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Evidence of fishery depletions and shifting cognitive baselines in Eastern Indonesia

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ABSTRACT

We analyzed fisher interview data collected in the Raja Ampat archipelago of Eastern Indonesia to demonstrate a perceived decline in the abundance of living marine resources targeted by commercial and artisanal fisheries. The decline appeared ubiquitous among all tested species and a clear trend emerged in which older fishers recall greater past abundance than younger fishers. This provides evidence for the shifting baseline syndrome, a dangerous cognitive condition in which each generation of fishery stakeholders accepts a lower standard of resource abundance as normal. We used a fuzzy expert system to standardize and quantify the anecdotal evidence, and combine it with additional depletion indicators to produce a decadal time series of resource abundance from 1970 to present. Using governmental catch-per-unit-effort data from more recent years we hindcasted to establish an absolute scale with which to interpret the perceived decline. The interview information suggested that some exploited species may have declined by as much as an order of magnitude since 1970.

1. Introduction

1.1. Raja Ampat

The Raja Ampat Archipelago lies off the westernmost point of New Guinea in the heart of the Southeast Asia Coral Triangle, a region noted for its exceptional coral reef biodiversity (McKenna et al., 2002; Donnelly et al., in Litt.). The low human population of Raja Ampat and minimal industrial development has ensured that its marine wilderness remains relatively undisturbed. The ecosystem is under threat, however, from human encroachment, logging and mining (Firman and Azhar, in Litt.), while destructive practices such as cyanide/blast fishing and coral harvesting have left marks on its reef system (McKenna et al., 2002; Erdmann and Pet, in Litt.; Donnelly et al., in Litt.). Some marine resources are in decline in Raja Ampat, but sustainable use is a prime concern to as many as 24,000 artisanal and commercial fishers who rely on a healthy marine ecosystem (Dohar and Anggraeni, in Litt.).

Despite a growing awareness of the declines in coral reef fish species here and around the world (Pandolfi et al., 2003) very few data sources exist on the status of marine resources in the remote island chain of Raja Ampat. In order to estimate long-term changes in the assemblage composition, researchers must rely either on historical evidence from naturalist's records (Palomares and Heymans, 2006), or turn to local ecological knowledge held by fishers and community members (Johannes, 1998). Their verbal accounts can be used to reconstruct ecosystem trends, but some effort is required first to

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convert the anecdotal information into a numeric data set representing changes in species biomass.

1.2. Quantifying perceptions of species abundance

Conservation International asked fishers to categorize the exploitation and population status through time for 44 different species groups (representing individual species, families or other taxonomic groupings) in Raja Ampat including fish, invertebrates, reptiles and mammals. This paper uses the fishers' scores of abundance by decade, along with additional depletion indicators and government catch-per-unit-effort data to back-calculate the relative abundance of organisms for the time periods 1970, 1980, 1990 and 2000.

Declines in fish species targeted by fisheries are well documented (Christensen et al., 2003; Myers and Worm, 2003; Rosenberg et al., 2005), but the true magnitude of decline may often escape the notice of scientists and the public due to shifting cognitive baselines in which each generation of stakeholders accepts a lower standard of resource abundance as being normal (Pauly, 1995). In this contribution, we looked for evidence of shifting baselines in the interview information and used the local ecological knowledge to reconstruct what the ecosystem might have looked like before significant exploitation by humans began. We used a fuzzy expert system (also called 'fuzzy logic'; Zadeh, 1965; Bellman and Zadeh, 1970) to combine the information received by interviewees in several fields related to population and exploitation status, and we used those data to infer the relative abundance for each species group by time period. Time series data provided by this analysis will help to improve the scientific understanding of ecosystem changes over time.

2. Methods

2.1. Local ecological knowledge interviews

Between the months of September and December in 2006 fisher interviews were devised and conducted in Raja Ampat (SE Misool Is. and Kofiau Is.) by field staff from Conservation International, the State University of Papua (Universitas Negeri Papua) and the Fisheries Academy in Sorong, Papua with the aim of gathering local ecological knowledge regarding the exploitation and population status of fish, invertebrates, reptiles and mammals. Two hundred and nine fisher interviews were conducted in 13 villages using a convenience sampling approach. Fishers were interviewed opportunistically at workshops and other functions under the Nature Conservancy Coastal Rural Appraisal survey (J. Wilson. The Nature Conservancy – Coral Triangle Center. Jl Pengembak 2, Sanur, Bali, Indonesia, 80228. Unpublished data).

The fishers were interviewed using the questionnaire form presented in Ainsworth et al. (2007) (Appendix C.1; available at www.fisheries.ubc.ca/reports/fcrr.php). Data fields include a qualitative ranking of abundance for 26 families of commercial and artisanal reef fish, as well as species groups for sharks, rays, eels, tuna, mackerel and anchovy. The invertebrate groups refer to octopus, squids, sea urchins and shrimp. Charismatic animals include reptiles (turtles and crocodiles), birds and mammals (Mysticetae, Odontocetae and dugong *Dugong dugon*). Fishers characterized the abundance of each family or species group into one of three categories (high, medium or low) for each period: 1970, 1980, 1990 and 2000. They were also asked to score three yes/no depletion indicators referring to whether the interviewees had noticed a reduction in the abundance of each family or species group, whether they have noticed a size reduction, and whether there had been a price increase. For the price increase indicator, an approximate year was also recorded representing when they considered that the price increase took effect.

2.2. Fuzzy logic approach

Vagueness is inherent in local ecological knowledge responses, but fuzzy logic offers a standardized method to integrate imprecise, uncertain or contradictory information. It allows researchers to address the potential bias of among-fisher interpretations of abundance categories systematically. It is reasonable to assume that fishers may hold different perceptions regarding what constitutes 'high', 'medium' or 'low' abundance. The interpretation may vary with fisher experience, gear type, sector specialization, or demographic attributes. The interpretation may also vary with the species group under review. For example, the abundance change in a targeted species, to which fishers owe their earnings or family's sustenance, may be perceived differently from an untargeted species that hold little commercial or nutritional value.

Fuzzy logic is used in artificial intelligence and control systems to emulate the judgment of an expert in a replicable way. It accepts input or measurement variables representing a certain system condition, and then consults a set of heuristic IF–THEN rules to establish a relationship among variables and determine an overall conclusion. The heuristic rules are similar to 'rules of thumb' that an expert may apply in order to reach a judgment. However, where classical logic might require the input variables to be arranged into crisp sets, for example, a Boolean control variable belonging exclusively to either 'true' or 'false' categories, fuzzy logic can accept a gradation of truth for each input variable in one or more linguistic categories whose boundaries are not sharply defined (Bellman and Zadeh, 1970). The input variable can be viewed as having a degree of 'membership' in each of these categories.

Depending on the set of linguistic input variables, relevant heuristic rules will fire in the fuzzy expert system with certain strengths (i.e., weightings based on the degree of membership) that reflect the certainty regarding the system condition. Each control rule leads to a conclusion about the system status (or appropriate response in the case of a control system). After all relevant control rules fire, the resulting range of possible conclusions is then reduced to a single point output through a 'defuzzification' process.

In the current application, fishers' perceptions of species abundance were categorized into fuzzy data sets so that the threshold between abundance categories is not crisp, but instead accommodates a gradation of membership in several abundance categories. Intermediate scores, which are not easily slotted into one category or the other (i.e., when there is no clear agreement among fishers) can be said to occupy