The good(ish), the bad, and the ugly: a tripartite classification of ecosystem trends

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Marine ecosystems have been exploited for a long time, growing increasingly vulnerable to collapse and irreversible change. How do we know when an ecosystem may be in danger? A measure of the status of individual stocks is only a partial gauge of its status, and does not include changes at the broader ecosystem level, to non-commercial species or to its structure or functioning. Six ecosystem indicators measuring trends over time were collated for 19 ecosystems, corresponding to four ecological attributes: resource potential, ecosystem structure and functioning, conservation of functional biodiversity, and ecosystem stability and resistance to perturbations. We explored the use of a decision-tree approach, a definition of initial ecosystem state (impacted or non-impacted), and the trends in the ecosystem indicators to classify the ecosystems into improving, stationary, and deteriorating. Ecosystem experts classified all ecosystems as impacted at the time of their initial state. Of these, 15 were diagnosed as "ugly", because they had deteriorated from an already impacted state. Several also exhibited specific combinations of trends indicating "fishing down the foodweb", reduction in size structure, reduction in diversity and stability, and changed productivity. The classification provides an initial evaluation for scientists, resource managers, stakeholders, and the general public of the concerning status of ecosystems globally.

Keywords: comparative approach, decision tree, ecosystem classification, ecosystem indicator, exploited marine ecosystems.

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Introduction

Marine ecosystems have been subjected to anthropogenic forcing since humans first learned how to fish many thousands of years ago (Jackson *et al.*, 2001; Lotze and Milewski, 2004; Lotze *et al.*, 2006). That pressure has grown to the extent where serious concern is being expressed about the health of the world's ecosystems (Hollingworth, 2000; Jackson *et al.*, 2001; Pauly *et al.*, 2005; Coll *et al.*, 2008a). Indeed, a recent study has shown that there is now barely any part of the world's oceans that has not been affected at some level by anthropogenic activity, be it fishing, pollution, shipping, or eutrophication (Halpern *et al.*, 2008). In addition, we are living through a period of significant environmental change, the effects of which we are only beginning to explore (Hays *et al.*, 2005; Bender, 2007; ICES, 2008a; Cheung *et al.*, 2009), and which are difficult to predict.

From a fisheries perspective, the traditional approach of single-species stock assessment and management is being replaced by a more holistic ecosystem approach to fisheries, EAF (or variations on that theme; FAO, 2003; Garcia *et al.*, 2003; Daan *et al.*, 2005; Pitcher *et al.*, 2009). EAF still includes single-species stock assessment, but is expanded to include the wider impacts of fishing on the ecosystem, the role of the environment on species and ecosystem dynamics, the impacts of other activities, and the engagement of stakeholders in the processes leading to decision-making (Rice, 2008). The response of the fisheries scientific community has been to develop tools to facilitate an EAF, a basic component of which is the development of ecosystem indicators (Daan *et al.*, 2005), to evaluate the status and dynamics of ecosystems, or components thereof.

One way to use ecosystem indicators in management is to link them to (i) clear objectives, i.e. what is to be achieved, (ii) reference points or reference trends, i.e. measures of management performance, and (iii) control rules, i.e. actions required when management does not meet objectives (FAO, 2003; Cury *et al.*, 2005a). Ecosystem-based objectives, reference points, and control rules are difficult to set because of a lack of theory or because of limitations in the understanding of ecological complexity, uncertainties in data quality and model behaviour, and difficulties in balancing