with little to no visible impact to resources. However, we found many instances ($n = 224$) of alteration of vital hellbender larval shelter (cobble habitat) and removal of rocks, and we documented evidence of repeated alteration of instream habitat in all stations including building of cairns and dams which can alter flow across all sites and years surveyed. Implementation of outreach programs could inform recreationists on the potential negative effects of rock moving, which may reduce alteration of instream habitat.

Key words: human use, forest management, aquatic conservation, salamanders, stream disturbance, Cryptobranchidae, neonate, public lands

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Public lands provide many opportunities for outdoor recreation and subsequently economic revenue for local communities (White et al. 2016). Recreational activities in many private and public areas, including national forests currently managed for multiple uses, are projected to expand as visitation increases (United States [U.S.] Forest Service National Visitor Use Monitoring Survey 2016). Visiting public lands to photograph wildlife and scenery, tour nature centers, and participate in aquatic recreation are among the fastest-growing, nature-based activities in the U.S. (Cordell 2008). However, there are potential negative effects of ever-increasing recreation on natural communities found on public lands (Larson et al. 2016). These effects include disturbing wildlife through increased physiological and reproductive stress, changes in animal behavior (Beale and Monaghan 2005, Naylor et al. 2009, Kangas et al. 2010), and direct effects on habitat including soil erosion and alteration of water quality (Marion et al. 2016). Moreover, many imperiled species in national forests are considered vulnerable to human-induced disturbance (George and Crooks 2006, Marzano and Dandy 2012). Water-based activities such as swimming or tubing, normally restricted to a limited number of small access points, has continually increased in popularity, particularly in national forest rivers (Flather and Cordell 1995, Bowker and Askew 2013, Cordell et al. 2013). This trend presents challenges to wildlife and resource managers, who must balance protection of species on public lands with recreational use and increasing visitation in parks and national forests (Cerveny and Ryan 2008). Therefore, obtaining baseline data to document recreational activities in national forests can potentially aid land managers to identify environmental impacts related to human resource use (Miller et al. 2017) and aid in conservation efforts.

Many amphibian species are declining throughout their geographic range due to a variety of reasons including habitat loss, climate change, emerging infectious diseases, illegal collection, or some combination of factors (Stuart et al. 2004, Whitfield et al. 2016). One such species, the eastern hellbender, *Cryptobranchus alleganiensis alleganiensis*, is a large, fully aquatic salamander that

occupies mountain regions throughout much of the southeastern, northeastern, and midwestern U.S. (Nickerson and Mays 1973). This salamander requires cobble for larval shelter and large boulders for adult shelter and nesting, where males guard nests for several months (Rossell et al. 2013, Hecht et al. 2019). The eastern hellbender is a species of conservation concern across its geographic range and has experienced precipitous declines and extirpations in many watersheds across its historical range (Mayasich et al. 2003, Wheeler et al. 2003, Pitt et al. 2017).

In North Carolina, where hellbenders are protected as a species of Special Concern, residents, visiting anglers, and stream recreationists frequently encounter this unusual salamander (Williams et al. 2019). Public lands including national forests represent some of the best remaining eastern hellbender populations and available habitat for these enigmatic salamanders, presumably due to dense forest canopy cover, low levels of impervious surface, and overall water quality (Freake and Deperno 2017, Jachowski and Hopkins 2018). While hellbender populations in some areas of the southeastern U.S. appear to be stable, they may be at risk for increased anthropogenic disturbance if shelter is altered (Unger et al. 2017). Negative effects of high levels of recreation disturbance have been implicated in affecting populations of a similar, fully aquatic species, the Chinese giant salamander (*Andrias davidianus*; Luo et al. 2018). Thus, watersheds in managed public lands with known eastern hellbender populations and intense recreational pressure present ideal locations to characterize human use of streams.

Trail cameras have been increasingly used to document wildlife presence; however, few studies have taken advantage of this affordable technology to assess visitor use in public lands (e.g., Fairfax et al. 2014, Lancaster et al. 2015). Areas where trail cameras are used to monitor human use include visitation to reefs (Wood et al. 2016), angler use of trout streams and reservoirs (Greenberg and Godin 2015, Hining and Rash 2016, Stahr and Knudson 2018), and visitation to urban forests (Arnberger 2006, Miller et al. 2017). This technology may provide land managers with a valuable tool to monitor overall visitation and, more importantly, resource use and documentation of recreational activities within public lands. The number of visitors and timing of visitation to national forests is an important metric for natural resource managers to track the potential impact those users can have on the environment (Morin et al. 1997). Holiday weekends may represent time periods in which stream habitats of national forests are heavily impacted by visitors performing a variety of recreational activities. Land managers can use trail camera image analysis to quantify overall patterns of instream recreation (e.g., swimming, fishing, tubing, boating) and concomitantly document instances of stream disturbance (e.g., moving or removal of rocks, building of dams, cairns) which can damage wildlife habitat.

In this study, we document the impact of recreational use of hellbender streams in Pisgah National Forest, North Carolina during 2017–2018 using trail cameras. We are unaware of any studies which have assessed the effects of recreation on rare stream-dwelling amphibians in the southeast within managed public lands, as most studies on the effects of recreation focus on either mammals or birds (Larson et al. 2016). Our objective was to document recreational activities of visitors during holiday periods while concomitantly documenting any incidences of instream habitat alteration that could be detrimental to eastern hellbenders. We also report on how these monitoring techniques can inform management strategies for streams and recreational areas on national forests.

Methods

Study Site and Background

We selected sites within the French Broad River watershed, Pisgah National Forest, in southwestern North Carolina. The U.S. Forest Service manages this area for multiple use including fishing, swimming, picnicking, hiking, mountain biking, camping, horseback riding, and sightseeing. Tributaries of the French Broad River located within the national forest contain stable populations of eastern hellbenders with documented recruitment including the presence of young and gilled larvae (L. Williams, North Carolina Wildlife Resources Commission, unpublished data). This area of the Blue Ridge Ecoregion also supports ample populations of both native and stocked trout (*Oncorhynchus* spp.) for recreational and subsistence fishing. The Pisgah National Forest has experienced a steady annual increase in recreational visitors (L. Stroup, U.S. Forest Service, Pisgah National Forest, personal communication), and is one of the top visitor locations in southwestern North Carolina (U.S. News 2019).

To quantify recreational use, we selected potential high visitation periods on the national forest, stratified across May, July, and September 2017–2018. We selected sites based on previous observations of highly utilized public access areas known to contain eastern hellbenders, and deployed cameras during summer holidays during 2017–2018. This time frame was chosen to increase the probability of detecting recreational activities during potential high use periods. We initially performed a pilot study in 2016, using a single trail camera at one location during the Labor Day holiday to test methodology, but do not include those results in our analysis. During 2017–2018 we selected Memorial Day, 4th of July, and Labor Day holidays to deploy cameras, as previous research on recreational use of water-based activities has documented increased usage on weekends during peak seasons of May–September (Sunger et al. 2012). These time frames also coincide with larval hellbender use of cobble and nesting periods of adults

(Nickerson and Mays 1973). All stream locations chosen contained eastern hellbenders, albeit at different relative abundances (L. Williams, NCWRC, unpublished data). Sites chosen for trail camera deployment within the French Broad River watershed included six locations in day-use recreation river access areas across three tributaries of the French Broad River (locations hereafter referred to as FB1, FB2, FB3, FB4, FB5, and FB6). Specific site details are not included due to potential for illegal collection but are on file with the North Carolina Wildlife Resources Commission. Sites had similar stream widths (mean =14.6): FB1 = 12.7 m, FB2 = 14.9 m, FB3 = 11.8 m, FB4 = 14.8 m, FB5 = 18.3 m, and FB6 = 15.2 m.

Camera Data Collection and Image Processing

We used Bushnell Trophy Cam HD Aggressor® trail cameras (Bushnell Outdoor Products, Overland Park, Kansas) to record observations of recreational visitors to streams within the national forest. We deployed cameras two days prior to the start of each holiday or holiday weekend and ran cameras through the duration with each deployment lasting exactly five days of each holiday period (or Thursday to Monday during each deployment period). We secured cameras to existing trees with lock boxes and cable locks and positioned cameras to allow adequate viewing of instream use, typically within 5 m of the stream access point or detection zone following Rowcliffe et al. (2011). Trail camera settings were as follows: Mode = camera, Image Size = 8 mb Image Format = full screen, Capture Number = one photo, LED Control = high, Mode Interval = one minute, Sensor Level = normal, Shutter = medium, Camera Mode = day, Mode Format = execute, Time Stamp = on, Field Scan = off. Camera images on 16-gigabyte secure digital cards were backed up following each deployment.

We quantified the number of instream visitors (recreationist) and recreational behavior using a protocol modified from Arnberger and Eder (2007), Lancaster et al. (2015), and Powers and Anson (2016). Specifically, all images recorded in each day were reviewed at approximately 5-minute intervals when available. We selected the clearest image with recreational activities and visitors in full view with minimal obstructions during this interval (hereafter referred to as an observation) to record and document all activities. We counted the total number of recreationists by enlarging and then enumerating each section of the image (top left, top right, bottom left, and bottom right) in Windows Photo Viewer. All visitors visible on a trail camera image were counted as a recreationist, with dogs noted and counted separately.

We characterized the type of recreational activities captured for the entire image as follows: 1) standing on stream bank, 2) wading, 3) swimming, 4) tubing, 5) fishing, 6) kayaking or canoeing, 7) playing with dogs (or letting dogs roam in the stream), and 8) actively moving rocks. This last category for moving rocks includes several activities such as building cairns (i.e., rock towers or sculptures), removing rocks from streams, or building dams to alter flow or create "kiddie pools." We confirmed rock moving by either close-up examination of visitors holding rocks aided by sequences of trail camera images taken before and after each rock moving observation. This protocol allowed for processing many images and characterization of visitor activities across locations, a more important metric of in-stream river use by recreationists. To inform our trail camera surveys, we noted the number of cairns, rock dams, and other structures within ~100 m observed in these same streams while deploying and retrieving cameras as well as during other hellbender population monitoring surveys.

Table 1. Number of trail camera images captured across all locations, holidays, and years.

Holiday	2017 image totals	2018 image totals
Memorial Day	1663	757
4th of July	2466	3939
Labor Day	518	1085
Totals	4647	5781

Data Analysis

We sorted data obtained from image-derived recreational activities by year, holiday, and location and calculated frequency of recreational activities within the cameras field of view. Then, we calculated the mean, minimum, and maximum number of visitors per image used for observation overall for each day, location, and time period. We primarily report summary statistics for observations of recreational activities in this study.

Results

We used 2211 (20.8% of total) images (observations) for data analysis ($n = 47$, 1149, and 1015 for 2016, 2017, and 2018, respectively) for all years, locations, and holidays (Table 1). We noted variation in the number of visitors across sites, with FB1 ($n = 55$) and FB4 (n = 47) having the maximum number of visitors captured per observation during the 4th of July time period. The average number of visitors per observation was also highest during the same sites and time periods (FB1 mean = 20.1, FB4 mean = 15.3). We noted similar numbers of visitors between 2017 and 2018 across camera locations (FB1–6) for average and maximum number of visitors per observation, with $\bar{X}$ of 6.5 ± 0.27 SE (max = 12.5) and 6.3 ± 0.35 SE (max = 10.7) visitors per observation, in 2017 and 2018, respectively. We noted a difference for number of visitors per observation across camera locations (Figure 1). We also

Table 2. Frequency of recreational activities for all camera locations showing totals, year, and holiday sample periods within survey locations at the French Broad watershed, Pisgah National Forest for 2017 and 2018.

	Standing on Bank	Wading in Stream	Tubing	Swimming	Photo	Moving Rocks	Fishing	Dogs in Stream	Kayak or Canoe	Total
Year										
2017	973	874	259	353	135	117	62	60	7	2840
2018	717	711	215	413	121	99	82	42	12	2412
Holiday										
Memorial Day	363	285	84	67	51	18	44	25	13	950
4th of July	1081	1047	322	588	164	164	68	57	6	3497
Labor Day	246	253	68	111	41	34	32	20	0	805
Grand Total										
2017–2018	1690	1585	474	766	256	216	144	102	19	5252

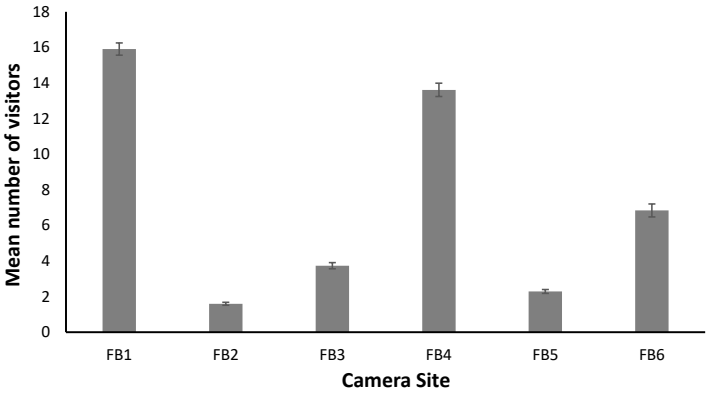

Figure 1. Mean number of observations across camera deployment sites FB1 to FB6 (error bars show ± 1 standard error) within the French Broad River watershed, Pisgah National Forest, North Carolina 2017–2018.

observed differences in number of visitors across holiday sample periods. The number of visitors in observations was highest during the middle of the sample period, with peak visitation occurring during the middle of the day, or between 1200 and 1600 hours.

The recreational activity with the highest frequency and percentage for 2017 and 2018 (total of 5252 recreational activities observed) was people standing on the bank ($n = 1690$, or 32.2%), followed by wading in streams (1585, or 30.2%), and swimming (766 or 14.6%; Table 2). Across all years, 9.0% of recreational visitors were tubing, with 4.9% taking photos, followed by 2.7% of total visitors fishing. Fishing was largely confined to FB5, FB2, and FB3. We also noted dogs in streams in 1.9% of observations and kayaks or canoes in 0.4% of observations across all years. Kayaking and canoeing as well as tubing were seen most frequently at FB5 and FB4, which are farther downstream with presumably higher flow than upstream locations. There was little variation in activities between 2017 and 2018, with slightly more recreational fishing in 2018. Recreational activity trends were also similar across the three holidays across years, with slightly less relative percentage of people wading or swimming. We noted more visitors fishing during the 4th of July time frame than Memorial Day and Labor Day (Table 2). We noted trail camera images from FB1 recorded a small number of images relative to other deployments during a prolonged rain event, but other than this occurrence all trail cameras functioned correctly during the study.

Evidence of rock stacking or fresh or remnant dams in stream channels were present for 85.5% of analyzed observations (Figures 2 and 3). We noted the highest frequency of rock moving during the 4th of July time period (164 instances), followed by Labor Day (42 instances) and Memorial Day (18 instances). FB1 images had the highest incidences of rock moving within a holiday period (62 in 2018 for FB1 and 44 for 2017) followed by 39 in FB4, all during the 4th of July holiday. In 2016 at FB3 during our pilot study processing 195 total images, we documented removal of several large bags and buckets of cobble (preferred hellbender larval areas) from the stream, and presumably to their vehicles, by two individuals during the Labor Day holiday in a span of 30 minutes. We noted alteration of instream habitat within 100 m of all camera locations, including different sized cairns composed of cobble, as well as moving of larger boulder sized rocks (potential adult hellbender shelter and nesting structures) in most locations.

Among the most striking evidence of stream alteration with the potential to impact hellbenders, we observed the highest incidence of rock stacking or cairn building each year at FB1, FB2, and FB3 with approximately four–five cairns present at any given holiday weekend period. At FB4 and FB3 we noted several instances of large (>8 m) and medium (<5 m) dam building, with one large

Figure 2. Examples of observations showing building of cairns at FB1 (A, B) in 2018, rock moving (C), and rock collecting and subsequent removal of several containers of cobble at FB3 (D) from stream in 2016, French Broad River watershed, Pisgah National Forest, North Carolina. All locations are occupied by eastern hellbenders (*Cryptobranchus alleganiensis alleganiensis*). Black boxes are used over visitors' faces to protect identity.

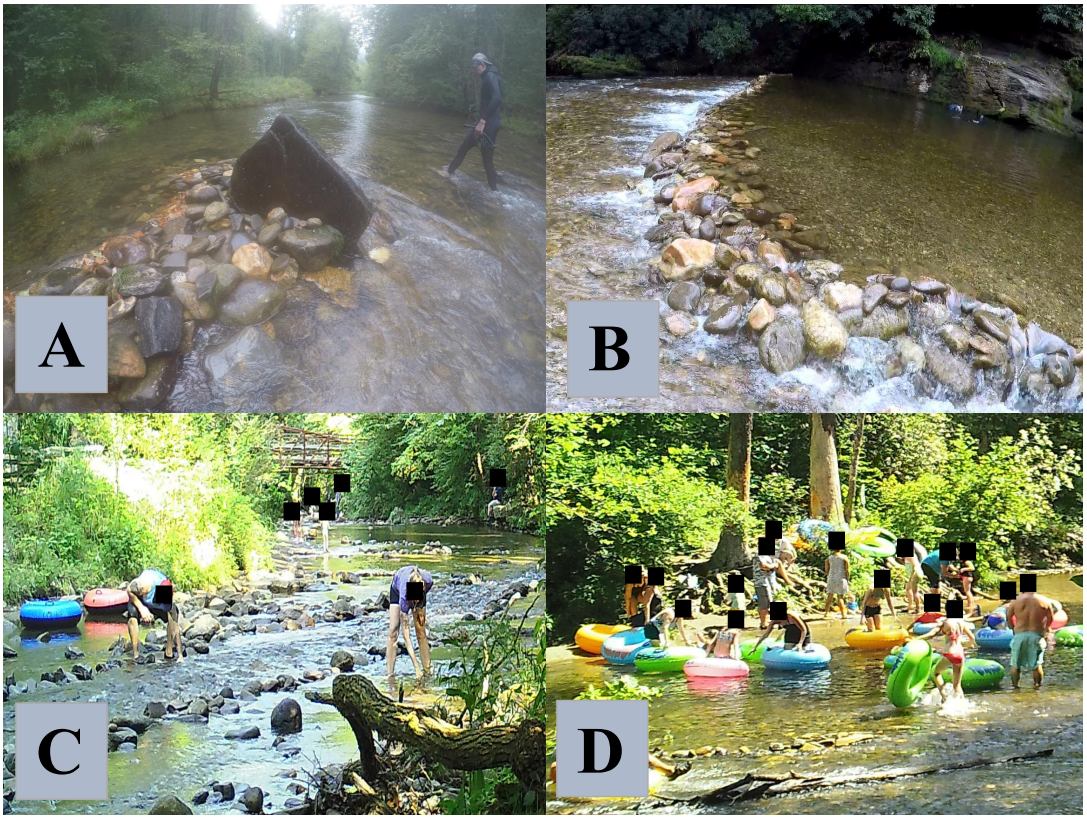

Figure 3. Examples of medium and large dam construction at FB3 (A) and FB4 (B) and inner-tube chute construction of FB6 (C) and FB4 (D) within the French Broad River watershed, Pisgah National Forest, North Carolina. All locations contain eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*) populations. Black boxes are used over visitors' faces to protect identity.

dam in FB4 spreading almost the entire width of the stream. In addition, FB3 and FB6 had tube chutes modified out of large stream cobble approximately 6 m in length to create a channel in each year of the study (Figure 3C, 3D). In every case where structures were torn down, they were rebuilt within two–three weeks, presumably by subsequent visitors.

Discussion

Trail cameras were a valuable tool in obtaining baseline data to document in-stream recreational use across waterways in a southeastern National Forest. We found support for our expectation that trail cameras would not only document recreational activities but also occurrences of stream alteration by visitors, as we documented 224 instances of habitat alteration in the form of moving, stacking, and removal of rocks. Most occurrences involved building cairns either in the stream or near the stream bank. Moreover, the total instances documented in our study area is an underestimate; on several occasions, while retrieving cameras or conducting other survey work, we noted rock moving activities in areas that were out of the field of view and therefore not captured in imagery. Therefore, to better estimate visitor impacts, we recommend trail cameras in combination with in situ surveys and posting signage to educate the public for more detailed studies on recreational use and resource impacts on public lands.

Previous research using time-lapse cameras has highlighted the importance of proper camera placement, image analysis, and how to calculate recreational effort from images (Greenberg and Godin 2015). We noted image processing was laborious in our study (taking several weeks for processing many images) and recommend researchers become familiar with trail camera use, deployment, and analysis options which align with research questions and goals. Future monitoring using trail cameras should also consider trail camera position with distance to recreational area to maximize photo image clarity and documentation of activity. We also noted some oversaturation in full sun areas in our streams, making some counts of individuals in a small number of images more difficult, which may be improved with proper deployment angle. However, placing trail cameras in full view with better deployment angles may lead to higher incidence of movement by recreational users or potential theft and damage. Moreover, recreational visitors may be uncomfortable with the presence of photographic equipment (Watson et al. 2015) and as a result change their behavior. However, posting signs or labels near cameras highlighting their use in monitoring environmental compliance and characterization of recreational activities may alleviate some of these concerns and warrants further study. On Memorial Day 2018, we also noted fewer overall images for FB1, possibly due to high humidity and moisture from a prolonged rain event, which may have interfered with the trigger mechanism, as most images that were photographed during this time frame appeared "cloudy."

Removal of cobble from the streambed in 2016 from FB3 was alarming, since larval hellbenders have been observed using rocks of that size, and nesting adults were present within the site. Recreational users who move rocks could be unknowingly violating additional federal regulations (CFR 261.9a) for resource damage or for removing rocks (CFR 261.9b) (Lorie Stroup, U.S. Forest Service, personal communication). Most detrimental in our observations of in stream habitat alteration include the large dam in FB4, and medium dam in FB3 which used larger boulders (potential nesting rocks) in the construction. During Labor Day weekend 2018, an extraordinarily high number of visitors were accessing streams on the national forest. When popular spots became too crowded or offered no vehicle parking, people moved to other, nearby stream access points. Often, in these less frequented stream reaches, recreationists proceeded to build dams and chutes in these "new" areas, too, thereby affecting more total habitat overall and/or introducing habitat disturbance in reaches less accustomed to that activity.

Recreational users of eastern hellbender streams in national forests engage in a wide assortment of aquatic activities, of which several could potentially be destructive to aquatic species' habitat given the number of visitors documented in our study. We expected to document a higher prevalence of fishing, but it is likely this activity is confined to other areas with fewer visitors for a better fishing experience and to decrease disturbance of fish. However, there are several day-use areas in other national forests and public lands throughout western North Carolina that we did not include in our study but where the authors have noted similar recreational impacts to habitat. The activities of rock moving, building dams, and creating cairns has the potential to increase in popularity, scope, and severity. It is possible social media may be fueling the visible increase in these harmful activities as we noted visitors taking pictures of themselves with cairns. Alternatively, rock moving activities may simply be correlated with the growing number of people recreating in mountain streams in general. Ultimately, the extent of rock moving across public access stream locations is currently unknown, however this activity warrants further study.

We caution interpretation of our results which show most visitors engaging in standard recreational activities such as wading and swimming, as we noted several instances of in-stream alteration. In addition, recreation during summer months and other seasons is ongoing, and rock stacking or dam building activities likely continue to have negative, cumulative effects throughout multiple seasons, including direct mortality of adult and larval hellbenders as we have observed (Unger et al. 2017). Alternatively,

our results may represent worst-case scenarios of rock moving and high visitation within streams because our study sites are extremely popular with recreationists, offer easy access points for people with varied physical abilities or small children, and are in relatively narrow stream channels where resource use and habitat impacts are exacerbated and concentrated. Additional studies assessing recreational use during less visited periods would provide a more detailed approach to visitor use across seasons. However, future studies could strategically place trail cameras at parking locations or stream entrances to characterize total number of daily visitors across a greater period of time.

Management Implications

Quantifying recreational use of eastern hellbender streams in a North Carolina national forest shows many daily visitors during warmer holiday periods. While most visitors were recreating by wading in streams, we caution that this seemingly innocuous activity may have direct effects on hellbenders because of large numbers of people stepping on or displacing rocks as they waded in concentrated areas. This study documented several instances of direct modification of habitat with elaborate dams and tube chutes. In some examples, people used large, flat boulders to construct dams; these boulders were known prior as hellbender nest rocks and were therefore rendered unsuitable for nesting, if not for shelter habitat in general. We observed that when dams were dismantled, they were often rebuilt within two–three days, indicating subsequent visitors frequently alter instream habitat and often in the same places repeatedly, intensifying negative effects.

We recommend wildlife and public land managers conduct outreach programs to educate the public about negative effects of rock lifting and rock removal in streams and the potential damage it can cause to fish and aquatic wildlife like eastern hellbenders and other aquatic species. We also recommend future monitoring of recreational activities by deploying interpretive signs at highly visited sites and possibly even station personnel at these locations so visitors can be informed on the conservation of this enigmatic salamander. Further, land managers should consider monitoring water quality including sedimentation, flow rate, stream substrate composition and quantity, and habitat use by target species before and after times of intense recreational activity at high-impact sites on public lands to understand more completely how recreational pressure affects natural resources.

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