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MACROINVERTEBRATES, WATERSHED IMPERVIOUSNESS, AND A WATER QUALITY INDEX: A CONFLUENCE OF GEORGIA ADOPT-A-STREAM'S VOLUNTEER DATA

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ABSTRACT

The relationship between a stream's macroinvertebrate community as quantified by Georgia Adopt-A-Stream's Water Quality Index and the impervious surface of an adopted stream's watershed was weak. Although the average WQI decreased with increasing watershed imperviousness, the R^2 was only 8.3%--an admittedly poor fit. To further investigate, a more comprehensive analysis was performed using forward stepwise regression. This model, which included both imperviousness and the abundance of just 15 out of the 20 kinds of macroinvertebrates, achieved an R^2 of 59.4%. Imperviousness alone may not be a good predictor of WQI, but a combination of selected macroinvertebrate data and imperviousness can yield a better fitting model. Furthermore, mayflies, aquatic sowbugs, clams/mussels, midges, and lunged snails, all of which were excluded from the model because they did not have a significant predictive value for WQI, generally seem to have specific habitat requirements which are dictated by stream-reach, rather than whole watershed characteristics.

Keywords: Georgia Adopt-A-Stream, watersheds, macroinvertebrates, water quality index, volunteer stream monitoring, imperviousness

INTRODUCTION

Impervious surfaces are generally regarded as bad for the water quality of streams, and in fact, there have been studies that have suggested that there is a strong negative effect of imperviousness upon macroinvertebrate communities (Kodani 2018). It would seem, then, that an index which is used to evaluate a stream's health based upon macroinvertebrates such as Georgia Adopt-A-Stream's Water Quality Index (WQI), should be negatively affected by the imperviousness within a watershed. Unfortunately, most published studies of imperviousness and macroinvertebrate communities have been limited by small sample size, limited geographic scope, and low levels of replication. Most of these studies are limited simply because it is difficult for one scientist to monitor more than a small handful of streams for any length of time. In Kentucky, Alberts et al. (2018) performed a wonderfully detailed comparison of urban and forested watersheds, but on only 8 streams for just one year. In the state of Georgia, Helms et al. (2009) were able to conduct an extremely thorough study of numerous factors affecting the macroinvertebrates of 18 watersheds for 24 months. In some regions of Georgia, there are relatively few published studies of factors known to be important to the function of streams, such as woody debris (Pitt and Bazter 2011). Fortunately, Georgia Adopt-A-

Stream provides a way for volunteers across the southeastern United States to be trained to collect reliable data from numerous watersheds (Safford and Peters 2017), that are safely deposited into a database for later use, which can then can be shared with the public, government agencies, and scientists. In this analysis, I will examine the relationship between a stream's macroinvertebrate community as reflected by its Water Quality Index, and the imperviousness of its surrounding watershed using data collected by the volunteers of Georgia Adopt-A-Stream.

MATERIALS & METHODS

Quality Assurance/Quality Control (QA/QC) certified volunteer stream monitors collected the macroinvertebrate data used in this analysis according to standardized protocols (Georgia Adopt-A-Stream 2006, 2015). Federally recognized volunteer programs are required to submit a QA/QC plan for training volunteers and ensuring the reliability of the data that their volunteers collect (United States Environmental Protection Agency 1996). In order to maintain Georgia Adopt-A-Stream certification, volunteers must: attend a workshop, show that they can correctly collect a macroinvertebrate sample, identify at least 20 macroinvertebrates with 90% correct, calculate the Water Quality Index correctly, pass a written exam with a score of at least 80%, and recertify annually (Georgia Adopt-A-Stream 2015). Adopt-A-Stream professional staff provided those data, in Excel spreadsheet form (Harbert and Hitchcock 2011, Georgia Adopt-A-Stream 2020). Information such as date of monitoring events, latitude and longitude of site was included. The abundance of individual macroinvertebrate taxa was provided as one of four levels: none (not found), rare (1-9), common (10-99), or dominant (100+). The Water Quality Index (WQI) for each monitoring event was also available from the database, and was calculated by assigning 3 points to pollution-sensitive taxa, 2 points to moderately tolerant taxa, and 1 point to tolerant taxa. Watersheds for each adopted monitoring site (see Appendix, Table V) were delineated and analyzed using ArcGIS Pro 2.5.1 (ESRI 2020). Of the 168 sites, 6 were analyzed in previously published work (Kodani 2018), whereas the data for the other 162 were reported by other Adopt-A-Stream volunteer monitors. Imperviousness was calculated using the National Land Cover Database (2020) layers—2001, 2006, 2011, and 2016 were available. In order to account for any changes in impervious surfaces within the monitored watersheds, only the macroinvertebrate data from these 4 years were selected. Minitab 19.2020.1 was used for statistical analysis. One-factor ANOVA was used to test for differences in average Water Quality Index (WQI) between years. Because seasonality affects macroinvertebrates, month was used as a predictor in the regression model along with imperviousness, with WQI as the response. When a more detailed model was desired, Minitab's general regression model was used to perform a forward stepwise regression with WQI as the response variable, the abundance of each macroinvertebrate as a categorical predictor with 4 levels (none, rare, common, and dominant), and percent impervious surface as a covariate.

RESULTS

Volunteers reported WQI values for 498 monitoring events, ranging from a high of 42 in 2016, to the low of 1 occurring in 2006, 2011, and 2016. The mean WQI in the four years was highest at 16.1 in 2001 (N=23), then steadily decreased over the next 15 years to 14.3 in 2006 (N=107), 13.4 in 2011 (N=150), and finally 12.4 in 2016 (N=218). Analysis of variance showed that over this period, mean WQI differed significantly between years (Table 1, p = 0.024).

Table I. Analysis of Variance for Water Quality Index vs Time.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Year	3	454.3	151.42	3.17	0.024
Error	494	23579.3	47.73		
Total	497	24033.6			

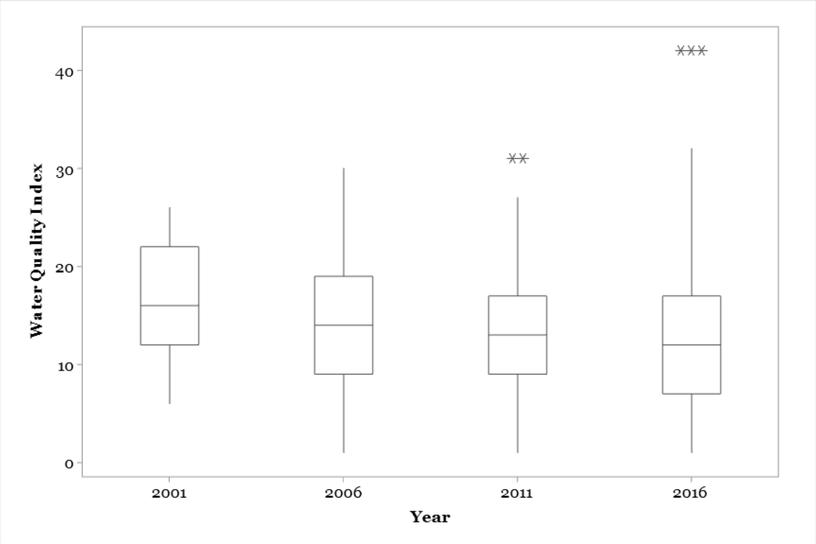

Figure 1. Water Quality Index over Time. Lines represent ranges, boxes represent interquartile ranges, and asterisks represent potential outliers. WQI differed significantly between years (p = 0.024).

The average imperviousness of the sampled watersheds did not differ significantly between years (p = 0.260). In any given year, volunteers could choose any stream to monitor. Average imperviousness ranged from 12.2% in 2006 to 15.0% in 2011.

Table II. Analysis of Variance for Imperviousness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Year	3	645.5	215.2	1.34	0.260
Error	494	79160.1	160.2		
Total	497	79805.6			

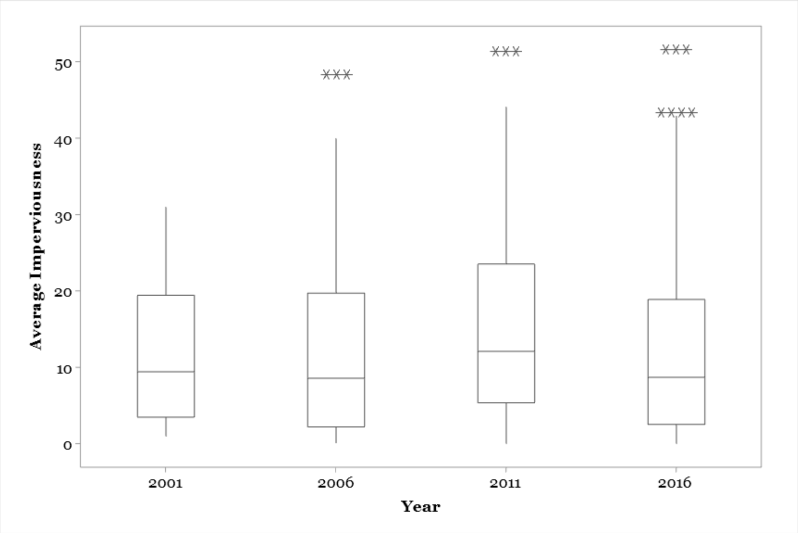

Figure 2. Average imperviousness of adopted watersheds over time. There was no significant difference between years.

Linear regression between Water Quality Index and Imperviousness revealed a significant relationship between the two variables (Table II, $p < 0.000$), but the fit was not very good (R^2 = 8.3%, Figure 3), and the linear equation was WQI = 15.40 – 0.1582 Imperviousness. Three observations were found to be outliers and all three had WQI = 42, but excluding them only changed the coefficient of determination to R^2 = 8.8%. Multiple regression using month and impervious as predictors for WQI yielded an R^2 only slightly better at 9.8% and the quadratic equation of WQI = 15.919 – 0.2993 Imperviousness + 0.0035 Imperviosness^2. Month was not a significant factor. Watershed area was not related to WQI (R^2 = 3.6%) or Imperviousness (R^2 = 1.7%).

Table III. Analysis of Variance for Water Quality Index vs Imperviousness

Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	1	1997.5	1997.46	44.96	0.000
Error	496	22036.1	44.43		
Total	497	24033.6			

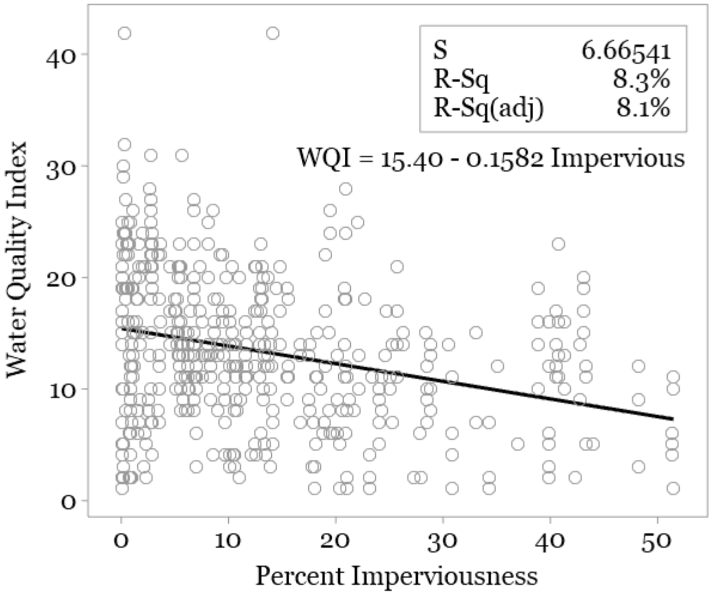

Figure 3. Water Quality Index vs Percent Imperviousness. The regression was significant ($p < 0.000$).

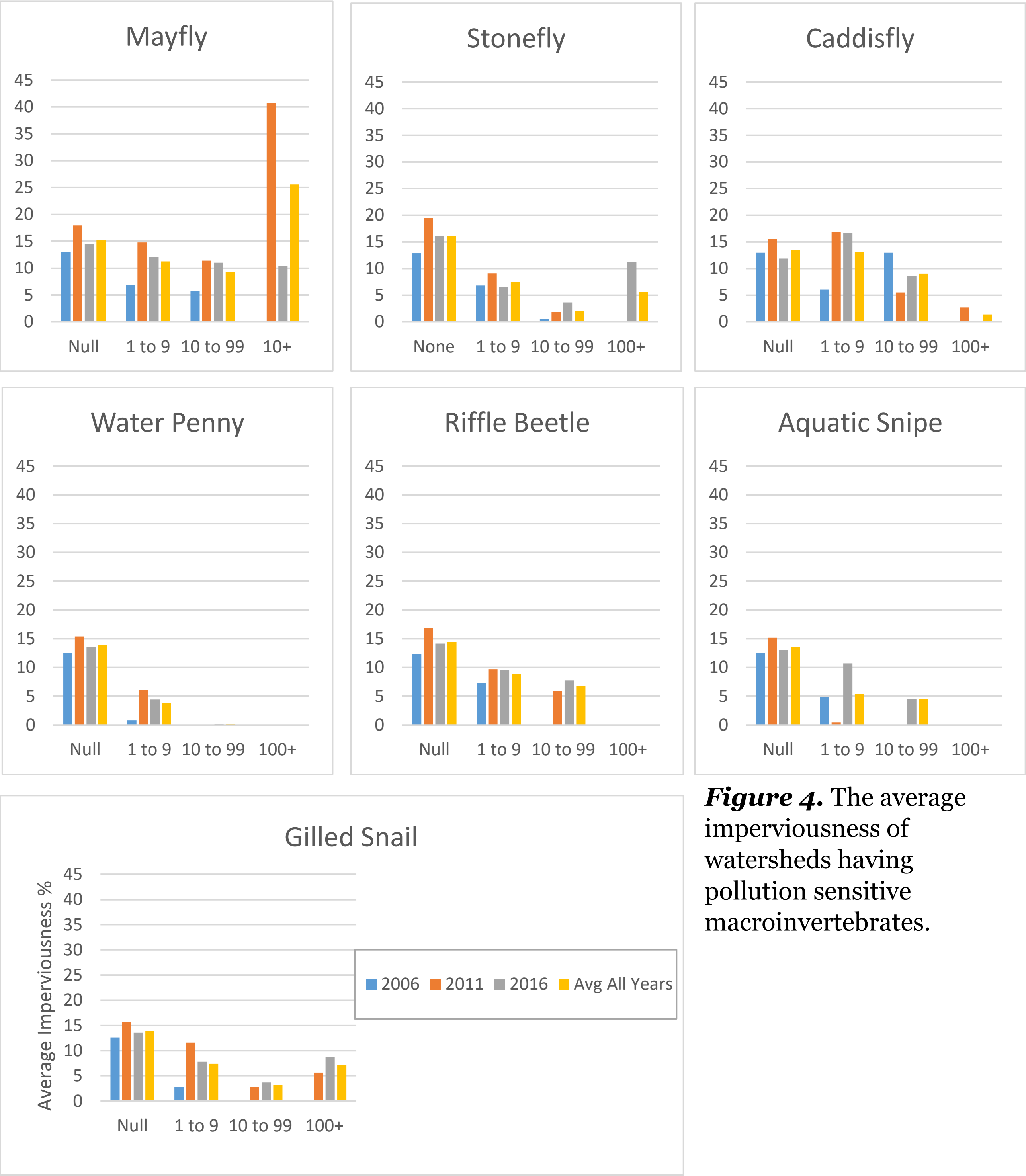

Figure 4. The average imperviousness of watersheds having pollution sensitive macroinvertebrates.

Figure 5. The average imperviousness of watersheds having somewhat sensitive macroinvertebrates.

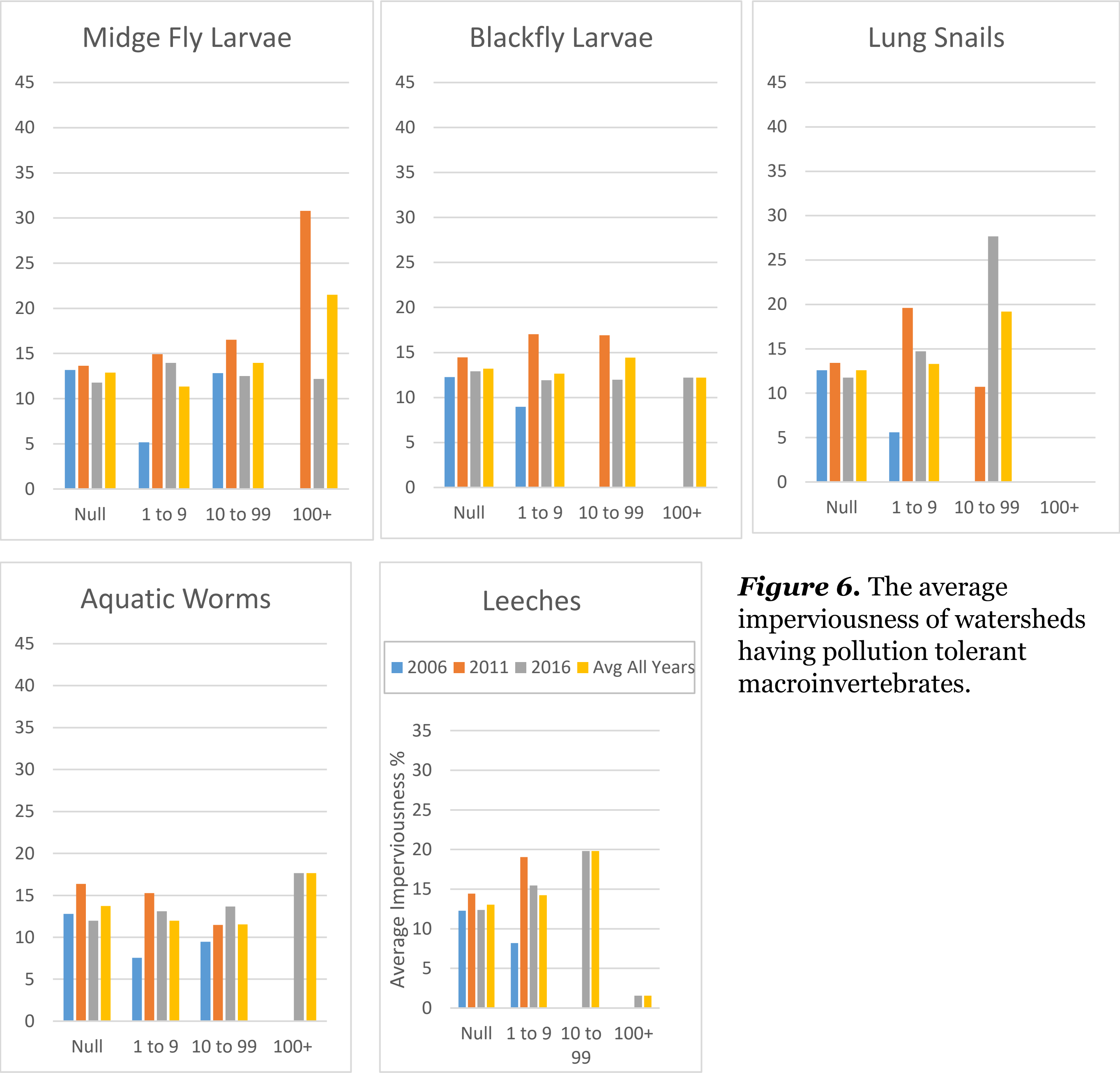

Figure 6. The average imperviousness of watersheds having pollution tolerant macroinvertebrates.

Table IV. Forward stepwise regression. The alpha to enter was 0.25. R^2 was 59%.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Imperviousness	1	729.7	729.72	33.48	0.000
Caddisflies	3	961.2	320.4	14.70	0.000
RiffleBeetleLarvae	2	494.8	247.4	11.35	0.000
Crayfish	3	311.6	103.9	4.77	0.003
StoneflyNymphs	3	314.7	104.9	4.81	0.003
AquaticWorms	3	298.5	99.51	4.57	0.004
ComNetSpinningCaddisflies	3	231.9	77.29	3.55	0.015
Scud	3	226.1	75.36	3.46	0.016
GilledSnails	3	218.3	72.75	3.34	0.019
CraneFlies	3	205.3	68.43	3.14	0.025
DragonflyDamselflyNymphs	3	160.6	53.54	2.46	0.062
WaterPennyLarvae	3	146.2	48.75	2.24	0.083
BlackFlyLarvae	3	119.2	39.72	1.82	0.142
AquaticSnipeFlies	3	118.7	39.55	1.81	0.144
Leeches	3	115	38.35	1.76	0.154
DobsonflyHellgrammitesFishfly	3	104.9	34.97	1.60	0.188
Error	429	9349.5	21.79		
Lack-of-Fit	382	8511.9	22.28	1.25	0.175
Pure Error	47	837.6	17.82		
Total	474	23013.2			

Both forward stepwise regression and several single-factor ANOVAs were performed, but here I present stepwise regression rather than individual ANOVAs for two good reasons. First, including all of the taxa in a single test would avoid the potential pitfall of the addition of errors that results from doing several individual tests (Minitab 2011). Secondly, by performing a single test, the F-value and P-value are easier to compare to each other because they were calculated using the same error term. The regression model consisted of WQI as the response variable, the continuous variable imperviousness was included as a covariate, and the different taxa of macroinvertebrates as the categorical predictors, each potentially having a level of none, rare, common, or dominant. An alpha = 0.25 was used as the criterion for entry into the model. Of the 20 different taxa of macroinvertebrates analyzed, only 15 were found to significantly affect the model. The 5 taxa excluded from the model because their p value was higher than 0.25 were: mayflies, aquatic sowbugs, clams/mussels, midges, and lunged snails. F-values for the included macroinvertebrates ranged from a low of 1.60 ($p=0.188$) for Dobson flies/Hellgrammites/Fishflies, to a high of $F = 14.70$ ($p < 0.001$) for stoneflies. Imperviousness, the covariate, achieved the highest $F = 33.48$ ($p < 0.001$). Overall, this model achieved an R^2 of 59%.

DISCUSSION

Despite the fact that impervious surfaces are often thought of as a convenient proxy for factors that degrade water quality, the data as presented in Figure 3, do not show a simple correlation between the imperviousness of a watershed and the water quality index (WQI) of its resident macroinvertebrate community. This is interesting, because we know that impervious surfaces come with a list of things that are typically associated with urbanization such as erosion, loss of tree canopy, higher water temperatures, excessive nutrients and pollutants from sewage and runoff, and unstable water flows. All of these are known to be bad for macroinvertebrates, and although WQI decreases with increasing imperviousness, the R^2 value of 8.3% leaves a very poor correlation indeed, which in light of the strong relationship between WQI and imperviousness from Kodani (2018), is somewhat disappointing. A study (Helms et al. 2009) in southwestern Georgia found that among biotic indices, the Shannon Index, which they consider to be a whole community index, was less correlated to watershed factors than other indices, such as a composite index like GA-BMI and taxa richness. Like the Shannon Index, WQI is also an index which reflects the diversity of the macroinvertebrate community, and so it might not be the best fit for imperviousness.

Given that most of the variation in a stream community's Water Quality Index is only poorly explained by a simple linear regression to imperviousness, it is quite reasonable to ask if other factors could explain that variation better. WQI is an index calculated solely on the presence or absence of macroinvertebrates, and logically, they should have the greatest impact on WQI. Fortunately, the data available also include the relative amount of each invertebrate taxa, as none, rare, common, or dominant, and these were used to construct a regression model for WQI, which includes imperviousness as a covariate. Table IV shows this stepwise regression analysis which reveals that imperviousness and had the highest F value in the regression model—F = 33.48. This was over twice that for the most influential macroinvertebrate, caddisflies with F = 14.70. When used together, the macroinvertebrate taxa of Table IV and imperviousness combine to have a strong predictive relationship to WQI, and with these data, the R^2 was 59.4%.

Furthermore, this analysis reveals that some species contribute greatly to WQI, and others, do not. Let us examine the group of macroinvertebrates that are traditionally considered to be the three most pollution-sensitive: the mayflies, stoneflies, and caddisflies. These three alone are so well-known to indicate good water quality, that the EPT ratio is considered a standard ecological metric for streams (United States Environmental Protection Agency 1999, Haney 2013, United States Department of Agriculture). In this analysis, caddisflies occupy the second highest rank in Table IV, and stoneflies rank fifth, so apparently these two taxa conform well to conventional thinking. The finding that stoneflies are able to live in forested watersheds but not in urban ones is consistent with Helms et al. (2009) and Alberts, et al. (2018). Mayflies, on the other hand, having been excluded from the model by the Minitab software, do not seem to contribute much either positively or negatively to WQI. Mayflies may be more affected by local, reach-scale influences (sensu Alberts, et al. 2018). From my own observations working alongside my students (as per Kodani 2018), mayflies can sometimes be difficult to find, but we often find them clinging to woody material and this has also been noted in the literature (Pitt and Batzer 2011). It is possible to imagine a watershed with low imperviousness but very few trees, such as might occur in agricultural areas. On the other hand, it is also conceivable that a stream in a somewhat urbanized watershed might have a well-protected stream buffer with a forest, such as might occur in a city park. If the most important factor for mayflies is the presence of woody debris, then perhaps imperviousness and even water quality might not matter to them, and they would not have much correlation with WQI. Generally speaking, stream-reach conditions have been found to be more important to macroinvertebrate communities than conditions over entire watersheds (Richards, et al. 1997). Interestingly, aquatic snipes, water pennies, and riffle beetles were also found to have some significant relationship to WQI, as one might expect from their traditional classification as pollution-sensitive organisms (Georgia Adopt-A-Stream 2015, Izaak Walton League of America 2021, Stroud Water Research Center 2021).

In addition to highly sensitive organisms, there are also macroinvertebrates that have usually been called moderately-sensitive to pollution, and we might expect them to only moderately correlate to WQI. In fact, inspection of Table IV reveals that the dragon/damselflies were important to a site's WQI, despite their moderate grouping. Similarly, crayfish with their P-value = 0.003, contribute very significantly to WQI. In the case of the bivalve mollusks, which are also moderately-sensitive, this is simply not the case, and they were so insignificantly connected to WQI that they were eliminated by Minitab. This is difficult to understand, as they are burrowing filter feeders whose feeding, respiration, and reproduction are harmed by the silt and suspended solids introduced by erosion (Machtinger 2007). Erosion often accompanies imperviousness in a watershed, as precipitation is not allowed to permeate into soils where there are high amounts of water-proof surfaces such as roofs, sidewalks, streets, and parking lots. Odonatans, which are comprised of damselflies and dragonflies, on the other hand, do not have an obvious connection to imperviousness or water quality, so it is not clear why their correlation is significant.

Then we come to the so-called pollution-tolerant taxa, whose presence seems to indicate nothing of water quality, as they could exist anywhere from pristine creeks in the north Georgia mountains to a sunny ditch in a parking lot. In Table IV, we can find three from this list, the blackfly larvae ($p = 0.142$), aquatic snipe flies ($p = 0.144$), and leeches ($p = 0.154$) apparently affected by the level of imperviousness. Very interestingly, the lunged snails, actually occur at their highest numbers where there is more impervious surface, and apparently have a high positive correlation with this kind of habitat, as was reported by other researchers in Georgia (Helms 2009). Their close relatives, the gilled snails, seem to have a high negative correlation with imperviousness. Taken together, these two groups may have a very interesting story—the difference between these two is where they derive their oxygen from. Gilled snails need to get their oxygen from the water that they live in, and so must inhabit cool, moving, highly-oxygenated water, whereas lunged snails come to the surface to breath air, and can exist in water devoid of oxygen (Voshell 2002). We can surmise, then, that these two species are exhibiting niche separation: gilled snails might be superior competitors and outcompete others, whereas lunged snails can only exist where gilled snails cannot.

Lastly, there were 5 kinds of macroinvertebrates which were eliminated from the analysis by the statistical software, presumably because they did not have a significant effect on WQI. Neither mayflies nor bivalves were important for WQI, but both of them have some very specific microhabitat requirements, for which for which the imperviousness of an entire watershed may not matter. Interestingly, these macroinvertebrates may be more affected by local reach-scale factors, such as siltation and the presence of woody debris. Midges and lunged snails, were also eliminated. These are both considered tolerant species, and happen to share unique adaptations for procurement of oxygen from air rather than water. Lastly, sowbugs were also eliminated, and other than their requirement for general detritus, do not seem to have any special needs. It could be that at least some of these 5 taxa are more affected by local, reach-level factors than by watershed imperviousness.

In summary, the amount of impervious surface in a entire watershed, by itself, is perhaps not a good predictor of a stream's health as measured by its WQI. The two variables are clearly related, but different, so a more detailed model for predicting WQI is needed. Macroinvertebrate abundance of 15 of the 20 available taxa, in combination with imperviousness yielded a model with better predictive value of 59.4%. Interestingly, mayflies, aquatic sowbugs, clams/mussels, midges, and lunged snails were not found to contribute to predicting WQI. These taxa might be more affected by local, stream-reach scale factors such as woody debris, silt, and stagnant water. Fortunately, data from a relatively new habitat assessment are currently being collected by the volunteers of Georgia Adopt-A-Stream, and it is possible that when these additional data are available, along with an anticipated GIS imperviousness coverage for 2021, that a model including these reach-scale data can be constructed. Lastly, from 2001 to 2016, on average, the watersheds that Adopt-A-Stream volunteers have chosen to monitor have not significantly changed in imperviousness, and there is no harm in that. On the other hand, there has been an ominous change in average WQI in the same time period—it has decreased steadily and significantly. If imperviousness did not cause this loss of diversity in Georgia's macroinvertebrate communities, then it is important that we should think about what did.

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APPENDIX

Table V. Locations of 163 adopted sites. These sites were monitored for macroinvertebrates at least once in 2001, 2006, 2011, or 2016, which were the 4 years when imperviousness coverage was available (National Land Cover Database 2020). The site names are as they appear in the Georgia Adopt-A-Stream database. *The 6 sites marked with a star were monitored by the author and their students, and these were part of a previously published analysis (Kodani 2018).

Site Name	Site ID S-#	Latitude (DD)	Longitude (DD)
#6 East Branch Long Swamp Creek	4037	34.4422	-84.2816
Alcovy River	26	33.5606	-83.8201
*Angel Creek	1455	33.6011	-84.3498
Bald Ridge creek Tributary	1813	34.2466	-84.1019

Balus Creek	342	34.2330	-83.8825
Bannister Creek	4181	34.3297	-84.1970
Bear Creek Tributary	477	33.9679	-83.4973
Beautiful Eagle Creek	3895	32.4324	-81.7820
Betty's Branch 3	885	33.5564	-82.1441
Big Amicalola Creek	224	34.4943	-84.2409
Big Ferguson Creek	3753	34.7773	-82.0288
Big Shoally Creek	3977	35.0410	-81.9551
Blanket's Creek	2065	34.1595	-84.5554
Bluestone Creek	24	34.1839	-83.1531
Brooklyn Creek	3733	33.9555	-83.4005
Brown's Creek	1966	33.4779	-84.7934
Bubbling Creek	3719	33.8952	-84.3171
Burnt Fork Creek	1520	33.8195	-84.2757
Butler Creek	1470	33.3995	-82.0235
Cabin Creek	2045	33.2700	-84.2550
Calls Creek	2558	33.8684	-83.4196
Camp Creek	639	33.4107	-84.5489
Camp Creek near Brown Lake	3995	33.3692	-84.5271
Canton Creek	1235	34.2298	-84.4918
Carr Creek	474	33.9469	-83.3534
Cash House	4134	35.1073	-85.3675
Cedar Creek (Atlanta Newnan Rd)	759	33.5108	-84.7308
Cedar Shoals Creek	3857	34.6153	-81.8832
Chattahoochee River Tributary	22	34.0081	-84.3742
Cherry Branch Creek	523	33.4065	-84.5816
Chester Creek	1464	34.6635	-84.1839
Chinquapin Creek	3547	34.9815	-81.9580
Cliatt Creek	2159	33.6204	-82.3885
Cobbs Creek	2342	33.7689	-84.2655
Cornish Creek	380	33.6242	-83.8022
Crooked Branch	2019	33.9613	-84.3890
*Crooked Creek	1456	33.5995	-84.3486
Crossroads Stream	1220	33.8124	-84.1479
Crossvine Creek	1398	33.8039	-84.1590
Cumbess Creek	4576	34.1108	-80.9833
Cupboard Creek	4366	34.5297	-82.5533
Dicks Creek	3206	34.6790	-83.9365
Disharoon Creek	4069	34.4635	-84.3056
Dodgen Pond	648	33.9905	-84.4435
East Sandy Creek	59	34.0208	-83.3688
Etowah River	733	34.5419	-84.0649
Euchee Creek	2361	33.5103	-82.2047
Euchee Creek Site 4	971	33.5555	-82.1797

Fairforest Creek	4458	34.9438	-81.9703
Fifteenmile Creek	401	32.5712	-82.1053
Fishing Creek	780	33.0725	-83.2211
Flat Creek	546	33.4033	-84.5643
Flint River	1637	32.9052	-84.5086
Fox Creek	1352	33.7420	-83.2179
Gin Branch	4004	33.4396	-84.5846
Hollow Creek 1	953	33.3345	-81.8534
Hollow Creek 2	954	33.3434	-81.8222
Holly Creek	619	34.1105	-83.1031
Holston Creek	4344	35.0907	-82.1463
Hood Branch	4523	34.2169	-80.9151
Hunnicutt Creek	476	33.9581	-83.4370
Hunnicutt Creek B	3463	34.6687	-82.8493
Jackson Creek	2264	33.8903	-84.1441
*Jester's Creek at Lake City Hall	2296	33.6060	-84.3450
Jones Creek	3976	33.5720	-82.0885
Kedron Creek	524	33.4419	-84.5749
Kelsey Creek	4226	34.8945	-81.8663
Lawson's Fork Above Dam	4556	35.0050	-81.9667
Lawsons Fork Creek at Glendale Shoals	3828	34.9417	-81.8394
Limestone Creek	20	34.3140	-83.7997
Line Creek	797	33.4036	-84.6084
Little Amicalola Creek	1147	34.5514	-84.1418
Little Noonday Creek	696	34.0578	-84.5331
Long Creek	1233	34.6647	-84.1833
Long Swamp Creek	689	34.4503	-84.3932
Lost Mountain Lake	825	33.9371	-84.6943
Lower Barber Creek	1040	33.9106	-83.4281
Maple Creek	4140	34.9275	-82.1841
*Martin Creekat Hidden Valley	865	33.6120	-84.2156
McCleskey Middle School	1673	34.0465	-84.5006
Middle Creek	4304	35.1307	-85.3609
Mill Creek	3522	34.7921	-84.9424
Mill Creek	4307	35.1124	-85.3744
Mineral Springs Creek	562	34.8638	-84.2974
Mountain Creek	170	32.8014	-84.9139
Mulberry Creek	387	33.9570	-84.3957
Mullens Creek	4313	35.1389	-85.4361
N. Middle Creek	4372	35.1352	-85.3583
North Suck Creek	4306	35.1612	-85.3907
Oconee River	2099	33.3473	-83.1526
Oil Camp Creek	4017	35.1119	-82.5489
Orange Trail Creek	475	33.9015	-83.3797

Outflow from Skylake	2025	34.7191	-83.6620
Pan Gap	4303	35.0642	-85.3847
Pappy's Creek	4443	34.7337	-82.7980
Peachtree Creek	196	33.8246	-84.4125
Pen Branch	4528	34.0088	-80.9646
Penhurst Lake	4201	33.9900	-84.4589
Placentia Canal	229	32.0340	-81.0604
Pleasant Creek	1465	33.5581	-84.1138
Pollywood Creek	3548	34.9991	-81.9707
Poplar Creek	2500	33.8797	-84.4948
Posey Branch	2036	34.1029	-84.5446
Rabin Creek at Neely Ferris bridge	4448	34.3821	-82.1027
Raccoon Creek	719	33.9694	-84.9309
Rae's Creek	2414	33.4825	-82.0607
RC Edwards Creek	4442	34.7248	-82.8318
Reed Creek	975	33.5352	-82.0838
Reedy River	3971	34.8344	-82.3795
Ritchie Falls Bottom	4084	35.0913	-85.4202
Ritchie Falls Lower	4085	35.0914	-85.4205
Ritchie Falls Upper	4108	35.0913	-85.4213
Rock Creek	4053	34.8950	-85.4064
Rock Eagle	4179	33.4252	-83.3904
Rockdale/Henry County Line Stream	1423	33.5627	-84.1174
Rocky Creek	4447	34.8603	-82.2978
Rottenwood Creek	651	33.9061	-84.4753
*Rum Creek at Monkey Island	2297	33.5120	-84.2556
Saluda River (Main)	4371	34.5219	-82.3697
Sandy Creek	580	33.9806	-83.3802
Shadow Creek	3989	33.3746	-84.5606
Shadow Creek at Three Ponds	3990	33.3830	-84.5580
Shoal Creek	2026	33.7542	-84.2870
Shoals Creek	2031	33.7567	-84.2871
Site 616, North Oconee River	131	33.8958	-83.3500
Smith Branch	4454	34.0275	-81.0432
Smithwick Creek tributary	4159	34.2488	-84.3264
Sope Creek	149	33.9426	-84.4377
South Chickamauga Creek	4005	35.0286	-85.1464
South Fork Peachtree Creek	1353	33.8034	-84.3070
South Tyger River	4225	34.8743	-82.0831
Stamp Creek	4301	34.8679	-82.9560
Stone Mountain Creek	316	33.7952	-84.1241
Stover Creek	1445	34.6611	-84.1892
Suck Creek Junction	4305	35.1457	-85.3882
Sweetwater Creek	2643	33.9460	-84.1119

Swift Creek	1766	33.7580	-84.1094
Tallapoosa River	204	33.7762	-85.2965
Toccoa River	635	34.8226	-84.2563
Toonigh Creek	154	34.1504	-84.5196
*tributary of Brush Creek	868	33.5520	-84.2350
Tributary of Chestatee River	2354	34.5112	-83.9875
Tributary of Long Island Creek East Branch	698	33.9131	-84.3853
Tributary of Long Island Creek West Branch	697	33.9133	-84.3861
*Tributary of Panther Creek	827	33.5860	-84.3318
Tributary Shoal Creek	3981	33.2299	-84.3002
Tributary Shoal Creek	3980	33.2315	-84.2959
Tributary to Rubes Creek	692	34.0467	-84.5057
Tributary to Skylake	2017	34.7254	-83.6838
Tyus Park Stream	3682	33.2856	-84.3163
Unname tributary to S. Utoy Creek	754	33.7183	-84.4794
unnamed (Hillview Stream)	4284	34.9512	-81.9056
unnamed tributary to Big Creek	1257	34.0399	-84.2896
Unnamed Tributary to Lake Lanier	573	34.4251	-83.8521
un-named tributary to Lake Zwerner	3605	34.5543	-83.9669
upper cherry creek	3999	33.4185	-84.5946
Upper Flint River Watershet	3713	33.4402	-84.5698
Weaver Creek	561	34.8678	-84.2974
Westminster Creek	1383	33.4885	-82.0440
Wildcat Creek	2020	33.8274	-83.3350
Willow Creek Tributary	656	34.0722	-84.4940
Woolsey Creek	3988	33.3591	-84.4176
Work Camp Creek	2015	33.4338	-84.1610