Heavy metal uptake by reef fishes in the Lihir Island Group: importance of gold mine wastes and natural sources of heavy metals

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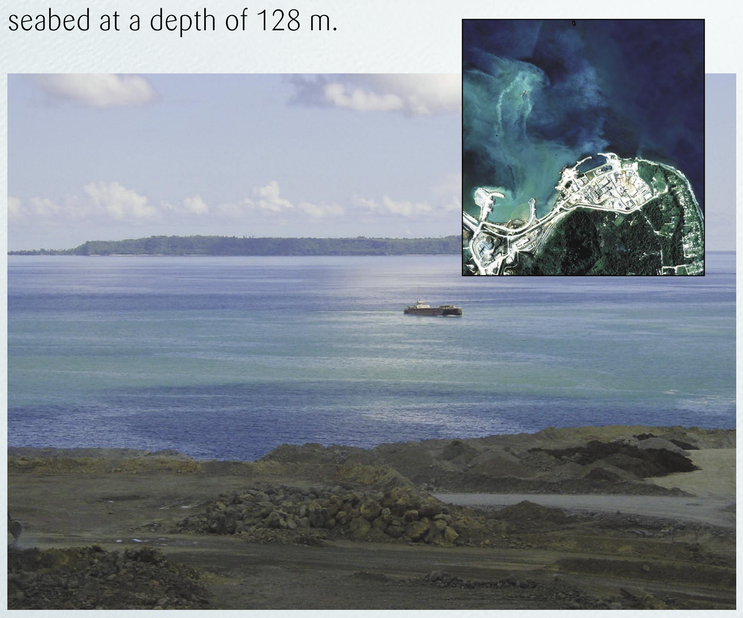
Introduction

Heavy metal uptake from gold mine waste disposal can be a major problem for aquatic animals and lead to a number of chronic illnesses in humans that eat them. Most of the current knowledge of these impacts comes from studies in temperate regions and mainly from freshwater. In the south-western Pacific Ocean, the Lihir Gold Mining Ltd operates a large open-cut gold mine on Niolam Island in the Lihir Island group, northern Papua New Guinea. The Lihir Island group are volcanic seamounts surrounded by fringing coral reefs. The gold mine, which began in 1997, disposes of large volumes of two types of waste (1) excavated overburden, which is dumped about 1 km offshore and (2) tailings slurry from the gold processing plant containing a wide range of heavy metals, which is de-aerated and then pumped out on the seabed at a depth of 128 m.



One of the barges disposing 'soft waste' overburden from the gold mine into Luise Harbour, Niolam Island. Note the sediment-filled water flume extending along shore from the dump site. Mali Island can be seen in the background.

We examined how these sources of heavy metal may have affected the coral reef fish fauna in three ways: (1) muscle and liver samples were analysed for 10 heavy metals (Ag, Al, As, Cd, Co, Cu, Hg, Ni, Pb, Zn) from fish collected both before the mine (in 1994) and in 2000 – 2001. (2) reproductive patterns and fecundity of 58 species of fish were compared between the mine affected region and away from the mine (3) compared the concentrations of 10 trace metals (Al, Ba, Li, Cu, Mg, Mn, Na, Rb, Sr and Zn) in otoliths of fish species from the proximity of the mine outfall and elsewhere.

Analytical approaches

Trace metal concentrations in tissues were measured with Inductively-Coupled Plasma Mass Spectrometry (ICPMS: Silver (Ag), Arsenic (As), Cadmium (Cd), Cobalt (Co), Copper (Cu), Chromium (Cr), Nickel (Ni), Lead (Pb), Selenium (Se), Zinc (Zn)), Inductively-Coupled Plasma Atomic Emission Spectrometry (ICPAES: Aluminium (Al)) and Cold Vapour Atomic Fluorescence Spectrometry (CV-AFS: Mercury (Hg)).

- Transects across otoliths for trace metals (Al, As, Au, Ba, Li, Cu, Mg, Mn, Na, Rb, Sr and Zn) with Lase-ablation ICPMS.
- Water samples taken seasonally adjacent to the mine outfall at 0, 50 and 100 m depth for same suite of trace metals with ICP-AES.
- Detailed studies of the reproductive biology of common deepwater snappers caught adjacent and away from mine dump outfall.

Major findings

- Thirty-eight of the 56 species examined had excessive concentrations in muscle of at least one of the four heavy metals (As, Cd, Hg and Pb) compared with their recommended Australian Food Standard (AFS) concentration.
- Over 70% of fish muscle tissues examined from before and after the mine had As concentrations above the AFS recommended concentration (2 $mg.kg^{-1}$).
- One species, the Orange-lined Triggerfish *Balistapus undulatus* had among the highest As concentrations recorded in fishes anywhere.
- Only two species of fish showed a significant increase in As at the mine site and one had high As and Hg.
- The majority of species had similar concentrations of As in tissue samples collected before and after the mine started.
- Contamination of fish tissues by other heavy metals (Ag, Al, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, Zn) was less widespread.
- Only three species from the recent sampling (2000-2001) had excessive Hg and another two species had elevated Cd and Pb.
- Two species that were abundant in the region of the outfall showed a negative relationship between As concentration and distance from the mine (*Cephalopholis urodeta*: $r^2 = -0.57$ and *Lutjanus timorensis*: $r^2 = -0.82$.
- Limited fecundity and egg size data suggest the reproductive productivity of deepwater snappers *Pristipomoides spp* are much lower near the mine outfall compared to studies of the same species elsewhere.

The Orange-lined Triggerfish is a common species on shallow reefs at Lihir Island. All fish of this species that were examined for heavy metal contamination had high As concentrations (mean 26.8 ± 2.9 $mg.kg^{-1}$ in muscle). (Photograph courtesy of Roger Steene).

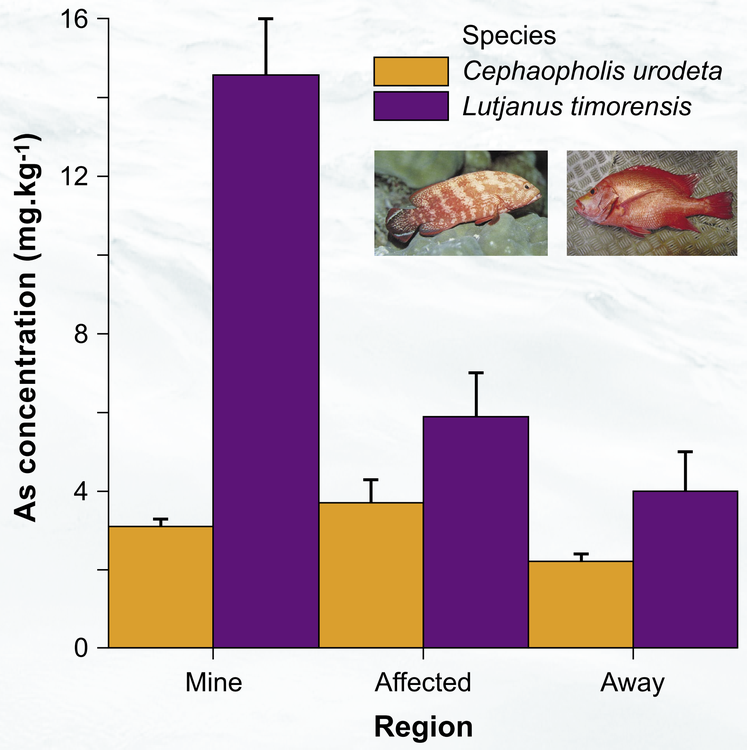
Blotched Seabream, *Wattsia mossambica*

Ruby Snapper, *Aphareus rutilans*

Regal Angelfish, *Pygoplites diacanthus*. (Photo courtesy Roger Steene)

Banded Jobfish, *Pristipomoides zonatus*

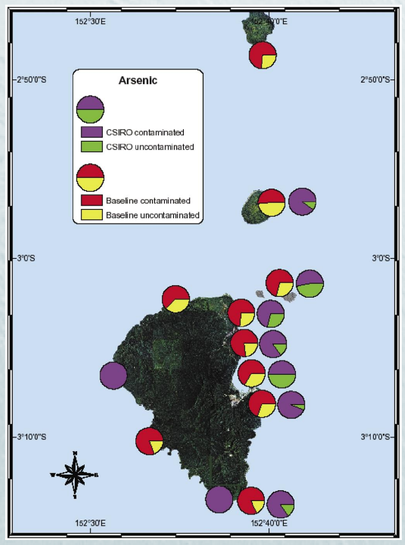
Examples of species from different fish families caught away from the mine that have high As concentrations in their tissues (> 15 $mg.kg^{-1}$).



The mean As concentration (± se) of *Cephalopholis urodeta* and *Lutjanus timorensis* in regions with increasing distance from the Lihir mine outfall site, showing that fish from locations more remote from the mine have lower As.

Interpretation

- These results have important consequences for marine resource use by coastal communities on Lihir Island and elsewhere in the tropical Indo-Pacific.
- The data suggest that most heavy metal contamination in fish was derived from bioaccumulation from naturally-occurring sources.
- Heavy metal pathways through the food web of tropical coral reefs are complex and can involve both natural and anthropogenic sources.
- More detailed analysis of heavy metal bioaccumulation in organisms at different trophic levels in the coral reef community is required.
- Heavy metal speciation in fish tissues is also needed to help assess the human health risk of eating contaminated fishes at Lihir Island.



The distribution of fish samples (species combined) with As concentration in muscle greater than the Australian Food Standards recommended concentration (2 $mg.kg^{-1}$). Pie graphs represent the percentage of samples at each site from the baseline (left) or CSIRO studies that were above the AFS threshold. The mine is located in the bay on the central east coast of the main island.

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