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Nutrient dynamics in a Greek temporary river

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Surface runoff in Greece is determined by the semi-arid and karstic conditions of a large part of the country. During the dry season surface waters are abstracted and groundwater aquifers are exploited for irrigation purposes. As a result, a large number of small and mid sized rivers are temporal. In fact, temporary catchments draining directly into the sea cover roughly 42 % of the country's surface (Nikolaidis, 2005). In addition, numerous of the tributaries dry completely out.

The Krathis R., located in Northern Peloponnisos, belongs to a mountainous, steep, forested catchment (mean altitude: 1092 m, mean slope: 33%, forest areas: 75%), with intermittent flow at a number of mountainous tributaries and at its lower reach, resulting from the combined action of summer draughts and water abstraction, very high sediment load and low pollution.

Nutrient dynamics in temporal rivers are controlled by drying out and rewetting. In summer, increased water temperature stimulates biogeochemical cycling in wetted sediments, so called "hot spots". In autumn, flush floods create sediment, solute and pollutant pulses, so called "hot moments". Moreover, wet-dry cycles may also indirectly influence the activity of soil organisms that control carbon and nitrogen mineralisation, sediment respiration, nitrification, denitrification, and ammonia volatilisation.

The main objectives of the study in Krathis were to assess the relative importance of nutrient species, to establish their background levels and trace their sources, to investigate the influence of draught and episodic events on nutrient levels and, finally, to allocate possible nutrient enrichment processes.

Two research scales have been defined; the macroscale, which concerned the whole catchment and based on monthly conventional monitoring, and the microscale, which concerned the lower reach of the river and based on automatic monitoring and inten-

sive campaigns, i.e. installation of piezometers for identifying surface/ ground water interactions, aerial photographs for identifying expansion/ contraction cycles, rebar installation for assessing sediment redox conditions, ecological assessment, substrate investigations and detailed topographical works to estimate the annual rate of deposition. Conventional monitoring included fifteen river stations (main stem and tributaries), two precipitation collectors and additional rain samples on an event base, four lysimeters and ground waters. Moreover, soils from different land uses and sediments from surface and core reach sediments ($\sim$25 samples) were examined. Discharge and physico-chemical parameters were determined in-situ. Water samples were collected and analysed for major ions, silicate, nutrients and DOC. Suspended matter was analysed for organic and total C, total N and total P. Sediments were additionally analysed for AFDM and organic P and XRF, XRD analyses have been performed. The automatic monitoring system was comprised by a meteorological station, a precipitation station, a gauging station for on-line measurement of water level and physicochemical parameters and an auto-sampler equipped with a water level actuator for sampling during episodic events and during the drying out process.

Compared to major Greek rivers, the levels of dissolved nutrients, except of TP, were substantially lower. In contrast, as a result of fluvial erosion, particulate nutrient concentrations were comparable with those of large polluted permanent rivers. Nutrient background levels, except of TP, were found to be lower than of nearly "pristine" European rivers and rather lower than the thresholds estimated for Greek reference streams. Nutrients and organic carbon were preferentially present in dissolved form than in particulate form, whereas the particulate/dissolved ratio increased downstream together with the increase of particulate matter concentration. A substantial part of dissolved nitrogen and phosphorous was in the organic form (in average 72 and 89%). A gradual downstream increase of dissolved inorganic N together with a decrease of dissolved organic N concentrations balanced their differences at the lower reach of the river. Reference forested areas and lysimeters located in forest land uses were enriched with ON and OP. In addition, particulate matter showed a substantial upstream enrichment in C, N and P percentages. These results provide evidence for the contribution of forest soils (transport and leaching) to the enrichment of the river with organic nutrients. Other sources of the examined nutrient species are precipitation, agriculture and point pollution. In a monthly base, hydrological factors controlled riverine nutrient variations and nutrient enrichment mainly resulted from flushing processes. Since there are no interactions between surface and ground waters at the reach (due to the low ground water table and the low permeability of the aquifer deposits), there was no notable enrichment of dissolved nutrients during the dry period. In contrast, flood events marked the reach area. The inundated area during the peak discharges was 5 times higher than during summer. In addition, the annual mean deposition in the reach

has been estimated at 7.7 cm. During episodic events substantial transport of sediments and associated nutrients took place (up to 17, 25, 27 and 58-fold enrichment for sediment, organic P, TN and TP respectively, compared to the annual average). In addition, a general ammonia and dissolved ON increase was evident. Suspended matter entering the reach revealed higher organic matter, organic C and N content compared with the reach sediments, whereas for P the opposite was evident. Moreover, the reach sediments, which presented low biological productivity and diversity, revealed oxic conditions. It is speculated that mineralisation processes drop the concentration of organic matter in the reach sediments, whereas P adsorption on the carbonate rich sediment fraction retains P in the reach.