How does gold mine waste disposal affect shallow coral reef fishes and habitats at the Lihir is and group, Papua New Guinea? • D. M. Dennis • D. T. Brewer • T. D. Skewes • G. C. Fry

We assessed the impacts of at-sea disposal of excavated overburden and tailings slurry from the Lihir Gold Mine (Lihir Island Group, Papua New Guinea) on the adjacent shallow reef-fish communities and coral reef habitats. The Lihir Island group, a series of volcanic sea mountains emerging from 2000 m, is situated less than 300 km south of the equator. The Lihir gold mine is situated on the shore of Luise Harbour on the central east coast of the main island, Niolam Island. The assessment of mine impact focused mainly on the effects of mine-derived sediment on the adjacent coral reef habitats and subsequent impacts on the reef-associated fish populations. A second objective of the research was to assess the potential for a sustainable shallow water artisanal or commercial fishery at the Lihir Island group, to address the long-term development of the coastal communities following the mine's closure.



The Lihir mine site in Luise Harbour on the mid-eastern

Island



60 - 50

usi 40

Affected Away

Mine

Mine North South

Region

Mean densities for all fish species recorded during UVC surveys at the Lihir Island group from the General Linear Model used to determine statistical differences between regions using the (a) Proximity to mine region design and (b) Sediment plume region design.

CSIRO divers conducted underwater visual census (UVC) surveys in the summers of 1999, 2000 and 2002 to quantify the distribution and abundance of reef fishes and habitats in relation to the mine site. Analyses of the possible impacts of the Lihir mine on the shallow reef-fish communities were made by comparing species abundance and diversity at different regions, based on their proximities to the mine. At each allocated site a diver estimated the numbers and sizes of all "conspicuous" fishes in a 100 m by 10 m belt transect. All reef-edge habitats from 20 m depth to the reef-crest were surveyed. The reef-edge habitat was characterised by standard abiotic and biotic categories; including live and dead standing coral cover. The reef-edge habitats were classified so that mine impacts could be separated from habitat differences in the statistical analysis. UVC sampling was conducted at 171 (1999), 107 (2000) and 100 (2002) sites on Niolam and Mali Islands providing 22%, 14% and 13% coverage of the 77 km reef-edge perimeters respectively.



Pie charts showing percent covers of eight substrate types at each of fourteen locations sampled around Niolam Island by CSIRO divers during 1999-2002. Note the high percent sand and low percent live coral in Luise Harbour (central eastern Niolam Island).

Rubb = coral rubbleCons = consolidated rubble Boul = boulders Bomm = coral bommies Pave = Limestone pavement Live & Dead = live & dead coral

The estimated densities of reef-fishes from the UVC surveys were low, for tropical reef communities, and comparable between years (530-641 individuals ha⁻¹) and between reefs. The total reef-fish population, given the estimated area of shallow (<20 m) reef (200.44 hectares) was approximately 117,000 (± 5%), 129,000 (± 6%), and 106,000 (± 9%) in 1999, 2000 and 2002 respectively. There were no significant downward trends in abundance for the fish families, which suggests these populations were in a steady state for the years studied. The estimated biomass of shallow water fish at Lihir Island was approximately 80 ±10 t and 86 ±12 t in 1999 and 2000 respectively.

was significantly more abundant in the mine region. Five species, Lutjanus semicinctus, L. fulvus, L. fulviflamma, Monotaxis grandoculis and Siganus lineatus were significantly more abundant in the away region than the affected or mine regions. One species, Naso unicornis was significantly more abundant in the affected region than the away or mine regions. The proximity to mine design (mine, north, south, away) showed similar trends although most species showed markedly different densities in the north and south regions. These regions had comparable habitats, but the mine impact was perceived to be greater in the north due to the northward flow of sediment from the mine dumping. Five species, *Kyphosus* cinerascens, K. vaigiensis, Naso unicornis, M. grandoculis and Lutjanus gibbus showed greater abundance in the north region whilst four species, Naso lituratus, Scarus microrhinos, Chlorurus *japanensis* and *Lutjanus fulviflamma* showed greater abundance in the south.

In summary, although overall species diversity and abundance were significantly lower in the mine region compared to the affected or away regions around the Lihir Island group, the impact was not consistent for all species with some as abundant or more abundant in the affected regions. The impact in the mine region appears to be mainly a result of localised turbidity and sedimentation increases that have affected critical benthic communities, particularly live corals. There was no downward trend in fish abundance during the 3 year study, but the estimated fish abundances recorded cannot be compared with virgin levels since baseline data are not comparable. For this reason, future monitoring using UVC was strongly recommended to evaluate possible long-term impacts of both mining activities and artisanal fishing. Following this recommendation the first repeat survey of the established UVC sites was undertaken by CSIRO in February 2005 and further surveys are planned.

Statistical differences in fish abundance between spatial regions were analysed using a General Linear Model, assuming a poisson distribution in the model and factors: proximity to the mine, year, and reef-edge habitat. 'Year' accounted for possible inter-annual differences in fish abundance while reef-edge habitat accounted for the influence of habitat on fish abundance that may also confound the assessment of impacts of mining. Stratified mean fish abundance and biomass for all fish and fish families were calculated. The potential for a long-term sustainable fishery was based on the estimated fish biomass and published estimates of "sustainable" harvest levels for tropical coral reef fishes.



CSIRO diver monitoring reef fish and seabed habitat on a typical steep Niolam Island coral reef-edge.



CSIRO diver counting shallow reef fishes and recording seabed habitat at Niolam Island. Note the trailing Chainman device used to accurately measure transect

Potential yield calculations were applied to the eight most common fish families recorded during the UVC surveys, as these families were most likely to be commercialized. The yield analysis showed that even with a high exploitation, the estimated harvest of fishes was relatively low at 24.9 – 27.9 t/year and it was unlikely the shallow fish populations could support a large commercial harvest, in addition to current harvest used for subsistence.

	Mine Region		Affected Region		Away Region	
Species	Mean	SE	Mean	SE	Mean	SE
All (***)	12.79	3.05	35.54	7.47	70.03	5.61
Chlorurus japanensis (***)	0.16	0.08	0.47	0.10	0.66	0.11
Siganus lineatus (***)	0.00	0.01	0.03	0.04	1.07	0.46
Lutjanus gibbus (***)	3.42	1.42	0.72	0.23	2.11	0.55
Chlorurus microrhinos (***)	0.00	0.01	0.68	0.55	1.65	0.29
<i>Monotaxis grandoculis</i> (***)	0.85	0.31	0.92	0.15	1.90	0.32
Kyphosus vaigiensis (***)	0.11	0.16	0.37	0.22	0.13	0.09
Naso unicornis (***)	0.00	0.01	1.45	0.26	0.59	0.16
Lutjanus semicinctus (***)	0.49	0.27	0.66	0.17	2.59	0.44
Lutjanus fulviflamma (***)	0.12	0.21	1.79	0.42	5.41	1.02
Acanthurus lineatus (***)	0.47	0.24	1.53	0.27	2.05	0.37
Macolor niger (***)	0.66	0.39	2.22	1.24	2.23	0.49
Lutjanus fulvus (***)	1.41	0.53	1.39	0.65	3.97	0.62
Scarus niger (***)	0.27	0.13	2.42	0.84	2.70	0.26
Naso lituratus (***)	0.63	0.29	2.64	1.58	2.24	0.35
Kyphosus cinerascens (***)	0.67	0.99	2.53	1.75	6.24	1.65

A total of 23,318 fishes from 110 species and 16 families were recorded during the UVC surveys in 1999, 2000 and 2002. The most speciose families were Scaridae (Parrotfishes; 18 species), Lutjanidae (Seaperches; 17 species), Serranidae (Groupers; 16 species), Acanthuridae (Surgeonfishes; 11 species) and Lethrinidae (Sweetlips; 8), typical of reef fish communities of the Indo-west Pacific. A total of 23 species from nine families were ubiquitous around Niolam and Mali Islands and these species were identified as suitable indicator species for long-term impact assessment. A total of 35 species were found in Luise Harbour, including the eight ubiquitous lutjanids and five lethrinids. The topsail drummer *Kyphosus cinerascens* was the most numerically abundant species (52 individuals ha⁻¹), followed by Naso lituratus, Scarus niger, Lutjanus fulvus, Macolor niger and Acanthurus lineatus. Each of these species is a potential target of the artisanal fishery at Niolam Island.

Mine Impact Results: The density of reef-fishes was significantly lower in the mine region $(12.8 \pm 3.0 \text{ individuals/transect})$ and the neighbouring regions (Proximity design: north, 39.9 ± 4.2 , south, 39.0 ± 7.2 and Sediment plume design: mine affected area, 35.5 ± 7.5) compared with the away regions (70.0 ± 5.6). The mean number of species observed in the mine region (6.25 per transect) was also significantly lower than the neighbouring (14.4 per transect) and away regions (17.6 per transect). However, this difference may be due to the lower number of sites surveyed in the mine region.

Using the sediment plume design (mine, affected, away), only one of the fifteen most abundant fish species, Lutjanus gibbus Means and standard errors of the fish density estimates (#/transect) from the General Linear Model (GLM) using UVC fish counts for the fifteen most abundant species and all fishes combined and sediment plume region design (Mine, Affected, Away). ***=p<0.001. Light blue shading represents significantly lowest fish density and purple shading represents significantly highest fish density.



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