Karstic submarine groundwater discharge into the Mediterranean: Radon-based nutrient fluxes in an anchialine cave and a basin-wide upscaling

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Anchialine caves are common in Mediterranean karstic shorelines and elsewhere, delivering point-source fresh groundwater and nutrients to the coastal ocean. However, there are few reports on whether these highly stratified anchialine ecosystems can drive red tide occurrence. Here, we first quantified submarine groundwater discharge (SGD) in a typical karstic ecosystem (Zaton Bay, Croatia) affected by anchialine caves using a ^{222}Rn mass balance model. We then combine our new estimates with the literature to provide a Mediterranean-scale estimate of karstic fresh SGD nutrient fluxes. We found that SGD and related nutrient fluxes in the upper brackish layer were much higher than those in the underlying layer. In the upper brackish layer, both SGD (m d^{-1}) and associated nutrient fluxes (mmol m^{-2} d^{-1}) in the wet season (SGD: 0.29−0.40; DIN: 52; DIP: 0.27) were significantly higher than those in the dry season (SGD: 0.15; DIN: 22; DIP: 0.08). Red tides were observed in the wet season but not in the dry season. Nutrient budgets imply that SGD accounted for >98% of the total dissolved inorganic nitrogen (DIN) and phosphorous (DIP) sources into Zaton Bay. These large SGD nutrient fluxes with high N/P ratios (190−320) likely trigger and sustain local red tide outbreaks. Combining our results with 28 previous studies in the Mediterranean revealed that point-source DIN and DIP fluxes via karstic fresh SGD may account for 11−32% and 1−6%, respectively, of riverine inputs in the Mediterranean Sea. Therefore, this study demonstrates the importance of karstic SGD as a source of new nutrients to the Mediterranean Sea and emphasizes its relevance for coastal biogeochemical cycles.