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Developing a frame of reference for fisheries management and conservation interventions

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ABSTRACT

Effective implementation of management interventions is often limited by uncertainty, particularly in small-scale and developing-world fisheries. An effective intervention must have a measurable benefit, and evaluation of this benefit requires an understanding of the historical and socio-ecological context in which the intervention takes place. This context or 'frame of reference' should include the baseline status of the species of interest, as well as the most likely counterfactual (a projected scenario indicating what would have occurred in the absence of the intervention), given recent trends. Although counterfactuals are difficult to estimate and so are not widely specified in practice, an informative frame of reference can be developed even in data-poor circumstances. We demonstrate this using a case study of the Bangladesh hilsa (*Tenualosa ilisha*) fishery. We combine qualitative and some quantitative analyses of secondary datasets to explore ecological trends in the hilsa fishery, as well as patterns of social, economic, institutional, and physical change relevant to its management over the last ~50 years. We compile all available information on the key parameters that determine hilsa abundance and distribution (movement, reproduction, growth, and mortality), as well as all available information on stock status. This information is used to produce a baseline and qualitative counterfactual which can be used to guide decision-making in this complex, data-poor fishery. A frame of reference provides a systematic way to break down potential drivers of change in a fishery, including their interactions, reducing the potential for unexpected management outcomes. Critical evaluation of contradictions and commonalities between a set of potential counterfactuals, as well as the reliability of sources, allows the identification of key areas of uncertainty and information needs. These can then be incorporated into fisheries management planning.

1. Introduction

An effective conservation or management intervention should have a measurable benefit, and thus requires the specification of an appropriate frame of reference against which it can be evaluated (Bull et al., 2014; Maron et al., 2013). A robust frame of reference should include a baseline that expresses conditions at a fixed point in time (whether a current or past reference state), and one or more counterfactuals (dynamic baselines or scenarios that use background rates of change to estimate potential states of a system in the absence of an intervention; Bull et al., 2016). This baseline and counterfactual should capture ongoing trends in the ecological status of the intervention target (in fisheries management, this will usually be a specific species of interest); as well as the institutional, social, economic, and physical factors driving these trends; and the potential interactions and feedbacks between these factors (Bull et al., 2015; Ferraro and Pattanayak, 2006; Nicholson et al., 2009). Ideally, the development and evaluation of any intervention should consider the historical context within which it operates, using major events and system shifts to understand the main factors driving the dynamics of the social-ecological system (Bull et al., 2015; Pooley, 2013).

Prior development of a counterfactual enables the rigorous measurement and attribution of impact, i.e. the difference between the outcome of the intervention and the estimated outcome in the absence of the intervention (Bull, 2014; Bull et al., 2015; Pattanayak et al., 2010). However, counterfactuals are rarely developed early in the intervention design process and, when they are, they often contain incorrect or vague assumptions (Gurney et al., 2015, 2014; Maron et al., 2013). A common reason for this is lack of data; counterfactuals are subject to numerous sources of uncertainty and it can be challenging to

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develop and validate projected trends when knowledge is poor (Bull et al., 2015, 2014). In fisheries management, uncertainties often limit the ability of policymakers to project trends and predict the effects of management interventions (Davies et al., 2015). These challenges are particularly pronounced in small-scale and developing-world fisheries, where data limitations mean even fixed baselines can be difficult to estimate (Carruthers et al., 2014). Useful counterfactuals can nevertheless be developed in these circumstances, as long as assumptions and limitations are acknowledged; and the process of developing them can highlight key areas of uncertainty which might hinder the development of effective interventions and limit evaluations (Bull et al., 2015, 2014).

Bull et al. (2015) conceptualized and demonstrated a structure for developing a frame of reference in the context of terrestrial biodiversity offsetting. This paper uses the hilsa (*Tenualosa ilisha*) fishery in Bangladesh as a case study to demonstrate the wider utility of this approach in conservation, and its potential value for fisheries management, even when data are limited. The hilsa fishery is currently managed through a combination of regulatory measures, as well as a fisher rehabilitation programme that aims to incentivize compliance with these regulations (Section 3.5.1 and mmc2 in Supplementary material), but since no counterfactuals were developed before the introduction of these interventions, attempts to evaluate impact have lacked rigor (Bladon et al., 2016). The frame of reference developed in this paper combines qualitative and some quantitative analyses of secondary datasets and literature in a qualitative way to explore: a) patterns of social, economic, institutional and physical change relevant to the management of hilsa in Bangladesh; and b) ecological trends in the hilsa fishery. Two plausible qualitative counterfactuals are put forward, which could be used to evaluate potential future hilsa management and conservation interventions.

2. Methods

This frame of reference is structured following the framework of Bull et al. (2015) who demonstrated the approach in the context of biodiversity offsets for the residual ecological impacts of oil and gas extraction in Uzbekistan. We adapted the framework slightly to fit the case study, e.g. we focused on a species target, not a habitat target.

2.1. Brief recent history

First, we took a historical perspective and compiled the key institutional, social, economic and environmental events in the recent history of Bangladesh. We selected these events according to their potential direct or indirect relevance to the hilsa fishery, which we established through literature review and key informant interviews (Bladon, 2016). The resultant figure (Fig. 1) provides a timeline that can be used for reference throughout the results section. Bull et al. (2015) set the context of their frame of reference with 100 years of history, since this is approximately how long Uzbekistan had existed as a defined international entity. We therefore restricted our analysis of Bangladesh to the years since its independence in 1971 – approximately 50 years of history.

2.2. Frame of reference

To develop the frame of reference, we explicitly considered trends in potential physical, social, economic, and institutional drivers of ecological change in the hilsa fishery, before exploring trends in hilsa abundance and distribution – scanning the available literature and analysing secondary data compiled from published literature, online sources, and collaborators at the Bangladesh Department of Fisheries (DoF). This allowed us to establish a current baseline for the hilsa fishery, structured by each of the four categories in our framework and presented in the context of historical change over the last 50 years.

Based on expectations formed through this analysis, we developed a conceptual map of the potential interactions between these drivers, within and between categories. We outlined the key expected interactions between hilsa and drivers of change (i.e. those most relevant to the sustainability of the hilsa fishery) and created two potential counterfactuals, consisting of projections based on these trends and interactions. Together, the baseline and counterfactuals form the frame of reference. Various potential counterfactuals could be projected from the trends presented in this study. We chose two feasible extremes to illustrate the range of potential outcomes, representing the 'most desirable' and 'least desirable' scenarios from the perspective of the sustainability of the fishery. Although this entailed making an implicit value judgement about what is and is not desirable for the hilsa fishery, it also allowed us to make our assumptions explicit. We interrogated the differences between the two potential counterfactuals to identify outstanding areas of uncertainty and their associated management implications. Finally, we highlighted information needs to improve the robustness of the frame of reference as a tool for action and intervention evaluation.

2.2.1. Selection of potential drivers of change

Based on our understanding of hilsa biology, and that of similar species, we identified factors that are known to or would be expected to a) directly affect hilsa populations, and b) indirectly affect hilsa populations. This selection process relied on extensive literature review and interviews with key stakeholders (Bladon, 2016). For each potential driver, we reviewed the literature and assessed secondary datasets for trends, conducting statistical analysis where possible. Here we provide a brief justification for selection of drivers in each category.

2.2.1.1. Physical drivers. The life history of hilsa is known to be influenced by environmental conditions including water salinity, turbidity, flow, temperature, pH, dissolved O^2, and phytoplankton availability (Ahsan et al., 2014; Rahman et al., 2012a). We therefore identified key physical drivers that have been linked to general fish abundance and distribution, to changes in those environmental conditions, or directly to the abundance and distribution of hilsa. These drivers were: climate change, water diversion activities, forest cover, and pollution (see mmc1 in Supplementary material).

2.2.1.2. Social drivers. We identified human population and poverty to be drivers of change in the hilsa fishery (see mmc1 in Supplementary material). Human population size influences the extent of fishing pressure in Bangladesh, because capture fisheries are essential for livelihood support and food security (Belton et al., 2014; FAO, 2014). Human population size also influences the extent of development and infrastructure, including agriculture and aquaculture, which place pressure on hilsa habitat (BOBLME, 2011). In hilsa fishing areas, low income is associated with fishing juvenile hilsa (known in Bangladesh as *jatka*) and with strong fishing dependence, which is characterised by illegal fishing and lack of other livelihood activities (Bladon et al., 2018).

2.2.1.3. Economic drivers. We identified the primary economic activities in Bangladesh, and those which are fast-growing or being explored, and assessed trends in these activities. All of these activities are relevant to the hilsa fishery through the impacts of livelihood availability and wealth on fishing pressure (Bladon et al., 2018). Some of them also have direct or indirect environmental impacts on hilsa populations: agriculture and aquaculture can affect hilsa habitat through eutrophication (BOBLME, 2011): factories can contaminate rivers (Karn and Harada, 2001); and mechanised vessels, shipbuilding, ship breaking, and oil and gas extractive industries can pollute coastal waters (Chowdhury et al., 2017; Hossain et al., 2016). Because of the direct impact of exploitation on hilsa abundance, we focused largely on bioeconomic trends in the fishing industry, looking for trends in commercial catch per unit effort (CPUE) and economic value in the