RESEARCH

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Water quality of streams flowing through Virginia golf courses

A three-year study monitoring the water quality of streams flowing through nine golf courses within a sub-watershed of Chesapeake Bay showed the courses did not contribute to water degradation of the bay.

The James River in Virginia flows from the Appalachian Mountains to Chesapeake Bay. The golf courses in this study are located within the James River watershed, a sub-watershed of Chesapeake Bay. **Photo by Thea Ganoe/Wikimedia Commons**

Figure 1. Stream sampling locations were identified at each golf course, with water collected at upstream locations where streams enter the course (inflows), and at downstream locations where streams exit the course (outflows). Course 5 is shown.

Seventy percent of Virginia's 350 golf courses are located within the Chesapeake Bay watershed. After many of the bay's waters were classified as impaired, the U.S. Environmental Protection Agency established, in 2010, Total Maximum Daily Load (TMDL) requirements aimed at reducing nitrogen, phosphorus and sediment losses. This action prompted the Commonwealth of Virginia to develop watershed implementation plans that identified areas of managed lands for potential reductions (4). At this time, the Virginia Golf Course Superintendent's Association, in conjunction with scientists at Virginia Tech, organized and published "Environmental Best Management Practices for Virginia's Golf Courses" (5). The Virginia GCSA and associated authors stated that the widespread adoption of the best management practices (BMPs) recommended in the book would result in lower nutrient loading to waterways and help achieve TMDL goals as established by the EPA for protection of bay water quality.

To ground-truth this statement, the Virginia GCSA, with matching funding from GCSAA's Environmental Institute for Golf, supported a three-year golf course water-quality monitoring research project conducted by Chantel Wilson for her Ph.D. under Erik Ervin, Ph.D., and Stephen Schoenholtz, Ph.D., at Virginia Tech. Few studies have been conducted anywhere in the United States to quantify the effects of golf courses' standard management practices on surface water quality, and of those few, none has been conducted in Virginia. This study therefore monitored water quality of streams flowing in and out of nine Virginia golf courses situated within the Chesapeake Bay watershed. Finally, a survey of 70 Virginia golf courses located around Chesapeake Bay was taken in 2014 to determine adoption rates of recommended BMPs aimed at water quality protection.

Materials and methods

For the three years of this study, researchers monitored streams flowing through nine golf courses located within the James River watershed (a sub-watershed of Chesapeake Bay), representing urban to suburban areas of Charlottesville through the Richmond corridor. All subject courses are private membership, have robust maintenance budgets, and in general must meet higher membership expectations for course conditioning.

Stream sampling locations were identified at each golf course, with water collected at upstream locations where streams enter the course (inflows), and at downstream locations where streams exit the course (outflows) (Figure 1). Upstream water sample collection sites served as baseline reference conditions

Dissolved oxygen levels

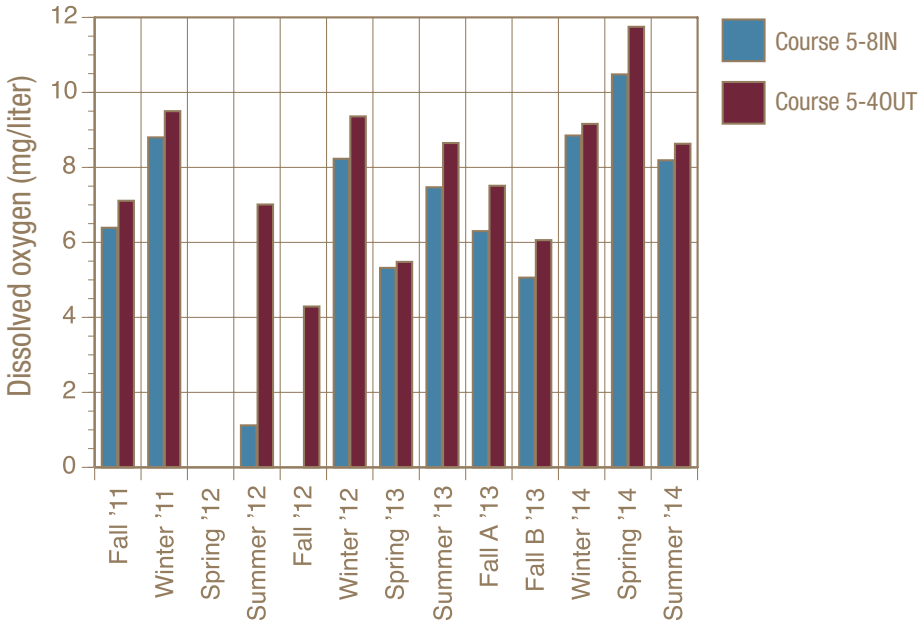

Figure 2. Seasonal dissolved-oxygen levels (mg/liter) on Course 5 at stream inlet and outlet points over four years.

for comparison with sites downstream of the areas influenced by golf course management practices. Water quality samples and measurements were collected four to six times per year.

In-stream physical indicators of water quality that were measured included temperature, pH and dissolved oxygen. These were measured with a calibrated multi-parameter probe (Hydrolab Quanta; Loveland, Colo.) at inflow and outflow sites at each course. The maximum temperature for non-impaired, non-tidal Virginia Piedmont waters is 90 F. Healthy dissolved-oxygen levels are listed as > 4.0 mg/liter for non-tidal waters in the coastal and Piedmont zones. Water pH for healthy streams ranges from 6.0 to 9.0 (6).

Samples for chemical indicators of water quality were taken consistently at the same locations and within 6 inches (15.24 cm) of the surface in areas of predominate flow. They were analyzed using a SEAL AutoAnalyzer III and standard methods: G-109-94 (nitrate-nitrogen), G-102-93 (ammonium-nitrogen) and G-103-93 (phosphate-phosphorus) (1). Mean concentrations of nitrate-nitrogen, ammonium-nitrogen and phosphate-phosphorus were calculated from each of the sample sites separately. Differences between the upstream and downstream locations were calculated by subtracting mean downstream nutrient concentrations from mean upstream nutrient concentrations for each stream. Differences were used to decrease the effect of autocorrelation within repeated measures so that the samples could be treated as independent statistical units (E.P. Smith, Virginia Tech Department of Statistics, personal communication). In cases where an outflow was connected to multiple inflows, data were analyzed by averaging the means of the multiple inflow streams. To test for significance, the calculated differences between inflow and outflow locations were compared with zero.

Virginia golf course superintendents were surveyed online to assess management levels and adoption of BMPs on their golf courses. Seventy golf courses — representing 42 Virginia counties within the bay watershed — returned completed surveys.

Results

Physical indicators

The temperature criterion was not exceeded for the non-tidal Piedmont waters except for one instance (92 F) at the outflow location of Course 1 during the summer of 2011. Water pH of the streams was rarely outside the acceptable range of 6.0 to 9.0. Exceptions were seasonal but temporary, with pH readings of 5.0 to 6.0 or 9.0 to 10.0 in less than 10% of the measurements across three years of monitoring.

Dissolved-oxygen levels were occasionally below established criteria for healthy aquatic life (4.0 mg/liter), but low levels were mostly associated with low baseflow (low-water flow) of these small streams in summer or early fall (see Figure 2 for an example of seasonal variation on Course 6). With sufficient rainfall or with runoff in cooler seasons, dissolved-oxygen concentrations were adequate for healthy aquatic life and did not differ significantly between inflow and outflow locations.

If any of these physical parameters had remained consistently worse at outflow locations relative to inflow locations, they would have served as indicators that golf course management practices were contributing to sediment or nutrient pollution. Our data indicate that this was not the case.

Chemical indicators

Nitrate-nitrogen. Nitrate-nitrogen concentrations were generally low or below detection limits at all golf course sites (Figure 3). Statistical analysis generally did not reveal significant differences between inflow and outflow locations. For example, three years of sampling revealed no inflow to outflow nitrate-nitrogen concentration differences on courses 1, 2, 3, 4, 7 and 9.

One of the exceptions in nitrate-nitrogen concentrations was stream B on Course 5, which had greater nitrate-nitrogen leaving the course (4 mg/liter) than entering (1 mg/liter). This stream flowed through an underground pipe on the course, and we had no way to determine the cause of elevated nitrate. Interestingly, phosphate-phosphorus levels were not elevated in the outflow of this underground stream (Figure 4). Course 6 nitrate-nitrogen levels were also higher at outflow (3 mg/liter) than at inflow (1.5 mg/liter). Finally, stream B on Course 8 had higher inflow nitrate-nitrogen (2 mg/liter) relative to the outflow concentration (0.2 mg/liter).

Nitrate-nitrogen levels

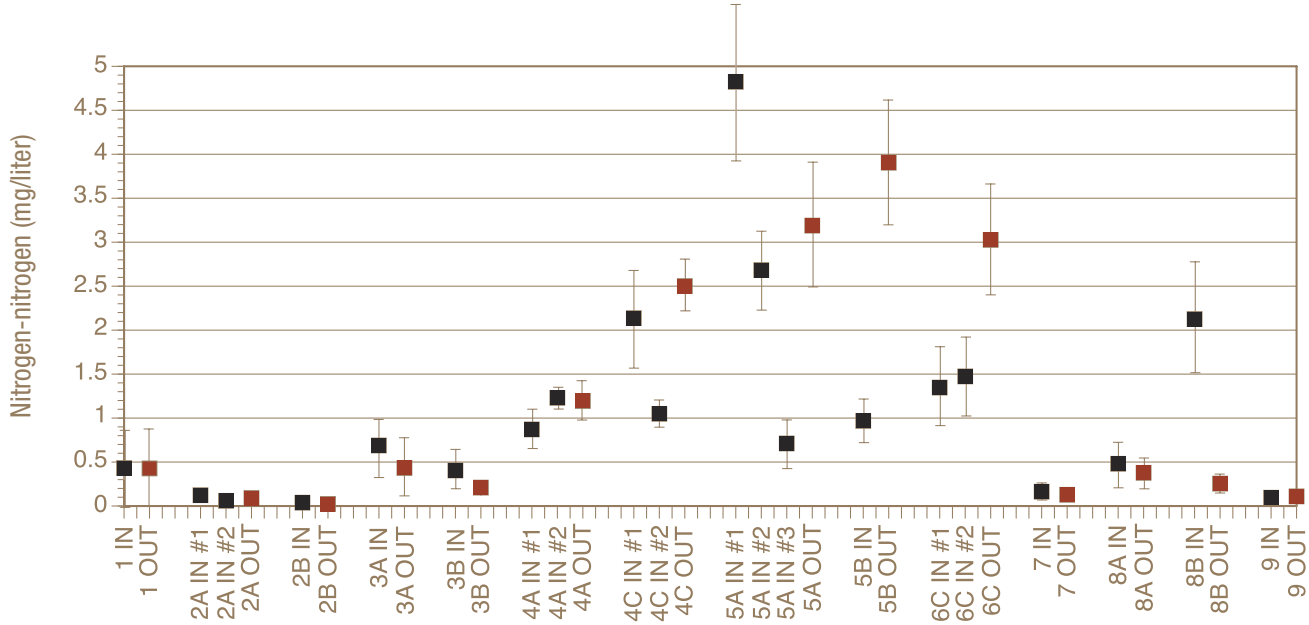

Figure 3. Three-year averages of nitrate-nitrogen levels at nine Chesapeake Bay golf courses at stream inlets and outlets. Bars indicate 95% confidence intervals.

Phosphate-phosphorous levels

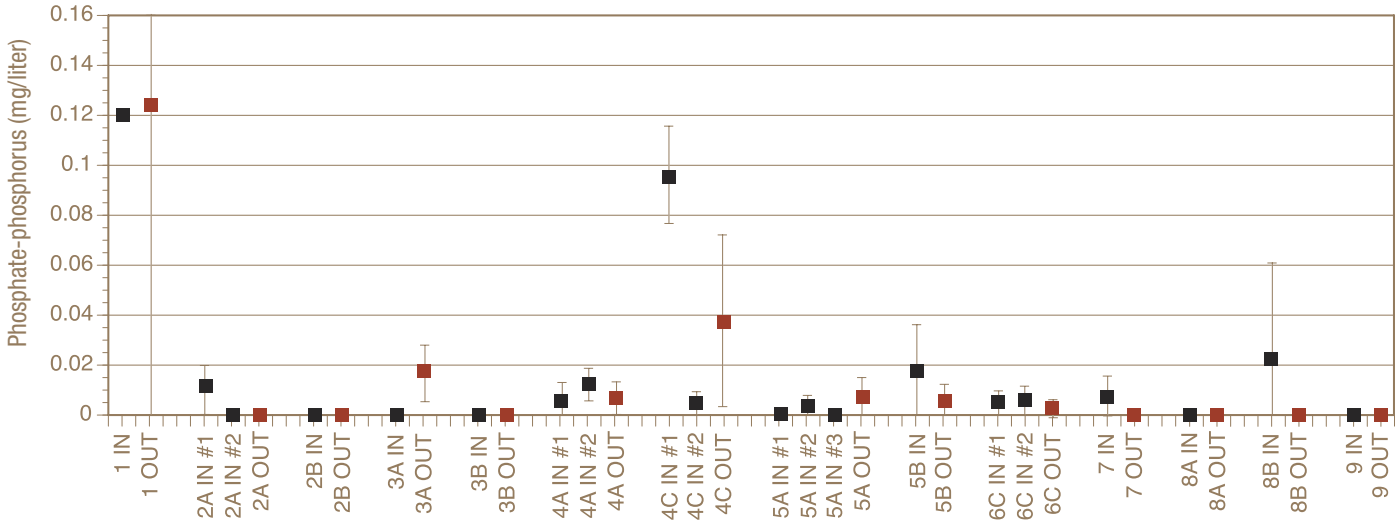

Figure 4. Three-year averages of phosphate-phosphorus levels at nine Chesapeake Bay golf courses at stream inlets and outlets. Bars indicate 95% confidence intervals.

BMP adoption rates

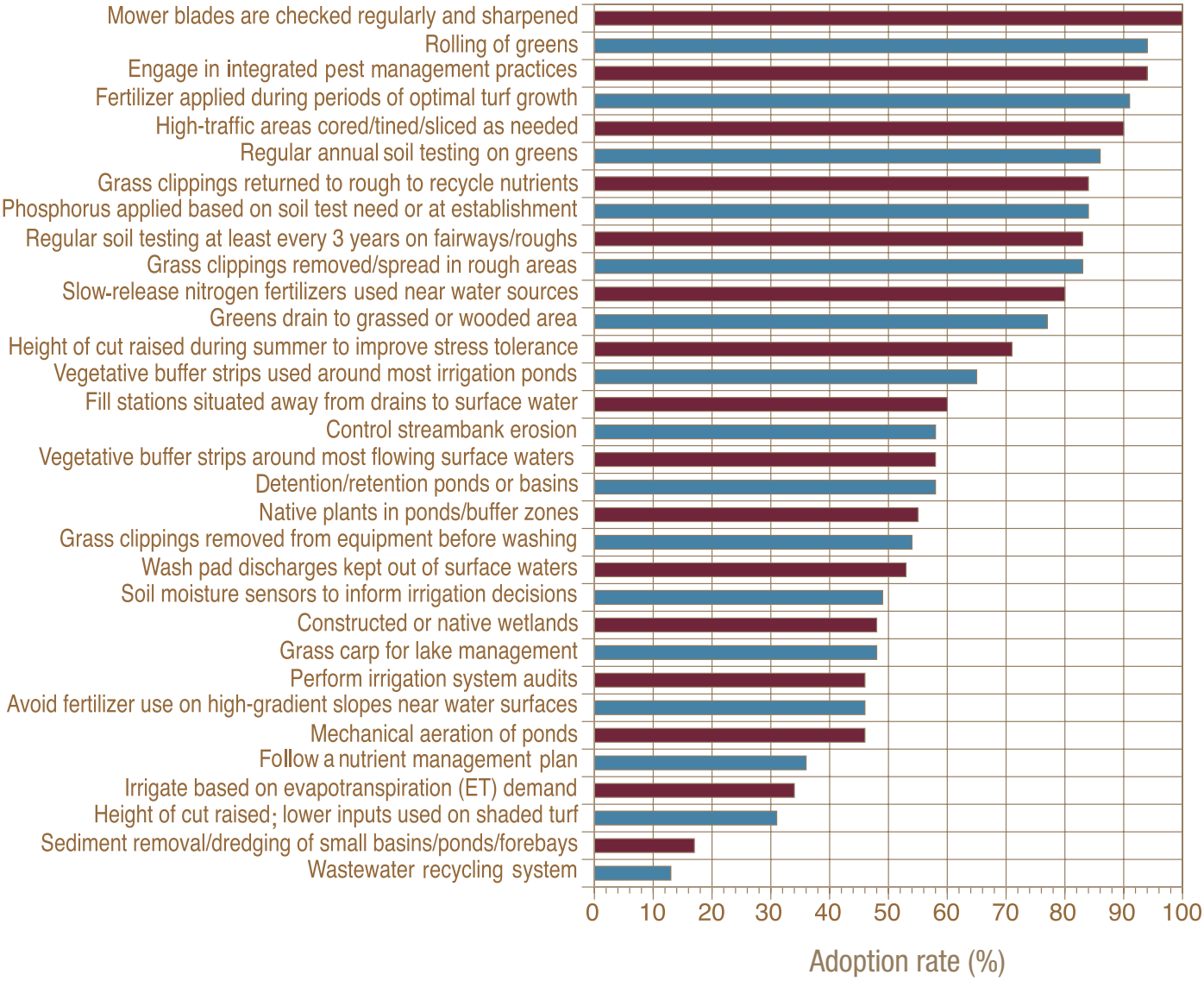

Figure 5. Percent adoption rate, self-reported by 70 Virginia golf course superintendents, of recommended BMPs for water quality protection.

No official guidelines exist for defining acceptable freshwater stream nitrate-nitrogen levels in Virginia, although scientists in Kansas suggest that < 1 mg/liter is considered "good," and 1 to 10 mg/liter is considered "fair" water quality (2). The EPA guideline for safe drinking water is < 10 mg/liter nitrate-nitrogen (3). Based on these guidelines, we can conclude that our three years of nitrate-nitrogen sampling revealed almost no improvement or degradation of water quality caused by the streams flowing through these golf courses.

Phosphate-phosphorus. Phosphate-phosphorus concentrations were generally low or below detection limits at all nine golf courses (Figure 4). There were no significant differences in phosphate-phosphorus concentrations between inflow and outflow locations, except at Course 4, stream C, where a small decrease was measured between inflow No. 1 and the outflow (Figure 4). Outflow concentrations of phosphate-phosphorus were always below EPA recommendations for streams not discharging into lakes (0.05 mg/liter), with the exception of Course 1, which was previously a dairy farm and therefore had very high soil test phosphorus levels. The overall phosphate-phosphorus results provide further support for our previous statement that there was no apparent risk of water quality degradation to Chesapeake Bay from the streams flowing through these golf courses.

Conclusions

Results of the online survey completed by 70 Virginia golf courses located in the Chesapeake Bay area revealed that many of the BMPs recommended in the 2012 Virginia GCSA guidelines (5) were in use (Figure 5). For example, water-quality protection BMPs with a greater than 50% adoption rate included:

- Use of slow-release nitrogen fertilizers near water sources
- Greens drained to grassed or wooded areas
- Vegetative buffer strips used around most irrigation ponds
- Fill stations situated away from drains to surface water
- Control of stream bank erosion
- Vegetative buffer strips used around most flowing surface waters
- Use of detention or retention ponds or basins
- Use of native plants in ponds or buffer zones
- Grass clippings removed from equipment before washing
- Wash pad discharges kept out of surface waters

These survey results, and the stream water quality data reported herein, indicate that Virginia golf course superintendents are committed to environmental stewardship and are voluntarily taking action to protect water quality.

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Literature cited

1. Bran Luebbe AutoAnalyzer Applications. 1999. Nitrate and nitrate in water, waste water, and soil extracts. AutoAnalyzer Method G-109-94. Bran Luebbe, Buffalo Grove, Ill.
2. Janke, R., R. Moscou and M. Powell. 2006. Citizen Science Water Quality Testing Series, PK-13 W-4 Nitrogen. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, Kan. (www.bookstore.ksre.ksu.edu/pubs/PK13W4.pdf) Accessed Aug. 22, 2017.
3. U.S. Environmental Protection Agency. 1986. Quality criteria for water 1986. EPA 440-5-86-001. United States Environmental Protection Agency Office of Water Regulations and Standards. (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=00001MGA.TXT) Accessed Aug. 22, 2017.
4. U.S. Environmental Protection Agency. 2010. Chesapeake Bay Phase 5.3 Community Watershed Model. EPA 903S10002 - CBP/TRS-303-10. (http://ches.communitymodeling.org/models/CBPhase5/documentation.php) Accessed Aug. 22, 2017.
5. Virginia Golf Course Superintendents Association. 2012. Environmental Best Management Practices for Virginia's Golf Courses. (www.vgcsa.org/-best-management-practices) Accessed Aug. 22, 2017.
6. Virginia State Water Control Board. 2011. 9 VAC 25-260 Virginia Water Quality Standards. (www.epa.gov/sites/production/files/2014-12/documents/vawqs.pdf) Accessed Aug. 22, 2017.

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The RESEARCH SAYS

- A three-year study monitored the water quality of streams flowing through nine golf courses within a sub-watershed of Chesapeake Bay.
- Upstream and downstream water samples were collected four to six times per year; temperature, pH and dissolved oxygen were measured for each sample.
- Additional samples were taken at the same locations and tested for nitrate-nitrogen, ammonium-nitrogen and phosphate-phosphorus.
- Testing showed almost no improvement or degradation of water quality because of the streams flowing through these golf courses.
- An online survey in 2014 showed that 70 Virginia golf courses located near the bay were following the 2012 Virginia GCSA BMPs.