In-Stream Wetland Mitigation of Nitrogen Contamination in a USA Coastal Plain Stream

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Nonpoint source N from streams and rivers is a major water quality problem throughout the world. In the Herrings Marsh Run watershed, a 425-ha sub-watershed had been overloaded with N, and the stream draining one sub-watershed contained excessive N. At the stream exit, there was a small wetland landscape area. We hypothesized that enhancement and repair of a breached dam at the wetland area would create an in-stream wetland (ISW) that would improve stream water quality by lowering the nitrate-N concentration. Plans for a water control structure were developed by the USDA Natural Resources Conservation Service. However, we deferred construction because of cost constraints and because beavers (*Castor canadensis)* began to fill the breached dam in April 1994. The sidewalls of the beaver dam were stabilized to reduce sidewall erosion, restrain stream flow and establish an in-stream wetland. The ISW impounded approximately 3.3 ha (about 1% of the sub-watershed), and it ranged in depth from about 0.2 to 2 m. Emergent aquatic weeds occupied approximately 40% of its surface area. The ISW perimeter (another 40% of the area) was dominated by trees [swamp tupelo (*Nyssa biflora*), red maple (*Acer rubrum*), and black willow (*Salix nigra*)]. The remaining 20% of area was occupied by downed tree boles, isolated individuals of various species, and open water.

Water samples for chemical analyses as well as flow measurements had been obtained since 1990 as part of the USDA-Water Quality Demonstration Project on the entire Herrings Marsh Run. This time period provided data for pre- and post-ISW conditions at the ISW outlet. Water samples were collected using automated samplers (ISCO or American Sigma samplers) at timed intervals. Flow at the ISW outlet was measured by the U. S. Geological Survey. The ISW inlet was initially well-defined and was monitored using an automated water sampling station established in October 1993. Flow was determined discretely rather than continuously using a current meter (Scientific Instruments Model 1205 Price-type current meter, Milwaukee, WI). In the winter of 1994, the beavers raised the height of their dam, and the original inlet sampling station was flooded. The new ISW inlet moved about 100 m upstream, and it had two inlet streams that were within 30 m of each other. Nitrate and ammonia values were obtained at the two new inlet streams using weekly grab samples from April 1994 until March 1995, when automated stream samplers were installed on the two inlets. Concentration values from the streams were flow adjusted to calculate ISW nutrient inputs. Quarterly mean values for the nitrate:chloride ratios were calculated from the ratio of each 3.5-day sample.

The 3-year-mean stream nitrate-N concentration entering the wetland was 6.6 ± 1.2 mg/L and was similar to the pre-ISW concentrations. However, the stream water exiting the ISW was dramatically lower in nitrate-N with a 3-year mean of 2.0 ± 1.4 mg/L. This difference resulted in a 70% reduction in mean concentrations was significantly different at the $P > 0.01$ level by the paired t-test and the Wilcoxon sign test. The removal of nitrate-N by the ISW was most effective during the warmer months; outlet concentrations were typically below 1 mg/L. Nitrate-N mass removal was highly correlated to inflow nitrate-N ($r = 0.93$) in the warmer months when biological processes were more active. The mean monthly mass inflow and discharge of nitrate-N for the ISW were 20.6 and 10.0 kg/day, respectively. The mean annual removal on an area basis for the 3.3-ha ISW was 3.2 kg N/ha/day. The annual nitrate-N reduction was 51%. The ISW loading was highest in the winter months (>22 kg/day) when nitrate-N removal was the lowest (≤ 9.1 kg/day). Consequently, nitrate-N discharges were higher during January through March (≥ 18.3 kg/day), but during the remainder of the year they were ≤ 10.1 kg/day.

Unlike nitrate-N, the mean ammonia-N concentration for the 3-year study increased from 0.5 ± 0.3 mg/L at the inlet to 0.7 ± 0.7 mg/L at the outlet ($P > 0.01$ by the paired t-test and the Wilcoxon sign test). However, this increase was only 0.2 mg/L and not continuous for the year. Increases were likely related to detrital mineralization under low oxygen conditions that limited the conversion of ammonia to nitrate in the ISW. In the winter when nitrate-N removal was lowest, the outlet ammonia-N concentrations were less than the inlet concentrations. Ammonia-N mass removal was highly correlated to inflow ammonia-N ($r = 0.81$) during the cooler months. The mean monthly mass inflow and discharge of ammonia-N for the ISW were 1.7 and 2.4 kg/day, respectively. The months of best ammonia-N mass removal were opposite those of nitrate-N. During the four cooler months, ammonia-N removed from the ISW; but during the eight warmer months, the ammonia-N was accumulated. Monthly ammonia-N removal ranged from 3.2 to -3.8 kg N/day in February and September, respectively.

Total annual N removal for the ISW was approximately 3 kg/ha/day, which was about 37% of the inflow N. The ISWs appear to be very good landscape features for mitigating excess nonpoint source N in the southeastern Coastal Plain of the USA and should be a good complement to other best management practices for improved water quality.

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