A Stable Isotope Snapshot of Exmouth Gulf Ecosystems

An interim report to M.G. Kailis for the Halt the Salt Alliance prepared by [1.] J.N. Dunlop, [2].Luke Twomey and [1.] Mike Van Keulen.

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Background

Exmouth Gulf is a large (3000km$^{2)}$ sub-tropical, strongly tidal, marine embayment. Work by the Australian Institute of Marine Science determined that it is the most productive, unaltered marine embayment on the Australian Coastline). It is located in a semi-arid region and under the prevalent low rainfall / high evaporation conditions is a reverse-estuary with increasing salinity with distance from its entrance. It becomes a typical estuary for short periods following major flood-out events usually, but not always, associated with the passage of tropical cyclones. Its eastern margins support an extensive mangrove system established on ancient terrigenous sediments (the Yannarie wetlands). Similar sediments cover the seabed in the deeper waters of the western Gulf.

There is considerable scientific uncertainty about the drivers for the Gulf's observed productivity particularly in relation to the contribution made to the nutrient pool from marine, inter-tidal and terrestrial sources. Zooplankton biomass and grazing pressure appear to be far in excess of available phytoplankton production (McKinnon & Ayukai 1996, Ayukai and Miller 1998). The highest copepod production occurred in the shallow estuarine waters on the eastern side of the Gulf leading to the postulation of carbon subsidies from the fringing mangrove / algal mat system mobilised by the tidal movements. Intermittent terrigenous (catchment) nutrient inputs may also occur in association with major regional rainfall events with flood-out waters distributed through the mangrove lined delta system. Such an event was clearly visible from space following the passage of Cyclone Bobby. A possible upwelling off NW Cape has been suggested as a source of fresh nutrients for the Gulf ecosystem.

This Yannarie Salt Project (now called Yannarie Solar) would intercept floodwaters from a 70km strip of the mangrove / algal mat system along the eastern Gulf and divert these waters into the Gulf to the north and south of the proposed solar salt pond complex. The significance of this to the input and assimilation of nutrients to the Gulf is of considerable concern to the environmental respondents to the project.

In November 2005 marine scientists organized by the North West Research Association undertook a snapshot stable isotope survey of the Gulf's marine ecosystems with logistic and laboratory -cost assistance from M.G. Kailis. The scientific team worked on a pro-bono basis.

Insights available from stable isotope analysis

Stable isotopes of carbon (^{13}C) and nitrogen (^{15}N) occur naturally in the environment. The ratios of the heavier isotopes to the common forms are changed by biological processes, such as photosynthesis in plants or food metabolism in microbes and animals. These changes in the isotopic ratio are referred to as fractionation. The values given to the stable isotope ratios (delta C or delta N) are measured in parts per thousand (^{o}/oo) and may be positive or negative because they represent variations from standard values.

The stable isotope ratios of nitrogen ^{13}N show stepwise enrichment with trophic level of 3-7^{o}/oo. This lift in value is probably slightly lower in grazers (around 3^{o}/oo) than in predators with protein rich diets (4 -5^{o}/oo) such as seabirds (Hobson 1993 and 1995, Hobson *et al*.1994). Effectively, the nitrogen ratios represent a homogenized measure of “mean trophic level”.

Nitrogen from “fresh” inorganic (nitrate) sources such as from marine upwellings, sewage or artificially enriched groundwater tends to produce relatively high ^{15}N values in the producers (plants) of between 4 and 7 ^{o}/oo. Plants taking up organic ammonia nitrogen tend to have ^{15}N signatures around 2^{o}/oo. Cyanobacteria including the species in algal mats, or forming marine slicks (eg. *Trichodesmium*), have very low ^{15}N signatures. This presumably reflects the gaseous isotope ratios. Thus the first step on the foodchain may be higher or lower depending on the source (s) of nitrogen being used by the producers.

Stable isotope ratios of carbon do not vary predictably with trophic level but most frequently show a slight increase in ^{13}C fractionation of less than 1^{o}/oo. The carbon isotope ratios are however broad indicators of the carbon source at the base of the food chain. (eg. Hobson 1993 and 1995, Hobson *et al*.1994).

The Exmouth Gulf survey - methods

In November 2005 the field team traversed the eastern and western sides of Exmouth Gulf on the trawler Point Cloates collecting plankton samples.

Phytoplankton were collected by passing 20L of unfiltered water through a series of nitex screens with decreasing pore size. Six size fractions (5 μm, 20 μm, 100 μm, 300 μm, 500 μm and 1000μm) were collected at each site by washing the plankton from the nitex screens with GF/F filtered seawater. Each size fraction was collected onto a 25mm GF/F filter paper and immediately stored on ice in the dark.

Landing and diving parties collected algal mat and intertidal surface sediment samples mangrove and seagrass leaves and macroalgae thalli the Simpson Island, Whalebone Island and Hope Point areas. Members of the team visited Simpson, Burnside and Whalebone Islands to attempt to capture shorebirds and collected moulted pelican, cormorant and tern feathers. Recently hatched Bridled Tern eggs were collected from the breeding colony on Whalebone Island.

Green and Hawksbill Sea-turtle eggs (washed out of nest pits) were collected by Fiona Maxwell from nesting beaches outside the Gulf, at Serrurier and Varanus Islands.

The trawl fishery provided recently captured specimens of adult Brown Tiger and Western King Prawns from the catch. The fishery also provided specimens of an abundant, demersal bycatch fish species, the Asymmetrical Goatfish *Upeneus asymmetricus*.

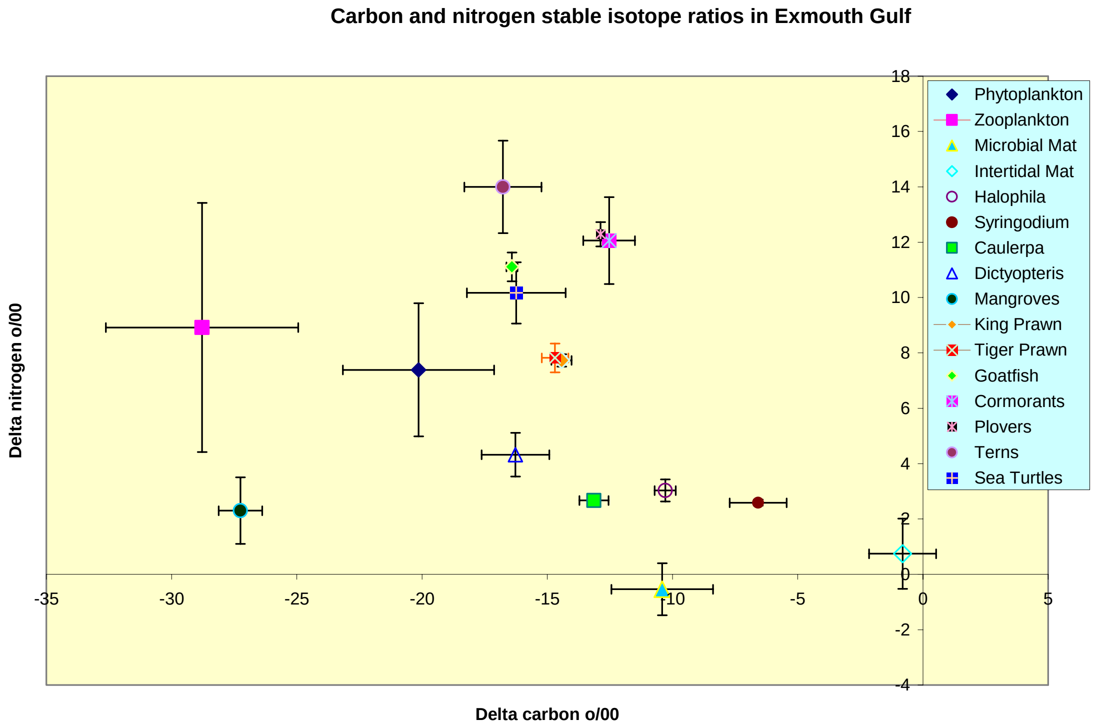
Plankton, benthic micro-algae and sediment samples (100 μg) were oven dried on 25mm Whatman GF/F filter papers at 60° C for 6 h. The dried filters were placed into a desiccator with HCl to disperse unincorporated N and C. These samples were then pressed into tin foil capsules and subjected to mass spectrometry at the Stable Isotope Facility, University of California, Davis.

Goatfish samples were collected by removing scales and skin to expose the white muscle tissue just behind the gills. White Prawn tissue samples were removed from the body in the first segment below the gills. Approximately 100 μg of fish and prawn muscle was removed and oven dried at 60° C for 6 h. Mass spectrometry was conducted at UC Davis.

Plant materials were dried in an oven before being ground down to a powder. Feathers and egg-shell membranes (turtles and seabird) were dried and cut fine. Higher plant, bird and turtle material (2-3um samples) were analysed at the Western Australian Chemistry Centre Stable Isotope Laboratory at the Botany Department of the University of Western Australia.

Results and Discussion

The results of the snapshot stable isotope survey of Exmouth Gulf are plotted in Figure 1. Delta C and N values are shown as means. The error bars are standard deviations. Data for the two mangrove species sampled, two sea-turtle species, cormorants and pelicans, Bridled and Crested Terns were not significantly different (with the small sample sizes) and were combined (ie. shown in Figure 1 as mangroves, sea turtles, cormorants and terns).



As is often the case the plankton samples were quite heterogenous. Size fractionation is an imperfect method of separating trophic levels in plankton as some phytoplankton are larger than zooplankton and many micro-zooplankton are mixotrophic (shifting from being producers to consumers). Blooms of phytoplankton are often episodic and as a result grazing zooplankton may be patchily distributed and the situation may be further complicated in time and space by currents.

For the purposes of this analysis the small (5+20+100 um) and large (300+500+1000 um) fractions have been combined for each sampling station. The small (phytoplankton) samples were significantly different from the larger (zooplankton) samples although the relatively high delta N values might suggest a heterotrophic/ mixotrophic component . The zooplankton delta C did not overlap the phytoplankton signature. This suggests that the bloom in the Gulf at the time of sampling was not the food source utilised by the zooplankton present. This may be related to the previously observed mismatch between zooplankton and phytoplankton production in the Gulf.

The high mean delta N of the phytoplankton (at around 7^{o}/oo) and of the zooplankton would suggest that the pelagic ecosystem is getting much its nitrogen from a ‘fresh’ nitrate source, possibly the upwelling off NW Cape.

There were significant differences in delta C and N signatures values between all the producers sampled with one exception. This was an overlap in delta carbon values between the seagrass *Halophila* and the microbial algae in inter-tidal surface sediments.

The low delta N values (between 2 and 5) for the seagrasses (*Halophila* and *Syringodium*), the macro-algae (*Caulerpa* and *Dictyopteris*) and the mangroves (*Avicennia* and *Rhizophora* combined samples) indicate that all the higher benthic producers were utilising recycled ammonia nitrogen circulating in the estuarine system.

The very low delta N values from the inter-tidal sediment and algal mat samples confirm that the microalgae in these habitats were fixing nitrogen from the atmosphere.

All the consumers sampled apparently derive most of their carbon (energy) from macroalgae, the dominant producers of the Gulf. The analysis may indicate a contribution from the seagrasses particularly in the inshore feeding piscivores (cormorants / pelicans) and in the shorebird (red-capped plover). Although the microbial mat carbon signatures partially overlapped some seagrass and algae the nitrogen delta N values were too low to indicate direct consumption by consumers (eg. the prawn species). Whilst the algal mats may well ultimately contribute significant energy and nutrients to the open waters of the Gulf ecosystem they probably do so, at least beyond the mangrove system, through the decomposition and recycling of their organic material. Perhaps not surprisingly none of the consumers sampled was obtaining their carbon (energy) directly from the mangroves.

The delta N and C signatures for the Brown Tiger and Western King Prawns were not different suggesting a common diet of macro-algae material, at least as adults on the trawl ground. The goatfish would be feeding on herbivour / detritivore invertebrate prey and possibly some macro-algae. The foraging areas for Green and Hawksbill turtles nesting on Serrurier and Varanus Islands are not specifically known. However the delta C and N signatures of their egg shell membranes are consistent with foraging in the Gulf ecosystem.

The two tern species forage in the open sea on pelagic fishes and crustaceans. Their delta C and N signatures indicate a stronger connection with the planktonic foodchain, however much of their energy still seems to be derived from macro-algae (potentially from floating wrack that was present in the western Gulf during our November survey).

Conclusions

- Representative groups of consumers in Exmouth Gulf were deriving their energy primarily from macro-algae and to a lesser extent seagrasses.

- These producers were obtaining most of their nitrogen from recycled, organic forms (eg. ammonia).

- The spring - tidal microbial mat material was not contributing carbon or nitrogen directly to the open water consumers of the Gulf.

- Oceanic sources of nitrate nitrogen were probably contributing to the phytoplankton biomass of the Gulf waters but not directly to the estuarine food-chain.

- For much of the time the production in the Gulf appears to be based on recycling of nutrients. However it seems probable that the nutrient pool would have to be recharged at some stage. The potential importance of infrequent, aperiodic terrigenous inputs cannot be discounted with our current level of knowledge.

- Repeating the stable isotope survey with a few months of a flood-out event may be useful in testing for intermittent terrigenous nutrient subsidies.

References

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