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Efficiency of erosion mitigation strategies in reducing sediment-loading rates from unpaved road networks into coral reef-bearing waters of the Eastern Caribbean

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Erosion from unpaved road networks represents a critical source of stress affecting the coral reef systems of the U.S. Virgin Islands in the Northeastern Caribbean. Combined community- and government-driven efforts to reduce sediment contributions from unpaved roads in the island of St. John have consisted in improving road drainage design, paving selected road segments, and constructing sediment retention structures. Here we describe empirical evidence attesting to the efficacy of these mitigation efforts.

Road drainage improvements reduced sediment production rates to about a third of pre-treatment levels. Road-segment scale erosion rates following paving ranged from 5-30% of pre-treatment levels, depending on road slope and road grading frequency. A 616-m^3 sediment retention pond proved to contain 86 Mg of sediment annually and about 94% of the runoff generated from a 12 ha sub-catchment with an unpaved road density of 19 km km^{-2}. Watershed-scale modeling evaluations suggested that the combination of these three treatments within the 13-km^2 Coral Bay watershed resulted in the reduction of annual sediment delivery rates from 445 Mg yr^{-1} to 327 Mg yr^{-1}. Cost-effectiveness analyses suggest that road drainage improvements and construction of the detention pond provided the greatest reductions in sediment delivery per total amount of funds spent. Even though paving is a proven erosion control method, the high costs involved made it a relatively cost-inefficient method.

Marine sedimentation of terrigenous sediment (land-derived) was regularly monitored (every 26 days) at 15 near-shore and reef sites from 2008 to 2013 below the treated and undeveloped watersheds. Sediment composition (% terrigenous) determined by loss on ignition was multiplied by the total sediment accumulation rate in tube sediment traps to obtain terrigenous sediment accumulation rates (in mg cm^{-2} d^{-1}). Mean terrigenous sediment accumulation rates were over 24 (near-shore) and 6 (reef) times greater below developed compared to undeveloped watersheds. Comparisons of marine terrigenous accumulation rates between undeveloped and developed areas were consistent with those based on modeled sediment yields. At all near-shore sites below mitigated watersheds, mean post-mitigation marine terrigenous sediment accumulation rates were reduced by up to 70% of mean pre-mitigation values. Nevertheless, further analysis is required to evaluate whether the observed post-mitigation reduction is strictly related to watershed restoration. At the developed coral reef sites, acute terrigenous sediment accumulation rates during major storms equaled or exceeded coral-stressing levels ($>$50 mg $cm^{-2}d^{-1}$). Results from this research are being employed in the design of mitigation strategies within our study areas as well as in other parts of the Caribbean where roads are considered a major threat to coral reefs.