Fluvial Nitrogen and Phosphorus in Hawaii:

Storm Runoff, Land Use, and Impacts on Coastal Waters

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ABSTRACT

Fluvial nitrogen (N) and phosphorus (P) are important to the natural functioning of coastal ecosystems, and human-induced changes in nutrient fluxes can alter ecosystem function and coastal water quality. Coastal waters are a critical resource in Hawaii, and fluvial nutrients frequently are cited as potential threats to coastal ecosystems, but the effects of development on nutrient fluxes, and the impacts of fluvial nutrients on coastal ecosystems have not been investigated extensively.

In Hawaii, small, steep watersheds and highly variable rainfall result in episodic, but often intense, runoff events. As a result, stream discharges consist of a small but steady baseflow component maintained by groundwater discharge, and a transient and sometimes large component derived from storm runoff. Analysis of data from long-term monitoring sites across the State and from six Oahu sites monitored in this study show that baseflow and storm runoff contributions to annual discharge vary between sites, and that storm runoff and thus total discharge can vary widely from year to year. The timing, magnitude, and form (dissolved versus particulate, chemical speciation) of fluvial nutrient fluxes to coastal waters depend on the relative magnitudes of baseflow and storm runoff discharges, and on the characteristic nutrient forms and concentrations in each flow component. Dissolved nutrient concentrations at control (predominantly conservation land) and urban study sites differed in baseflow and storm runoff samples, but were similar in baseflow and storm runoff samples at agricultural sites. Agricultural, urban and control sites all had distinct dissolved nutrient concentrations, with urban

sites exhibiting the highest concentrations in storm runoff samples, and agricultural sites having the highest levels in baseflow samples. Particulate nutrient concentrations (expressed as weight percent of suspended sediment) were less variable than dissolved concentrations, although particulate inorganic phosphorus was elevated strongly in storm runoff samples from urban sites, and particulate organic nitrogen and carbon were reduced slightly at urban and agricultural sites compared to conservation samples. On an annual basis, baseflow fluxes of dissolved nutrients were comparable to or greater than storm runoff fluxes, while particulate nutrient fluxes were associated almost exclusively with storm flows. Comparison to global river and stream data indicate that Hawaiian watersheds export water, sediment, and nutrients at rates similar to, or lower than, global averages based on watershed size and runoff.

The impacts of fluvial nutrients on coastal waters were evaluated in southern Kaneohe Bay on Oahu. Streams in the watershed are affected by extensive urban development, resulting in elevated dissolved nutrient concentrations in baseflow and storm runoff discharges. Nutrient budgets demonstrate that streams contribute roughly half of the reactive nitrogen and the majority of the reactive phosphorus to southern Kaneohe Bay, but mostly via particulate organic N and P delivered during storm events. Present-day fluvial fluxes of dissolved inorganic nutrients are elevated strongly compared to estimated pristine conditions, but analysis of historical data suggests that ecosystem-scale impacts of the increased fluvial nutrient loads, and of nitrogen loads derived from non-point sewage sources, probably are minor. Biweekly data from a parallel study monitoring three marine sites in southern Kaneohe Bay show that obvious

impacts of stream discharges were restricted to a small region around stream mouths, primarily due to the unusually low runoff characterizing the monitoring period and the resulting lack of significant runoff events prior to Bay sampling. However, historical data show that large storm events can produce dramatic impacts on water quality and biota in southern Kaneohe Bay, and 'typical' storms probably also have significant impacts.

Extrapolation of results from southern Kaneohe bay to other sites in Hawaii suggests that the impacts of fluvial nutrients on coastal marine systems normally should be minor. However, the potentially large nutrient subsidies associated with fluvial sediments suggest that streams may play an important role in supplying new N and P to some coastal ecosystems. As a result, nutrient loading to coastal ecosystems should be considered both in terms of dissolved inputs from streams and groundwater, and in terms of recycling of particulate nutrients delivered with terrestrial sediment. In areas subject to increased nutrient loading due to human activities, impacts on coastal ecosystems will depend on a number of factors, but obvious impacts are rare in Hawaii. This can be attributed to two primary factors: obvious problems associated with significant point sources (e.g. sewer outfalls) already have been addressed, and the impacts of non-point-source loading normally are minor due to the rapid dilution characteristic of Hawaiian coastal waters. However, extreme loading or loading to regions with very restricted circulation may result in significant impacts, and more subtle or transient impacts may largely go undetected with existing monitoring protocols. Better resolution of the coupling between land and coastal waters in Hawaii

will require greater understanding of nutrient fluxes, especially fluxes from groundwater and sediments, and better characterization of the impacts of the episodic runoff events that are responsible for the majority of the total nitrogen and phosphorus loads to coastal waters.