Accumulation of organochlorine pesticides in reef organisms from marginal coral reefs in South Africa and links with coastal groundwater

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Background

Coral reefs support rich levels of biodiversity, but are globally threatened by a multitude of factors, including land-sourced pollutants. Coral reef communities found along the Maputaland coastline on the north-east coast of South Africa constitute the southern limit of their distribution in the western Indian Ocean. Although the reefs are protected within the iSimangaliso Wetland Park World Heritage Site, and are relatively pristine, they are potentially subjected to anthropogenic impacts. Long-term monitoring at Nine-mile Reef over the past 25 years has indicated a steady decline in soft coral cover of almost 1\% per year. Due to their marginal geographical location, these communities have not been significantly affected by bleaching and receive negligible direct fluvial input. Factors contributing to the long-term decline in soft coral cover at this location therefore remain unknown. However, these reefs are located adjacent to an extensive coastal plain that is host to several large lakes and expansive wetlands, where high concentrations of organochlorine pesticides (OCPs) have recently been detected. This led the authors to postulate that the decrease in the cover of soft coral at Nine-mile Reef may be attributable to the chronic effects of OCP exposure via groundwater seepage from an adjacent coastal lake, Lake Sibaya. This study aimed to quantify OCP concentrations in the tissues of two common species of soft coral and a sponge from the Central and Southern Reef Complexes in Maputaland. We hypothesised that a contamination gradient exists, with concentrations decreasing from Regal Reef in the north, situated adjacent to Lake Sibaya, a likely source of the pollutants, southward to Leadsman Shoal.

Methods

Concentrations of organochlorine pesticides (OCPs) in the soft corals \textit{Sarcophyton glaucum} and \textit{Sinularia gravis}, and in the sponge \textit{Theonella swinhoei} were quantified at five sites along the Maputaland coast, South Africa. Sites were specifically chosen to extend along the coast at regular intervals, so that gradients and point sources of pollutants could be detected if present. A solid phase extraction procedure (QuEChERS) was used to extract 18 OCPs from the samples. The analysis was performed using an Agilent 7890B gas chromatograph (GC) coupled to a Leco Pegasus 4D GCxGC Time-of-Flight mass spectrometer. Quantification was performed against high purity (>98\%) reference standards purchased from Dr. Ehrenstorfer GmbH (Augsburg, Germany) and Supelco (Bellefonte, PA). Pesticide concentrations were expressed as ng.g\textsuperscript{-1} wet weight (ww). Lastly, nitrogen isotope signatures (δ\textsuperscript{15}N) of the holobiont were determined for \textit{S. gravis} colonies at each site to assess the potential influence of groundwater discharge on spatial variations in OCP concentrations, using an elemental analyser connected to an isotope ratio mass spectrometer. The primary hypothesis was tested with a permutational multivariate analysis of covariance, where distance from the
hypothesised pollution source was included as a covariate and fitted first, before variation among sites and species were tested.

Results
Markedly high levels of a range of OCP residues were detected within tissues, with total concentrations (ng.g$^{-1}$ ww) ranging from 460 to 1200 (Sarcophyton glaucum), 1100–3000 (Sinularia gravis) and 450–1500 (Theonella swinhoei), respectively. A statistically significant decreasing gradient in total pesticide concentrations was detected southward from Regal Reef, opposite Lake Sibaya, the hypothesised source of the pollutants. Sinularia gravis contained significantly higher pesticide levels than both S. glaucum and T. swinhoei, which did not differ significantly. The ratio of dichlorodiphenyltrichloroethane (DDT) with one of its metabolites (DDE) was higher than one at all five sites. Significant differences in $\delta^{15}$N among sites were detected a priori, but post hoc tests determined that differences were non-significant. A positive relationship was found between total pesticide concentration and $\delta^{15}$N in S. gravis, although not statistically significant.

Conclusions
Our study found some of the highest levels of OCPs in coral reef organisms globally. An obvious north-south OCP concentration gradient was evident, which appears to reflect terrestrial environmental gradients and suggests that OCP contaminants are probably introduced via groundwater discharge into the coastal zone. Observed gradients in pesticide concentrations, DDT:DDE ratios and nitrogen isotope signatures all suggest coastal groundwater to be the likely source of the pollutants. Further studies are planned to determine the full scale and extent of the pollutants, and to assess the potential ecotoxicological impacts of these contaminants at the organismal and ecosystem level.