Groundwater-ocean interaction and its effects on coastal ecological processes – are there groundwater-dependant ecosystems in the coastal zone?

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In aquatic ecosystems, water fluxes are key drivers of ecosystem functioning. Like river flow, terrestrial (fresh) groundwater fluxes and the recirculation of seawater through sediments can have 'downstream' biogeochemical and ecological effects. Emerging evidence for hydrological-ecological coupling in diverse tropical coastal ecosystems, including the examples below, invite the question if we should not consider these coastal ecosystems to be groundwater-dependent, in analogy to groundwater-dependency in freshwater aquatic systems.

Groundwater-supported freshwater vegetation in the intertidal zone

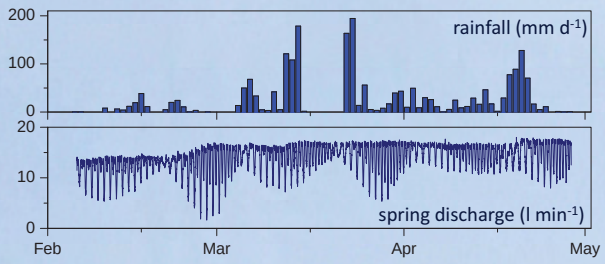

Figure 1a: Long-term time series of groundwater discharge flux recorded with automated seepage meters indicate a tidal modulation and a substantial time lag between recharge and discharge.

Perennial fresh groundwater discharge from a confined aquifer system in coastal sand dunes has for long been a source of water for local Aboriginal people in north-eastern Australia. The discharge from 'springs' permits the growth of freshwater-dependent vegetation in the intertidal zone. The tide interacts with the hydraulic head in the aquifer in a way that effectively 'squeezes out' the freshwater from the aquifer, resulting in a net positive discharge throughout the tidal cycle (Holliday et al, 2007).

Figure 1b: Melaleuca trees usually associated with freshwater swamps are here growing in the intertidal zone, with their roots inundated by seawater at every high tide.

The 'Mangrove Pump' – crab burrows, tree health and the carbon cycle

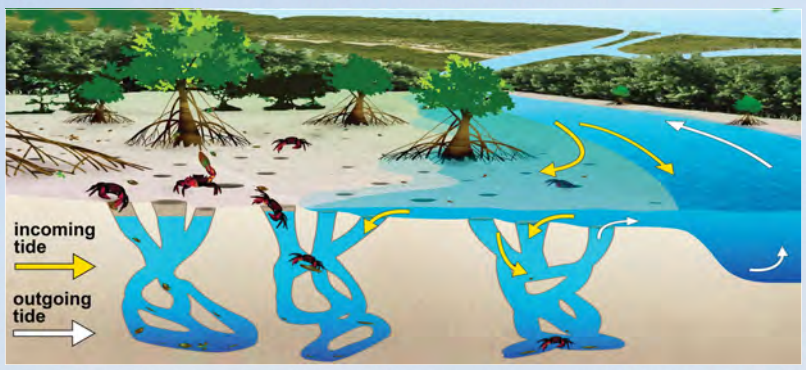

Figure 2: Water flow paths in the mangrove pump (Stieglitz et al, 2013).

More and more studies show that groundwater flow is an important transport path of nutrients and other dissolved matter to the coast (e.g. Slomp & Van Cappellen, 2004). Tidally-driven seawater circulation through animal burrows in mangroves provides an efficient pathway for removal of excess salt accumulated in the soil due to exclusion of salt during water uptake by the tree, thereby directly contributing to tree and ecosystem health (Stieglitz et al, 2000). Annual average circulation fluxes through mangrove burrows are of the same order of magnitude as annual river discharge in the central Great Barrier Reef (Stieglitz et al, 2013), and transport with them a substantial amount of organic and inorganic matter to the coastal zone.

Groundwater-fed refuge habitats of the Caribbean queen conch

The queen conch *Strombus gigas* is one of the most important fishery resources of the Caribbean region. Despite being a 'truly marine' animal, considerable populations of this marine snail live in groundwater-fed coastal inlets along the Mexican Yucatan coastline (Peel & Aldana 2012). There, perennial groundwater discharge supports a permanent stratification of freshwater overlying seawater. These to date 'un-accounted' nearshore habitats constitute an important refuge and nursery ground for this species: juveniles tend to live closer to the freshwater source, and animals move towards the mouth as they grow older before finally leaving the inlet to the ocean (Stieglitz & Dujon, in review). The ecological 'reason' is unclear to date. Perhaps the freshwater 'blanket' protects the juveniles from predation (as 'offset' for benthic oxygen stress caused by the stratification). These findings provide important information for fisheries management of this threatened mollusc species.

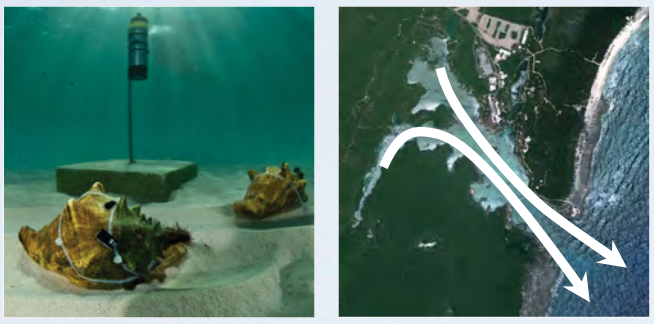

Figure 3: Tagged conch & acoustic receiver and long-term movement patterns of queen conch documented by acoustic telemetry.

Groundwater-Dependent Ecosystems

… rely on groundwater for some or all of their water requirements (e.g. Eamus & Froend, 2006). Typical examples are wetlands without standing water. Often, groundwater flow creates unique habitats supporting a comparatively high biological diversity and productivity.

Acknowledgements: P Ridd, P Cook, E Deemal, D Holliday, J Clarke, G Hancock and G Brunskill and others collaborated in the work in the Great Barrier Reef, and E Amice, A Dujon, J Peel, L Chauvaud, D Aldana-Aranda, Parque Xel-Ha and others supported recent work in Mexico. I gratefully acknowledge funding support from the Australian Research Council, James Cook University, the European Union FP7 Marie Curie International Incoming Fellowship program, the Laboratoire des sciences de l'environnement marin LEMAR and Europole Mer. Sebastien Hervé provided graphics support. Finally, I thank B Burnett, H Bokuniewicz, M Taniguchi & C Rocha for co-chairing the Europole Mer Gordon-like conference 'Land-Ocean Connectivity - from a Hydrological to Ecological Understanding of Groundwater Effects in the Coastal Zone' in Aber W'rach (France) in September 2012, and the speakers and attendants at that meeting for their great contributions in the brainstorming exercise.

References: Derek E & Froend R 2006. Australian Journal of Botany 54, 91–96; **Holliday D, Stieglitz T, Ridd P & Read WW 2007**. Journal of Geophysical Research 112, C04015. **Peel JR & Aldana AD 2012**. Revista de Biologia Tropical 60, 127-137. **Slomp, CP & Van Cappellen P 2004**. Journal of Hydrology 295, 64-86. **Stieglitz TC, Clark JF & Hancock, G 2013**. Geochimica Cosmochimica Actae 102, 12-22. **Stieglitz TC & Dujon A**, in review. Marine Ecology Progress Series. **Stieglitz T, Ridd PV & Müller P 2000**. Hydrobiologia 421, 69-76.