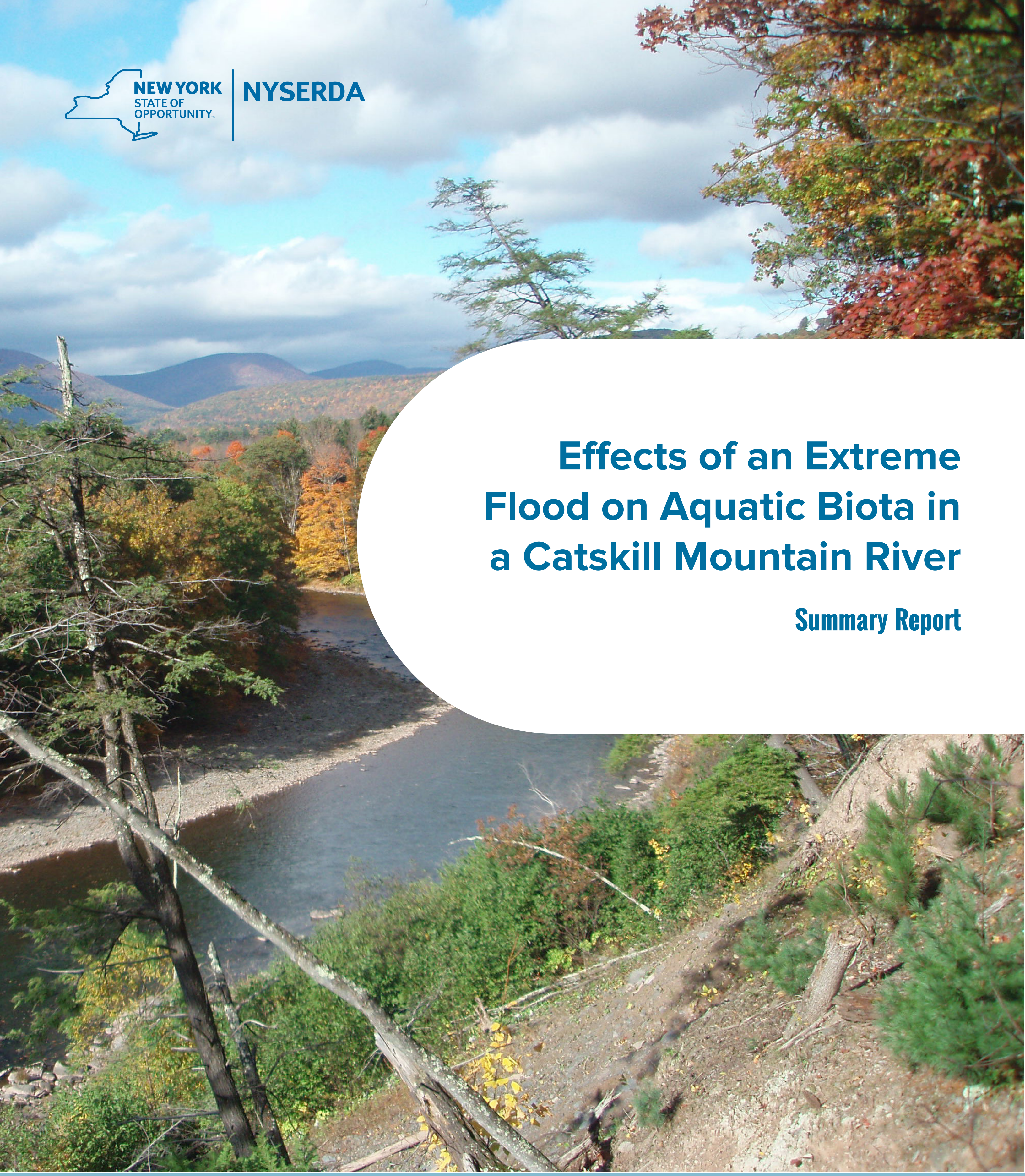

Effects of an Extreme Flood on Aquatic Biota in a Catskill Mountain River

Summary Report

March 2015

Report Number 15-08

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Cover photo: Big Bend Pool on the Upper Esopus Creek near Boiceville, NY.
Photo credit to Ed Ostapczuk.

Effects of an Extreme Flood on Aquatic Biota in a Catskill Mountain River

Summary Report

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NYSERDA Report 15-08 NYSERDA Contract 31846 March 2015

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Acknowledgements

This research was funded by grants from the NYSERDA Environmental Monitoring, Evaluation, and Protection Program under the direction of Greg Lampman; Cornell Cooperative Extension of Ulster County; New York State Department of Environmental Conservation; and the U.S. Geological Survey. Assistance with field sampling was provided by Walter Keller (retired) and Justin Zimmerman of the New York State Department of Environmental Conservation, Tyler Ross of Cornell University, Luis Rodriguez of the State University of New York at Albany, Noel Deyette of Paul Smith's College, and numerous student interns from Ulster County Community College. For more information on the response of fish communities, please see the full article in *Freshwater Biology.* The full citation for this paper is:

George, S. D., Baldigo, B. P., Smith, A. J. and Robinson, G. R. 2015, "Effects of extreme floods on trout populations and fish communities in a Catskill Mountain river." *Freshwater Biology* doi: 10.1111/fwb.12577

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1 Focus

This project investigated the response of fish and macroinvertebrate assemblages and the standing crop of periphyton (algae and other microorganisms) to a catastrophic flood in the Upper Esopus Creek in the Catskill Mountains of New York. The severity of the impacts, degree of recovery, and the landscape or hydrologic characteristics that may have afforded resistance or resilience to local assemblages were assessed. Factors that influence physical habitat, hydrology, ecosystem condition, and water quality in the Upper Esopus Creek are important because this system supports premier brown and rainbow trout fisheries and it channels approximately 40 percent of the New York City drinking water supply.

2 Context

Catastrophic floods can seriously affect in-stream and riparian habitats and associated aquatic assemblages in mountainous streams and rivers. Although stream fish, macroinvertebrate, and algal communities have evolved with dynamic geomorphological conditions and are relatively resilient to extreme hydrologic events, significant reductions in the density and biomass of these communities and shifts in community composition have been documented following severe floods. Because most climate change models predict an increased frequency of extreme hydrologic events over the next several decades, understanding how these communities respond to disturbances will be important for protecting lotic ecosystems.

3 Goals and Objectives

The primary objective of this project was to increase our understanding of the response and recovery of fish assemblages to extreme hydrologic events. A secondary goal was to assess the response of macroinvertebrate communities and the standing crop of periphyton to the extreme flood. Based on extensive changes to in-stream and riparian habitats and results from prior flood-impact studies, it was hypothesized that flooding on the Upper Esopus Creek would:

- Reduce fish community metrics basin-wide.
- Alter the composition of fish communities.
- Disproportionately affect early life stages and disrupt the age structure of trout populations.
- Affect fish assemblages proportional to the flood magnitude.
- Adversely affect macroinvertebrate communities and reduce periphyton standing crop.

4 Study Area and Methods

The Upper Esopus Creek, a popular trout-fishing and recreational stream located in the heart of the Catskill Mountains, received historic flooding from Tropical Storm Irene on August 28, 2011. Rainfall at Slide Mountain in the headwaters of the Esopus totaled 29.3 centimeters during Irene. Stream flows approached or surpassed the 0.01 annual exceedance probability (100-year) flood levels at several U.S. Geological Survey (USGS) streamgages in the watershed. In-stream and riparian habitats were severely altered at most study sites and emergency repair efforts by local municipalities and private landowners further affected several sites. The most frequently observed habitat alterations were loss of riparian vegetation, loss of canopy (greater sunlight exposure), and decreased channel complexity (Figures 1 and 2).

Figure 1. Confluence of the Upper Esopus Creek and the Shandaken Tunnel

In August, 2009 prior to Irene (left) and in September, 2011 less than one month after Irene (right).

Source: U.S. Geological Survey

Figure 2. Stony Clove Creek

In July, 2009 prior to Irene (left) and in July, 2012 following Irene (right) during a USGS fish survey.

Source: U.S. Geological Survey

Fish surveys were conducted annually by the USGS at 18 sites in the watershed from 2009 to 2011 as part of a prior investigation. Flooding from Tropical Storm Irene occurred immediately following completion of the 2011 surveys. Additional funding from the New York State Energy Research and Development Authority (NYSERDA), Cornell Cooperative Extension of Ulster County (CCE), and the USGS allowed for annual post-flood surveys to be continued at nine of these sites from 2012-2014 (Figure 3, Table 1). At five of these sites, the New York State Department of Environmental Conservation (NYSDEC) sampled macroinvertebrate communities and the USGS sampled periphyton standing crop on multiple occasions before and after the flood. Hydrologic data were produced by or estimated from USGS streamgages located at five of the nine sites.

Figure 3. Locations of study sites on the Upper Esopus Creek and tributaries and the biological assemblages that were surveyed

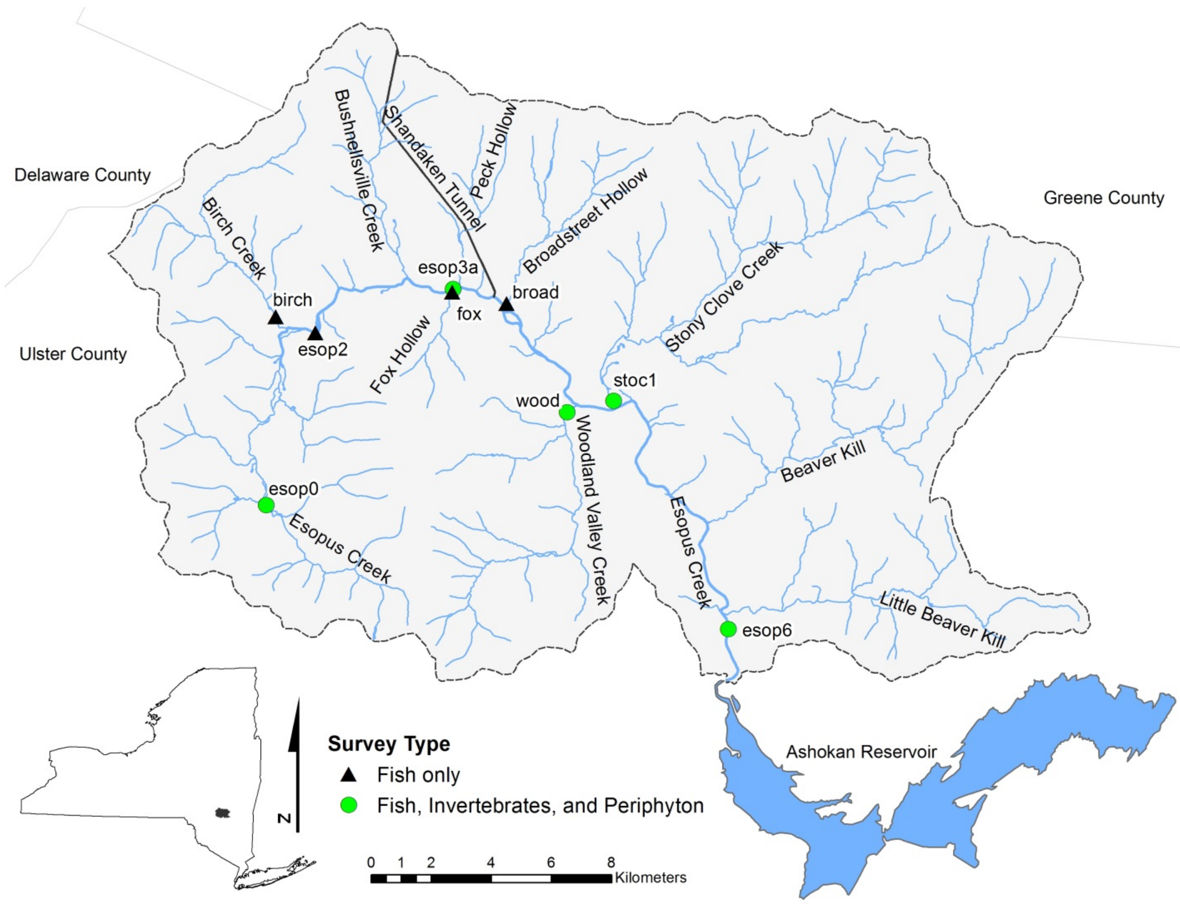


Table 1. Study site information and peak discharge for the flood that occurred on August 28, 2011 in the Upper Esopus Creek Basin

Stream and site name	Site ID	DA (km^2)	Elevation (m)	Peak discharge ($m^3 s^{-1}$)
Fox Hollow	fox	10.3	309.4	-
Broadstreet Hollow	broad	23.7	295.8	-
Birch Creek	birch	32.4	377.4	41.3
Woodland Valley Creek	wood	53.4	267.6	189.4
Stony Clove Creek	stoc1	83.9	245.2	404.9[1]
Esopus Creek at Oliverea	esop0	30.3	454.5	-
Esopus Creek at Big Indian	esop2	111.9	354.9	-
Esopus Creek at Allaben	esop3a	165.0	304.6	829.7
Esopus Creek at Boiceville	esop6	497.3	188.8	2146.4

[1] Data from a USGS streamgage located on Stony Clove Creek 3 km upstream of study site

At each site, fish were collected from a 50-100 meter reach with a backpack electrofisher using a three-pass depletion method. All fish were identified, weighed, measured, and subsequently released. Population estimates for each species and the entire community were calculated from the number of fish captured during each pass at each site. These values were divided by the total area sampled at each site to estimate density and biomass of fish populations or communities per unit area. At sites where other assemblages were sampled, macroinvertebrates were collected using standard kick samples and periphyton was collected using standard rock scrapes. Macroinvertebrates were identified to species and the data were analyzed using:

- The NYSDEC Biological Assessment Profile Score (BAP), which assesses the overall integrity of the community on a scale between 0 and 10.
- The percent of the sample material processed in the laboratory in order to find 100 organisms.

The second metric serves as a semi-quantitative measure of density in which higher values indicate fewer organisms were present and lower values indicate that more organisms were present. The standing crop of periphyton was determined using standard methods for determination of ash-free dry mass (the mass attributed to organic material that is lost when ashed at high temperatures).

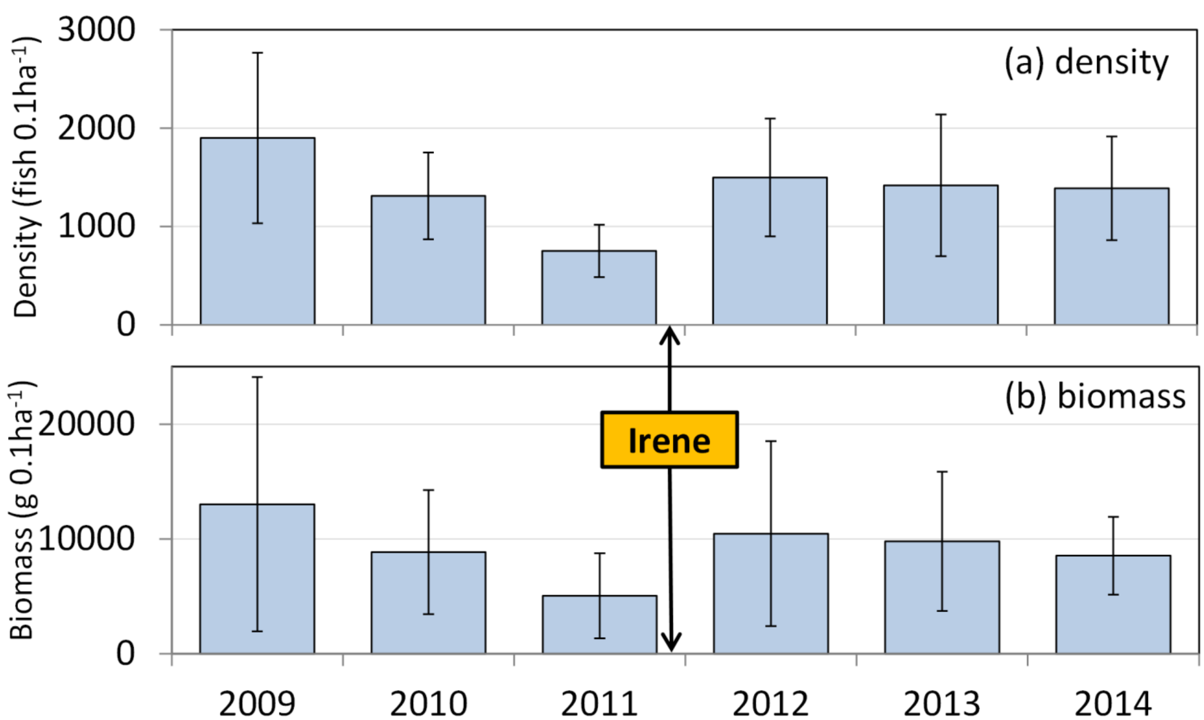
5 Project Findings

5.1 Density and biomass of fish communities

Comparisons of annual mean community density and biomass estimates from all sites show that both metrics declined during the three years preceding the flood before approximately doubling between the pre-flood and post-flood year (Figure 4). This unexpected result indicates that both the number of fish and the biomass in the community were greater 10-11 months after the flood than 1-2 months prior to the flood.

Figure 4. Mean (a) Density and (b) biomass of fish communities surveyed 2009-2014

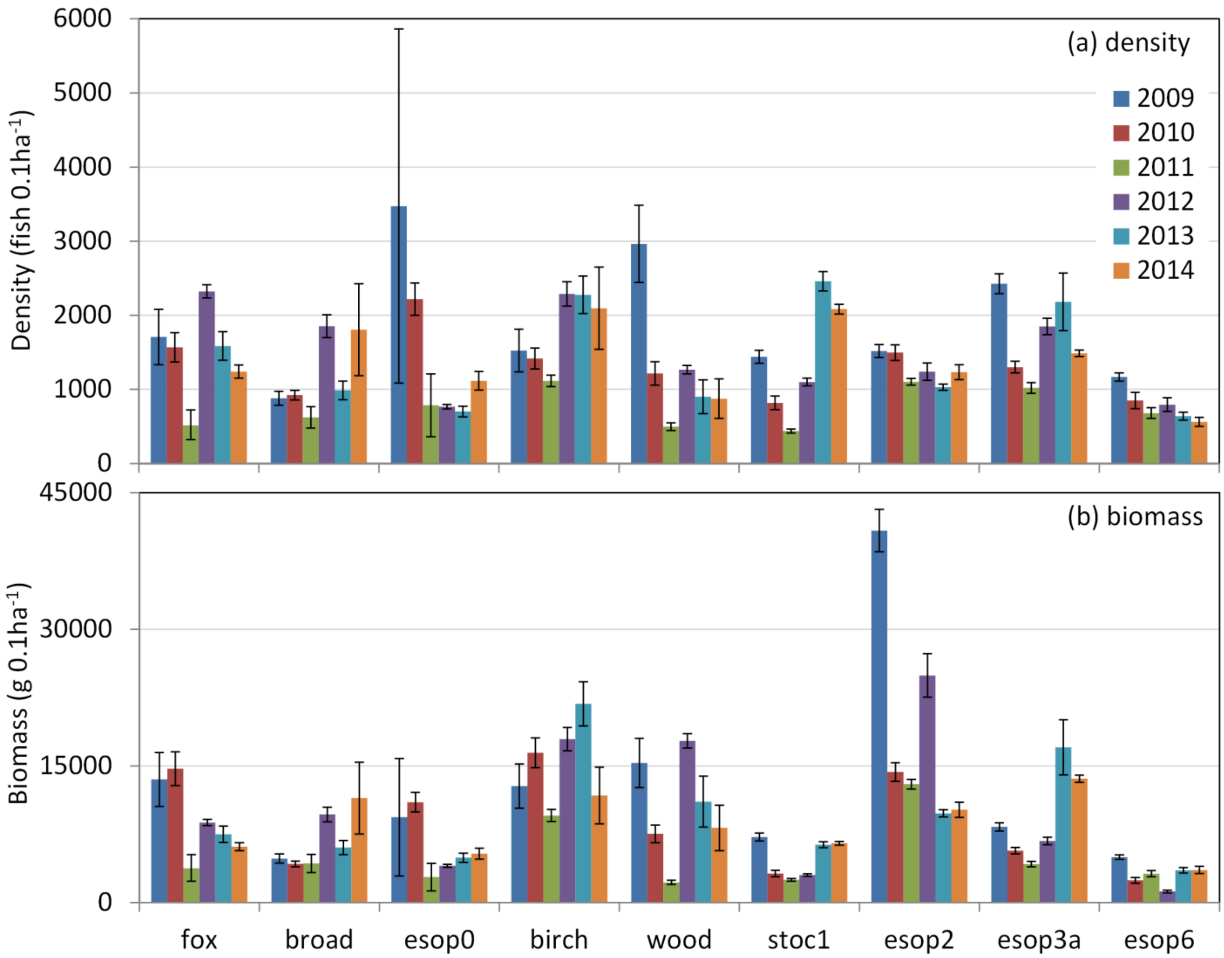
Error bars show one standard deviation about the mean.



Year-to-year differences in density and biomass of fish communities at individual sites (Figure 5) were frequently large and often followed the pattern shown by the aggregated analysis (Figure 4). It is noteworthy that during the first post-flood survey (2012), total fish density and biomass increased at eight of the nine sites from the pre-flood (2011) condition. Somewhat surprisingly, total fish density and biomass increased during both 2012 and 2013 at esop3a and stoc1, the two sites that were further disturbed by emergency in-stream repairs after the flood (Figures 1 and 2). There were no significant correlations between the level of fishery impact (changes in density and biomass of fish communities) and site elevation, drainage area, or flood magnitude.

Figure 5. (a) Density and (b) biomass of fish communities at each site for each year

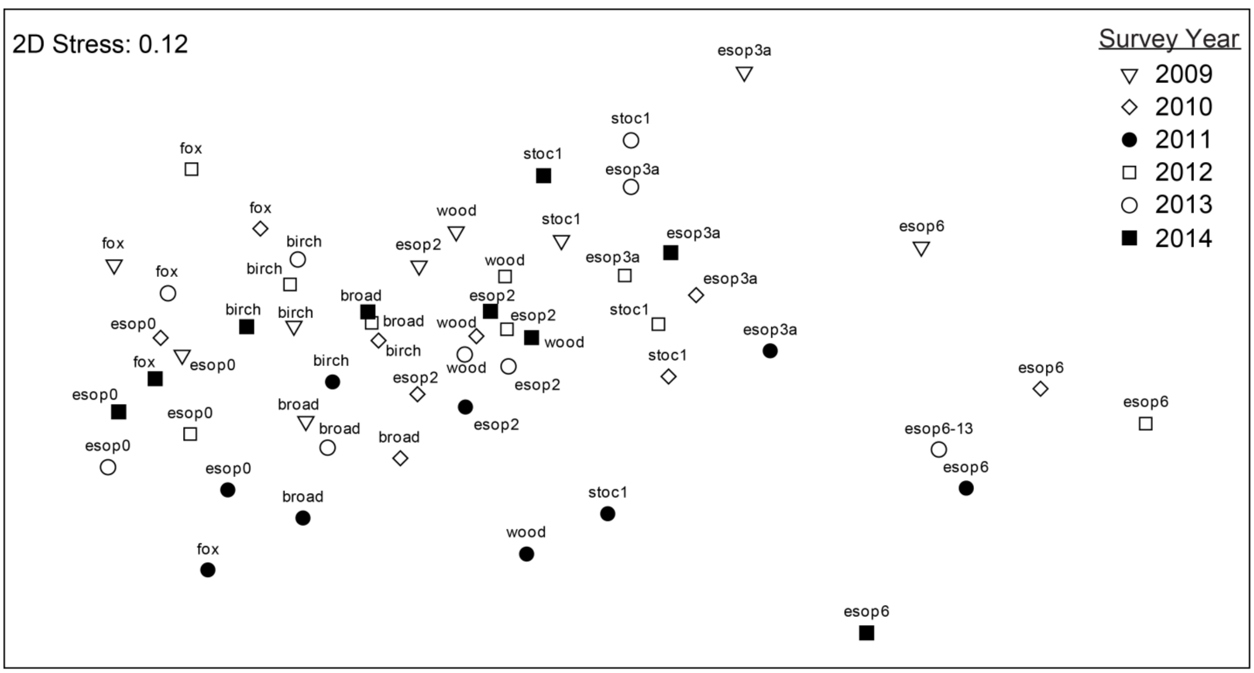
Sites are arranged by drainage area and error bars show 95% confidence intervals based on population estimates.



5.2 Composition of fish communities

Some studies have found that the composition of fish communities can change markedly following a disturbance. Multivariate analysis of fish communities in the Upper Esopus Creek, however, suggests that the severe, bed-mobilizing flood from Irene did not cause a large change in community composition. The wide dispersion of sites across both axes of the multidimensional scaling ordination (Figure 6) indicates fish assemblages differed considerably between sites, but not between pre-flood (2009-2011) and post-flood (2012-2013) surveys. Sites with small drainage areas and low species richness, such as fox and esop0, clustered to the left of the ordination, whereas, main stem sites with large drainage areas, such as esop3a and esop6, generally grouped to the right. Analysis of similarity (ANOSIM) confirmed that there were no significant differences between fish assemblages sampled in different years. Consistent with the above analyses, fish assemblages from the pre-flood surveys (2011; shown as solid black circles in Figure 6) were actually the most unique while assemblages from post-flood surveys appear more typical.

Figure 6. Non-metric multidimensional scaling ordination showing fish assemblages for each site during each year

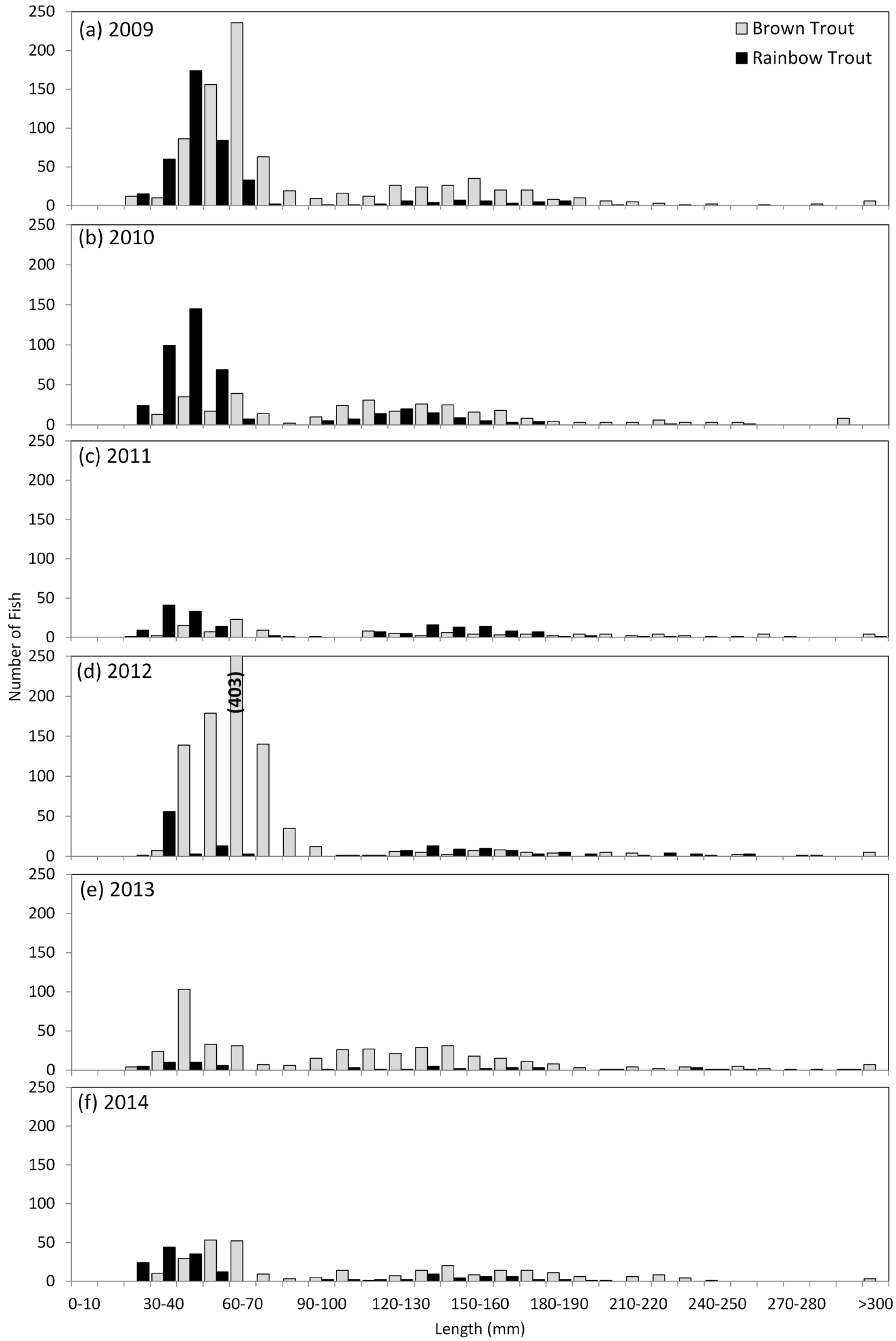


5.3 Trout populations

The effect of Irene on the density and biomass of brown and rainbow trout populations was evaluated because both species are ecologically significant and heavily sought-after sport fish. The density and biomass of brown trout populations generally followed the pattern exhibited by the overall fish community, decreasing between 2009-2011 before increasing sharply in 2012, and diverging in 2013 and 2014. Rainbow trout, in contrast, decreased in density and increased in biomass between 2009 and 2011. Following Irene, density remained low but biomass increased in 2012 before dropping markedly in 2013 and 2014. By 2014, rainbow trout were present at a mean density of only 37 fish $0.1ha^{-1}$ and a mean biomass of 316 g $0.1ha^{-1}$, the second lowest and lowest estimates for each metric respectively during the six-year study.

Prior research has shown that the early life stages of many fish species (e.g., young-of-the-year) are the most vulnerable during flooding. In this study, the abundance of young-of-the-year brown trout and rainbow trout declined between 2009 and 2011, and very weak 2011 year classes made it difficult to evaluate the effects of the flood on this cohort (Figure 7). The 2012 year class of brown trout (first post-flood cohort), however, was the largest observed during the study (mean density of 231 young-of-the-year $0.1ha^{-1}$). This suggests the mature brown trout that survived the flood and spawned in the fall of 2011 found favorable spawning conditions and (or) that their offspring experienced unusually high survival. In contrast, rainbow trout did not have a strong post-Irene year class in 2012 or during subsequent post-flood years. There were no meaningful correlations between the impact on trout populations and site elevation, drainage area, or flood magnitude.

Figure 7. Length frequency distributions of all brown trout and rainbow trout captured from nine study sites during 2009-2014

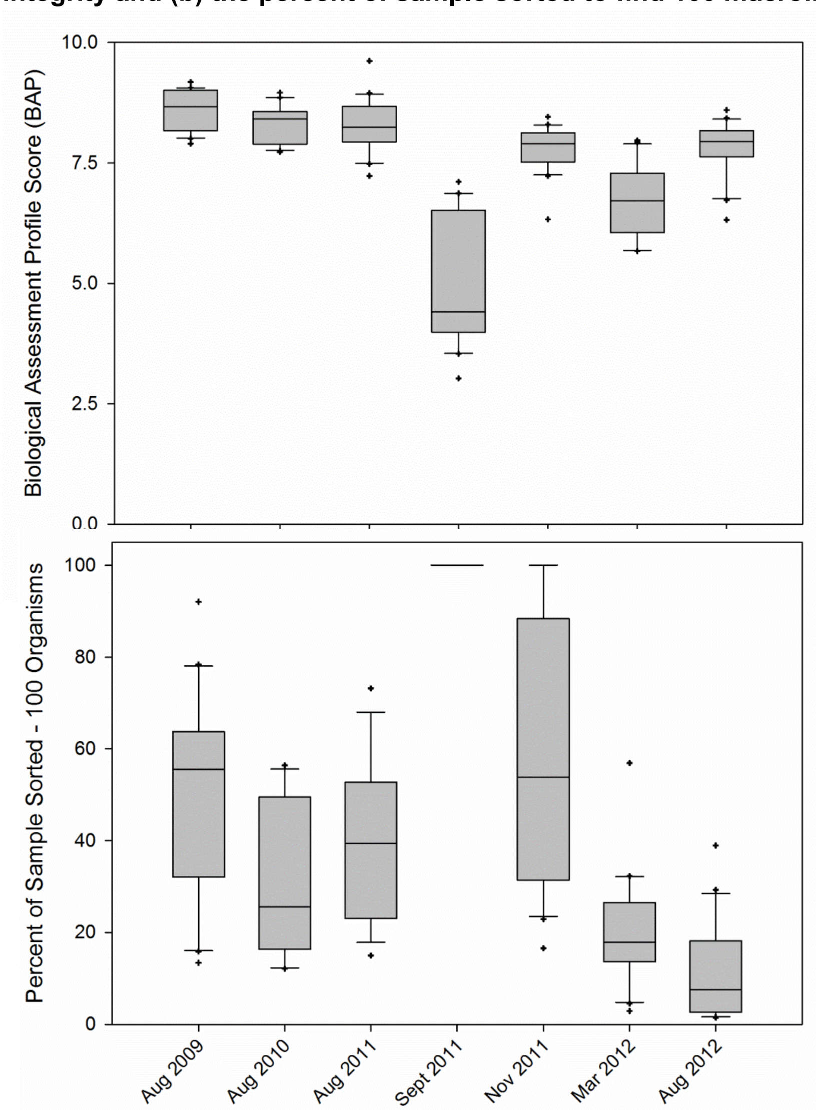


5.4 Macroinvertebrate communities

The response of macroinvertebrate communities to catastrophic flooding can vary tremendously and recovery can occur on the scale of weeks to years. During the three years prior to Irene, BAP score was consistently high and percent of sample sorted was consistently low on the Esopus (Figure 8), which suggested the integrity and density of macroinvertebrate communities were high.

The September 2011 samples, collected 17 days after Irene, showed that both metrics were significantly reduced. Each recovered quickly, however, and one year after the flood (August 2012) BAP scores were almost fully recovered and the density of macroinvertebrates was actually higher than that of the pre-flood condition.

Figure 8. (a) Biological Assessment Profile Score (BAP) for macroinvertebrate community integrity and (b) the percent of sample sorted to find 100 macroinvertebrates

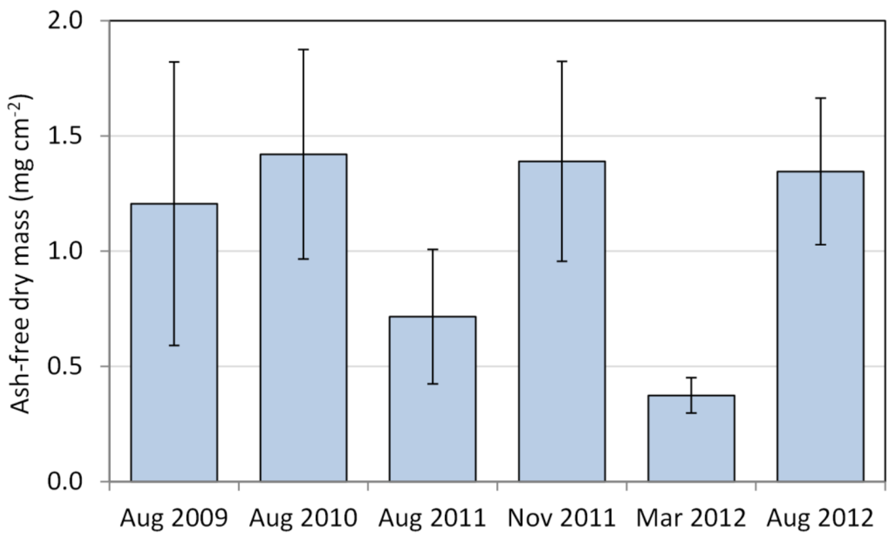


5.5 Periphyton standing crop

Many studies have shown that bed-mobilizing floods greatly reduce the standing crop of periphyton. This community is highly resilient, however, and often is able to recover from hydrologic disturbances in one month or less. Our results indicate that mean periphyton biomass was higher approximately two months after the flood than it was one week prior to the flood (Figure 9). Thus, any reduction in standing crop that may have occurred during Irene was brief. The low standing crop in March likely reflects seasonal patterns of periphyton growth and the high values observed during August 2012 appear consistent with the 2009 and 2010 samples.

Figure 9. Mean ash-free dry mass of periphyton sampled from five study sites

Error bars show one standard deviation about the mean.



5.6 Project implications

The findings of this study have a number of important implications for assessing and managing natural resources in the Upper Esopus Creek and other streams of the region and provide direction for future research. First and most notably, the results indicate that the density, biomass, and composition of fish communities were not adversely affected by the flood, suggesting that fish communities are highly resistant or resilient to the effects of extreme summer floods. It appears that the timing and nature of extreme hydrologic events are more important to the impact on stream fish assemblages than their sheer magnitude. For example, the low values for many community metrics in 2011 suggest that factors prior to Irene actually depressed fish communities before the flood impacted the region. Specifically, three coldwater floods affected the basin between October 2010 and April 2011, and a long period of low flows and warm stream temperatures occurred during late summer of 2010. These prior floods coincided with trout reproduction and the drought conditions likely caused a decrease in the quantity and quality of habitat available to all fish and together may be responsible for the atypical 2011 fish community. In contrast, the severe flooding from Irene occurred in the late summer, a period when little fish spawning occurs and the young-of-the-year of most species have advanced beyond their most vulnerable stage.

Second, the enormous 2012 year class of brown trout (spawned in the fall of 2011 immediately following Irene) suggests that post-flood conditions were advantageous for recruitment of this species. Third, our findings provide evidence that rainbow trout populations are declining across the basin, which is consistent with prior research and anecdotal observations. It is unclear if Irene is responsible for the three poor year classes of rainbow trout after Irene (2012-2014), but the sharp decline of this species prior to Irene suggests other factors also contributed. Fourth, the response of fish assemblages at sites subjected to emergency mechanical repairs was similar to that of most other sites. Although in-stream repair efforts had to be disruptive, fish metrics at these sites did not indicate an adverse effect 10-11 months later. Fifth, macroinvertebrate communities were severely affected immediately following the flood but experienced nearly a full recovery in one year while the standing crop of periphyton, if affected at all, recovered too quickly for an impact to be detected. Finally, these findings underscore the value of long-term monitoring programs. A complete interpretation of the flood impacts, provided herein, was only possible because three consecutive years of baseline data were available prior to the flood.

6 Conclusions

Most basin-wide analyses suggest that the flooding from Tropical Storm Irene did not have an adverse effect on the overall fish community by 2012 and beyond. When the three biological assemblages were considered, most metrics were higher in 2012 (10-11 months after the flood) than in 2011 (1-2 months prior to the flood). Extended low-flow (drought) conditions or cold-weather floods prior to Irene appeared to be more disruptive to local assemblages than the late summer flood.

These findings indicate that fish, macroinvertebrate, and periphyton communities in the Upper Esopus Creek, and likely other mountainous watersheds of the Northeast, are highly resistant or resilient to extreme, late-summer floods. A better understanding of the effects of extended droughts, warmer water temperatures, and changes in the timing and frequency of flood events, however, is needed to protect and manage aquatic ecosystems as climatic conditions continue to change in the region.

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