Qualitative modelling of gold mine impacts on Lihir Island's socioeconomic system and reef-edge fish community

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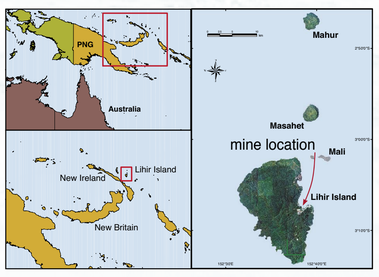
Local communities from the Lihir Island group rely on the fish resources and have a significant impact on many species.

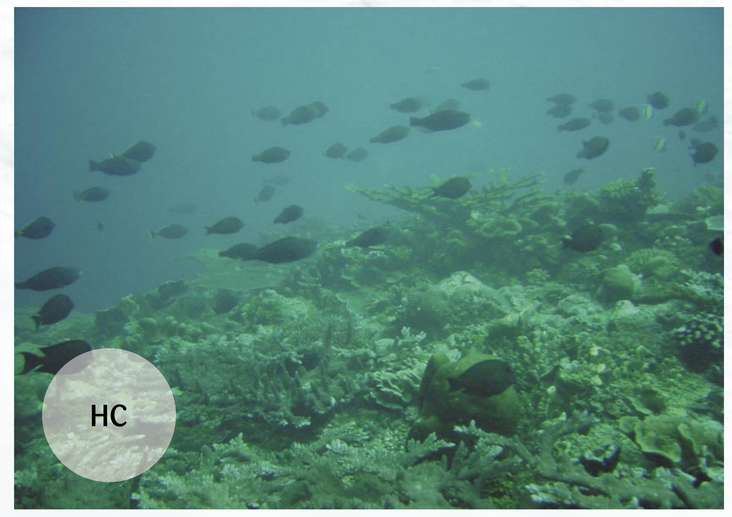
Complex interactions

Inhabitants of Lihir Island, Papua New Guinea, have a local economy based on reef fishing, rotational farming of slash-burn forest plots, and royalty and compensation payments from the island's gold mine. Direct effects of the gold mine have primarily been two-fold: through cash flow into the island's socioeconomic system and sedimentation effects to reef-edge coral communities.



Lihir Island group; Niolam (Lihir), Mali, Masahet and Mahur Islands, off the north-eastern coast of New Ireland Province, Papua New Guinea.

Studies of the island's human population have documented changes in population size, local customs (*e.g.* feasting), education, and rates of forest clearing, and studies of the reef biota have revealed measurable differences between sites with and without sedimentation from mine wastes. The flow-on effects of these impacts are complex and potentially overwhelming when viewed only from within isolated studies. Understanding the interdependence and implications of these impacts requires a holistic approach addressing the structure of both the marine fish community and human socioeconomic system. In this study we have applied qualitative modelling as a tool to approach the complexity of Lihir Island's human and ecological system.



The model correctly predicts a decrease for herbivorous scrapers (e.g. scarid fishes shown here) in mine-affected areas where coral mortality is higher.

Schooling sphyraenids, one of many pelagic predators around the Lihir Island group.

Qualitative models

Qualitative models are based upon the linkages between variables in a dynamic system. Variables in biological systems are interacting populations of different species, and their dynamics can be accounted for by the Lotka-Volterra equations, wherein each contributes towards either the birth or death of another (Dambacher *et al*. 2002, 2003 a&b). Similarly, dynamics of human social and economic systems can be accounted for by interactions between different sectors and entities of society (*e.g.* governing bodies, social customs, *etc*.) that control flows of resources, goods, and services that are measurable, such as money, but also immeasurable, such as status and world view. Qualitative modelling provides a flexible theoretical framework without measurement of system parameters, and seeks generality in the understanding of complex systems by including relevant but immeasurable details, thus capturing the essential dynamics of whole system.

A model of the reef-edge fish community was constructed based on the major functional groups of organisms associated with the coral habitats in shallow (<30 m) water. Fish species were combined into functional groups based on their feeding habits and associations with coral. A socio-economic model was constructed based on observations and survey data gathered during the study of impacts of the gold mine upon resource use and culture of Lihir Islanders. The model reflects the major causal links connecting cultural norms and attitudes towards land use, as affected by the infusion of royalties and cash compensation into the island's economy (figure 1).

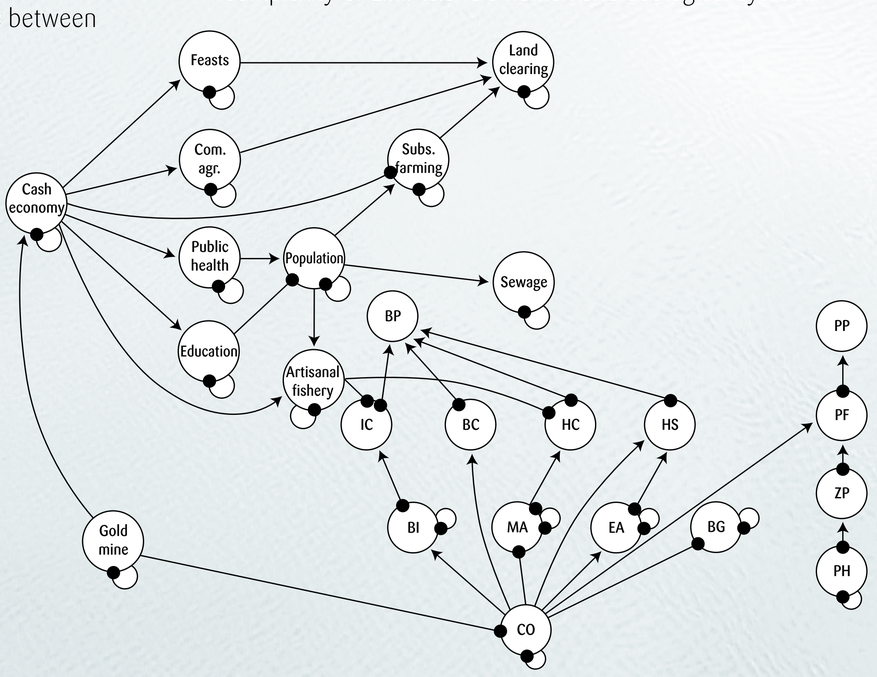


FIGURE 1. Signed digraph of socio-economic and shallow water reef-edge fish community for Lihir Island. Direct effects between model variables are shown by links ending in arrows, for positive effects, or filled circles, for negative effects; self regulation of a variable is shown by links connecting a variable to itself. The gold mine provides input to the island's cash economy and introduces sediment into nearshore habitats. BC, benthic coral cropper; BG, blue-green (inedible) algae; BI, benthic invertebrates; BP, benthic piscivorous fish; CO, coral; EA, epiphytic algae; HC, herbivorous cropper (fish); HS, herbivorous scraper (fish); IC, benthic invertebrate consumer (fish); MA, macroalgae; PF, planktivorous fish; PH, phytoplankton; PP, pelagic piscivorous fish; ZP, zooplankton; Com. agr., commercial agriculture; Subs., subsistence.

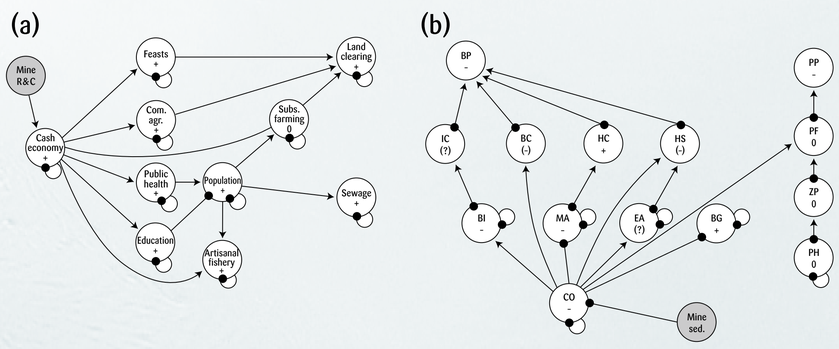
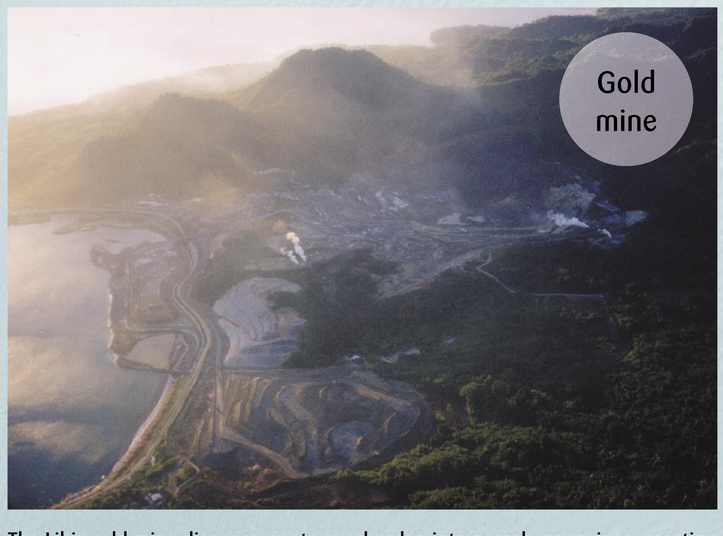
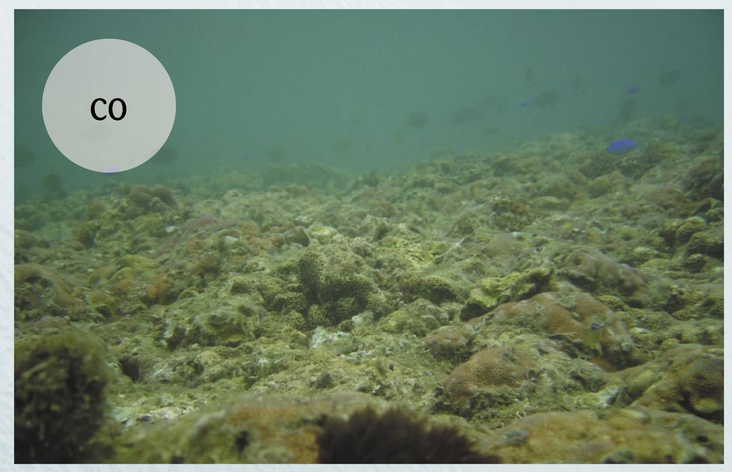


FIGURE 2. Signed digraph of reef-edge fish community as in Fig. 1, showing responses of model system to (a) increase in the cash economy, and (b) mine wastes that impact corals. Qualitative predictions of change in variable are shown as "+" for increase, "-" for decrease, and "0" for no change. Responses enclosed by parentheses are potentially ambiguous, and those denoted by "?" are strongly ambiguous. Shaded circles denote source of perturbation.



The Lihir gold mine disposes waste overburden into nearshore ravines, creating local sediment plumes; and deep sea tailings (at 128 m depth) from the processing plant, containing heavy metals and other waste.



Coral reef habitat supports much of the biological marine communities around the Lihir group of islands. This photo shows an affected reef that has been colonised by algae.

Qualitative models

The influx of cash into the Lihirian economy is predicted to increase the size of the human population, rate of land clearing, production of sewage, and intensity of artisinal fisheries (figure 2a). The intensity of subsistence farming is predicted to remain unchanged.

Model predictions (figure 2b) were consistent with observed difference in fish abundance between sites affected and unaffected by mine sediments. The model correctly predicted observed differences in herbivorous croppers and scrapers. However, predictions for benthic invertebrate consumers are ambiguous, while their abundance was significantly lower in impacted sites. Another perturbation scenario (not shown here) considered the impact of increase in the artisinal fishery for benthic invertebrate consumers and herbivorous croppers. The model predicts the two target species to decrease, and benthic coral croppers, invertebrates, and macroalgae to increase. No change is predicted for other model variables.

The modelling techniques presented here provide a useful first attempt at describing the whole island system of Lihir as it is currently known. Where possible we have validated model predictions based on effects measured from various impact studies. The models developed will be used to structure future research hypotheses and directions. This approach has great potential to provide a predictive ability to the management of these land/water/social interactions in the years ahead.

References

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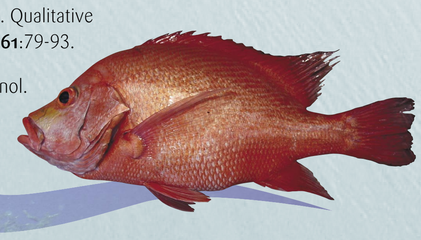

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