How to Analyze Fish Community Responses to Coral Mining

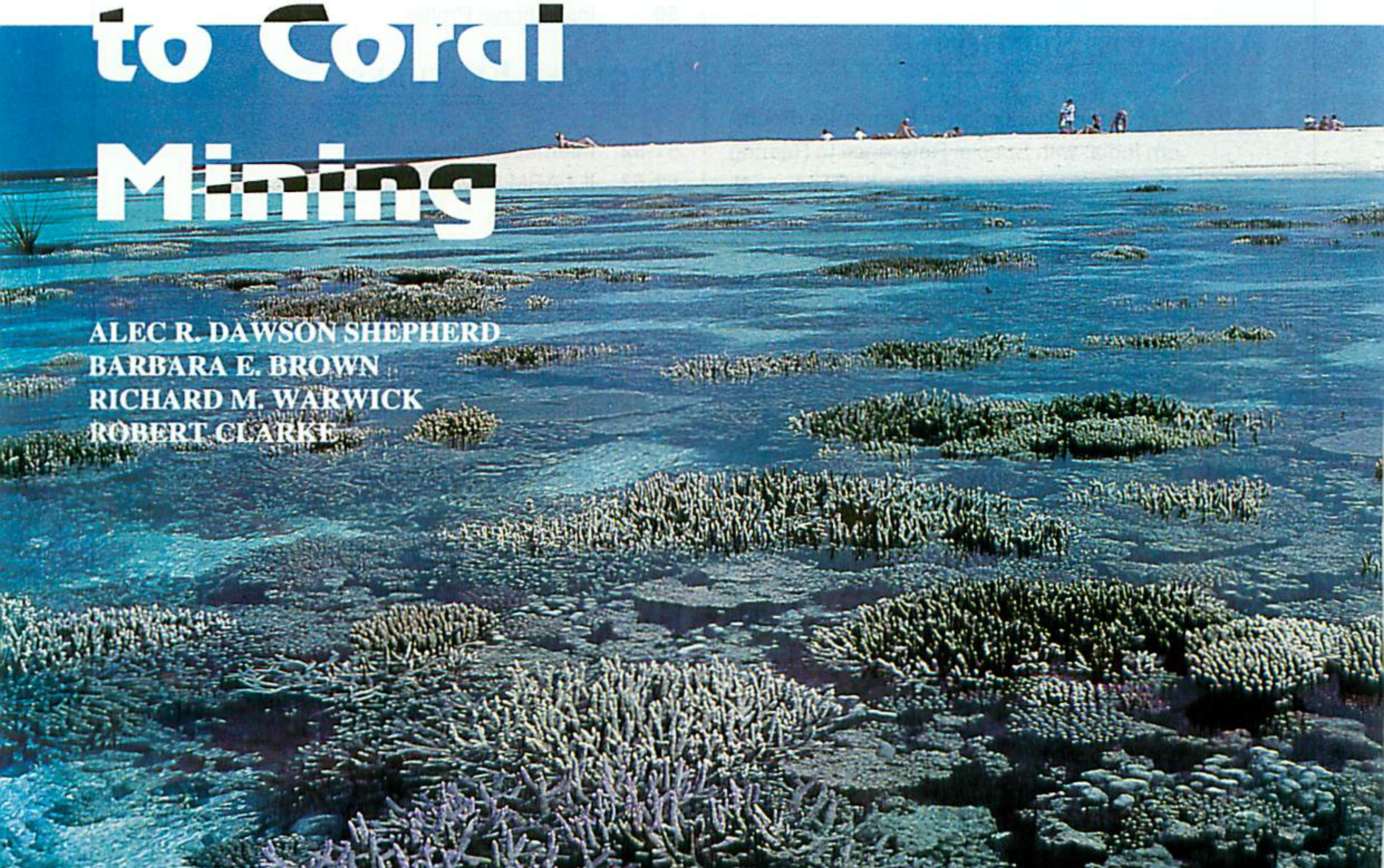
ALEC R. DAWSON SHEPHERD
BARBARA E. BROWN
RICHARD M. WARWICK
ROBERT CLARKE

Introduction

Environmental change is an important issue facing the global community in the last decade of the 21st century. As scientists, we hope that political decisions will be based on the scientific evidence for change. Honest politicians and their supporters hope the same thing. However, we all know from any courtroom drama, or from the statistics that are the sword and shield of political infighting, that evidence for change can be presented in a number of different ways and mean different things to different people.

Fortunately as scientists, we are merely required to provide the evidence for change. Unfortunately we are still working out what change is and how to present impartial evidence for it.

In our paper "An analysis of fish community responses to coral mining in the Maldives," we investigated ways of evaluating the effects of environmental



Profuse coral reefs

degradation from coral mining on reef fish communities. The investigation involved a process which included asking the right question and then answering that question through data collection, data analysis, and data presentation.

Method

Asking the right question

The more specific the question, the more accurate and efficient the process and the less chance for misunderstandings. A vaguely worded question may encourage the collection of unnecessary information and can be interpreted differently at different stages of the investigative process.

The question should contain a causal (independent) variable and a variable that is affected (dependent). It should be answered by using information gained by sampling ... a sample is a discrete set of information.

In our mining study the independent variable was coral mining and the dependent variable affected by coral mining was fish community structure.

Definition of variables

The question is likely to be more specific if the variables that constitute the question are more rigorously defined.

Coral mining and reef fish community structure were both defined in the paper. Coral mining was defined qualitatively. Mined reef flats were characterized as "stripped almost bare of coral." Nonmined reef flats were not. Reef fish community structure was defined as the relative numerical abundance (or biomass) of a restricted list of fish species.

The criteria for selecting fish species to characterize the community were that they be representative species from a variety of trophic groups and/or that they were fish of importance to various fisheries.

Unfortunately it can be argued that neither the definition of coral mining, nor the definition of reef fish community structure was very comprehensive. Ideally they should both have been derived from investigative studies themselves before proceeding to the main question. This was not done and is a flaw in the work. All that can be said in defense said in defense of this is that the definitions have remained standard through the data gathering process.

Controls and sampling

In this study, common sense requires that samples of reef fish communities be taken in mined and nonmined reef areas and any differences be identified and compared. In making this comparison it is critically important that some samples are controls. Controls are samples that are taken outside the influence of the causal (independent) variable but from an otherwise identical environmental regime. Each sample should also be taken in an identical fashion or it will not be a standard reflection of the environment it is sampling.

Unfortunately, in natural systems it is extremely difficult to meet the requirement that the controls are both independent of the independent variable but also under the same regime. An lack a control. There would be no way of confirming that any change that occurred was solely due to the influence of the independent variable.

If the samples are taken from different places, they may be under different regimes. For example, if fish communities are sampled in obviously different environmental regimes like the Caribbean and the Pacific, the major differences will be zoogeographic (there are few species common to both areas) and probably not due to coral mining. Of course this is an extreme example but more subtle factors need to be avoided or the control may be invalidated.

In the case of the mining study there was a geographic problem in providing a control. Nearly all mined reef samples had to be taken from one atoll and all nonmined ones from other atolls. It could be argued that observed differences were due to zoogeographic differences. Fortunately, analysis showed that one nonmined site in the mined atoll clustered

The Maldives is a nation of coral reefs and coral reef formed, and protected, islands in the Indian Ocean.

ecosystem, for example, is to a greater, or lesser, extent interdependent.

Sampling repeatedly at the same site does not avoid this problem and so may

with nonmined sites in other atolls, suggesting that there were no significant zoogeographic effects.

The way of getting around the

contradictory conditions for an ideal control is to cover for all possibilities and sample randomly in time and space for the effect of the independent variable.

If the samples that are influenced by the independent variable differ in a significant way from those that are assumed to be controls, then it is reasonable to suggest that they are controls and that the observed differences are due to the influence of the independent variable.

If no significant difference is observed, this does not mean that the independent variable has no effect but rather that the assumption that there are controls cannot be validated so the question cannot be answered.

However, a random sampling regime can be extremely time consuming and it is difficult to define the requirements for such sampling without setting conditions that may be biased. Where time is limited it is probably better to concentrate sampling at geographically discrete but environmentally similar sites because geographically discrete sampling allows greater opportunity for cross-checking the validity of assumed controls than does repeat sampling at the same site.

It was not possible to sample before and after coral mining in the coral mining study so the repeat sampling option was not, in any case, available.

As suggested above, it follows from the definition of, and need for, controls that sampling must be standardized for all samples. It is not, for example, appropriate to add new species to the list making up the sample after sampling has started.

In view of the requirement that the species list be fixed, careful thought needs to be put into identifying the list of species making up the sample. Whilst the list could be generated randomly, this was not done.

If random sampling is not used, a pilot study should precede the main study and aim to develop a sampling strategy that minimizes variability between samples, save for those changes in fish community influenced by coral mining. However, to some extent this is answering the question before it is asked. To overcome this problem, it would be better to use a sampling strategy that minimizes variability between assumed control samples. If the variation is large it will be that much more difficult to determine significance between samples for the dependent variable.

In our study, no rigorous method was developed to minimize variability between controls in the coral mining study. Instead, the pilot study was also the main study which was a calculated risk.

The method that was adopted did, to some extent, minimize the risk. We maximized sampling time for rare species and minimized possible variability due to population heterogeneity (like fish schooling) for abundant ones. There were significant differences between mined and nonmined areas, suggesting that sampling variability between controls was less than variability between samples for the factor under investigation.

Given limited time it is probably better to evaluate community differences using abundant rather than rare species and obvious rather than camouflaged and shy species. Variability between controls is less likely to lessen with increased sampling intensity for obvious and abundant species because the probability of an encounter is less likely to increase with increasing time.

In order to validate the assumed controls, we made sure that at least half the samples were assumed controls. In this way maximum opportunity was provided to determine variability between assumed controls.

Processing strategy

A good strategy is to sample information so that it can be entered in rows and columns and preferably without significant manipulation. In our study, each row was a standard observation of numerical abundance of a species making up the community and each column was the community sample.

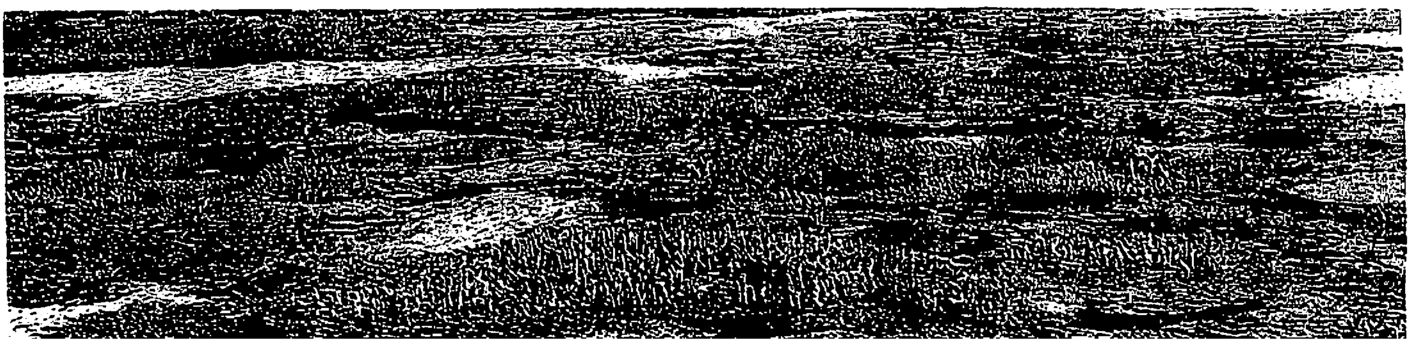
Species	Site 1	Site 2	Site 3	Site 4
a	1	1	1	3
b	2	1	2	1
c	3	1	4	1

Considerable effort was put into standardizing numerical estimates between species in our study because the estimates had been made in two ways. One method producing a standard figure, without the need for subsequent manipulation, would have been more efficient.

Considerable effort was also put into deriving biomass estimates from numerical estimates. The fact that biomass is valuable as a step towards evaluating productivity may not, however, be relevant to the community structure question.

Statistical analysis

Our analysis was divided into semiquantitative and nonquantitative (species presence/absence) methods. Semiquantitative methods can be used to describe overall community change and changes in components of the community. It must be stressed that there



is little point in knowing that the community differs as a whole without knowing how it differs.

Semiquantitative analysis included univariate, graphical/distributional, and multivariate methods. Univariate methods compare a single summary value for communities in mined versus nonmined areas whilst multivariate methods take account of the community structure and allow for an investigation of what it is that makes up the differences between the communities in mined versus nonmined areas. The graphic/distributional methods were targeted at identifying whether or not the stress of mining resulted in community dominance by large numbers of small individuals, as is the case in soft-bottom communities subject to stress.

Results

Perhaps the most significant conclusion from the study was that nonquantitative species presence/absence assessment did distinguish reef fish communities from mined sites from those from nonmined sites.

Univariate methods, including number of species, species richness (Margalef's D), Shannon diversity (H') and evenness (Pielou's J), showed no significant effects from mining. However, both species richness and number of species showed differences between reef flats and reef slopes.

Multivariate methods proved effective in distinguishing mined from nonmined sites and provided effective mechanisms for graphically representing the difference through hierarchical agglomerate clustering (Bray Curtis) and multidimensional scaling ordination (MDS). The species mainly responsible for the Bray Curtis dissimilarity were identified using the SIMPER program. It was possible to use the known feeding habits of component species to investigate the possible trophic basis for any observed differences in community structure.

The graphic/distributional methods showed that the response of reef fish communities to the stress of mining was not the same as has been observed in soft-bottom communities, namely dominance by large numbers of small individuals.

Conclusions

The fact that nonquantitative species presence/absence distinguished mined from nonmined sites argues for the use of this time-effective technique in similar studies. Whilst an investigation based on this technique would not identify differences in abundance, this lack is not necessarily sufficiently critical to justify the significant increase in effort that would provide that information.

The fact that species presence/absence proved effective in distinguishing mined from nonmined sites seems rather contradictory in view of the fact that the univariate techniques generally employed to make management decisions regarding environmental impact, e.g., changes in number of species, species diversity, etc., did not. It can be argued, however, that this insensitivity was based on a restricted species list and that an ideal sampling framework would have been to sample for presence/absence in more species.

Multivariate methods proved effective in distinguishing mined from nonmined sites and in graphically illustrating this. The SIMPER program allowed for identification of the species mainly responsible for the multivariate based difference between mined and nonmined sites. This information gave opportunity for effective investigation into the trophic, and other, community basis for the differences.

A similar approach can be used to investigating any possible links between a defined cause and a possible effect on community composition: Ask the right question. Develop a standardized sampling system that incorporates controls and checks for confirming the validity of controls. Enter information into a rows and columns matrix and carry out appropriate statistical analysis. Present the results in the best way for assimilation by decisionmakers. Do all these things and you are well on your way towards fulfilling your scientific remit to society.

Acknowledgement

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Further Reading

The paper under discussion, which contains all analytical details, is:

Dawson Shepherd, A.R., R.M. Warwick, K.R. Clarke and B.E. Brown. 1992. An analysis of fish community responses to coral mining in the Maldives. Env. Fish. Biol. 33:367-380.

A.R. Dawson-Shepherd *is with the IUCN Project Office, c/o Ministry of Regional Municipalities and Environment, P.O. Box 3461, Muscat, Oman, until April 1994 and after that can be contacted at TMRU Ltd., Department of Biology, University of York, York, YO1 5DD, United Kingdom.* **B.E. Brown** *is from the Centre for Tropical Coastal Management Studies, Department of Biology, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU United Kingdom.* **R.M. Warwick** and **R. Clarke** *are from Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, PL1 3DH United Kingdom.*