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Commentary

Paradigm shifts required to promote ecosystem modeling for ecosystem-based fishery management for African inland lakes

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ABSTRACT

Ecosystem-based fishery management (EBFM) is the best option where other fishery management objectives have failed. This makes EBFM important for the African inland lakes and fisheries resources that are among the most threatened in the world despite existing management interventions. Ecosystem modeling provides information that guides EBFM, and, to promote EBFM for the African inland lakes and fisheries, we present strategies required to promote ecosystem modeling. The strategies are based on an examination, presented herein, of (i) publication trends in literature applying two leading aquatic ecosystem modeling platforms, Ecopath with Ecosim (EwE) and Atlantis, on the African Great Lakes as representatives of African inland lakes and (ii) deficiencies in data eminent in ecosystem models existing on these lakes. The examination indicated that ecosystem modeling is inactive on the African Great Lakes, and there is limited local and regional capacity for ecosystem modeling with existing models predominantly led by foreign researchers and marred by data deficiencies. The implications of these observations for ecosystem modeling and EBFM for the African Great Lakes are discussed. The strategies required to promote ecosystem modeling include supporting short-term training workshops to equip local scientists with basic skills for ecosystem modeling, mainstreaming ecosystem modeling in fisheries training curriculum of local universities, and conducting data collection surveys to fill data deficiencies. These are envisaged to increase capacity and activate ecosystem modeling, and consequently promote EBFM.

Introduction

Fish production from African inland fisheries is estimated at 2.7 million tonnes, a third of total fisheries production on the continent (FAO, 2014). The fisheries are important for food and income for riparian populations, national foreign exchange and revenue, employment for about 4,958, 000 people, 26.7% of them being women, and contributes 0.33% to GDP of African countries (De Graaf and Garibaldi, 2014). However, inland fisheries resources in Africa are the most threatened of anywhere in the world, apart from Asia (Welcomme et al., 2010), probably due to weaker fisheries governance and management institutions compared to developed countries (Sumaila et al., 2011). The fishery resources are faced with many socio-economic and environmental drivers, including overexploitation, eutrophication, pollution, habitat degradation, biodiversity loss, invasive species, water extraction and damming (Hecky et al., 2010), which modify aquatic ecosystem function and services. African fisheries are expected, also, to be hit the hardest by climate change, with associated challenges such as reductions in fish catch, which will intensify livelihood problems of millions of vulnerable people and lead to economic hardships and loss of development opportunities (Allison et al., 2009; Ogutu-Ohwayo et al., 2016).

Sustaining the benefits from fisheries resources, and particularly preventing or reversing the economic hardships and loss of development opportunities expected under the changing climate, requires interventions to increase production and promote sustainable exploitation. Indeed, there are management efforts in place in Africa to manage inland fisheries spearheaded by national and regional governments, and international development agencies, such as World Wildlife Fund (WWF) and The Nature Conservancy (TNC), that have made the management of some of the lakes that support fisheries and biodiversity a priority. A highlight of the fishery management approaches on the African inland lakes is co-management, where resource users such as fishers have a recognized role in management. Although this approach has been demonstrated to successfully solve problems in small scale fisheries (e.g. Castilla and Defeo, 2001), it has not been completely successful in Africa as lakes remain among the most overexploited in the world, and faced with multiple stressors (Njiru et al., 2007; Hecky et al., 2010; Welcomme et al., 2010). For sustainable

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development, business-as-usual is not an option, and, accordingly, immediate paradigm shifts to improve fishery management are required if the benefits and biodiversity supported by the lakes are to be sustained to contribute to sustenance of the African population projected to be over 2.4 billion by 2050 (United Nations, 2015).

The role of ecosystem-based fishery management (EBFM)

Ecosystem-based fishery management (EBFM) considers the ecosystem in totality in order to maintain its resilience rather than advancing single species-specific management measures (Pikitch et al., 2004). The approach facilitates tradeoffs between different fisheries and other aquatic resource stakeholders and their needs, improves access to information for management decisions, improves ability to predict management outcomes, and translates into better management plans. The approach, together with its sister approach in aquaculture, Ecosystem Approach to Aquaculture, (EAA), have been envisaged to facilitate the implementation of the FAO Code of Conduct for Responsible Fisheries, which was unanimously adopted by member states at the FAO Conference in October 1995 (FAO, 1995). Consequently, EBFM has been adopted by several developed countries, such as the United States of America (USA), where it currently underlies interventions for the National Oceanic and Atmospheric Administration (NOAA) Fisheries mission that is responsible for management of fisheries resources in the country (National Marine Fisheries Service, 1999). Countries that have complied with the FAO code of conduct, and therefore implementing EBFM (to some extent), such as USA, Norway, Canada, Australia, Iceland, Denmark, Ireland, Norway, United Kingdom, and Japan (Pitcher et al., 2008), have good scores for a health coupled human-ocean system based on diverse indicators (Halpern et al., 2012). Because these examples are not just anecdotes, EBFM can transform fisheries management to achieve fisheries management objectives where other approaches have failed. Thus, EBFM is most appropriate for inland water bodies in Africa, where, despite the existing management efforts, manageable challenges have persisted.

However, for EBFM to effectively counter threats of environmental change as it is designed to (Pauly et al., 1998; Worm et al., 2006), understanding and making predictions about the direction, magnitude, and consequences of the changes and designing the best mitigation options to counter their undesirable consequences have increasingly become very important given that threats are intensifying and becoming increasingly interconnected. These are best facilitated by ecosystem modeling (Canham et al., 2003; Evans, 2012), which makes it (ecosystem modeling) important for promoting EBFM (Christensen and Walters, 2005).

To recommend evidence-based strategies, to promote ecosystem modeling on the African inland lakes, and to ultimately promote implementation of EBFM, we examined the application of ecosystem modeling on African inland lakes by: (i) analyzing publishing trends of literature applying leading ecosystem modeling platforms on the lakes; and (ii) assessing data deficiencies on the lakes for ecosystem modeling. The results of the publishing trends and data assessment were used to identify implications for ecosystem models and modeling, fisheries research, and management and recommend the strategies required to promote application of ecosystem modeling.

Publication trends in literature applying leading aquatic ecosystem modeling platforms

To analyze publication trends in literature applying ecosystem models, we focused on African Great Lakes (AGL) in the AGL region as representative of other African inland lakes and two leading ecosystem modelling platforms, Ecopath with Ecosim (EwE) and Atlantis. The African Great Lakes (AGL) for the purposes of this paper are Lakes Victoria, Tanganyika, Malawi, Turkana, Albert, Kivu, and Edward. Consequently, the AGL Region includes any country that borders any of these lakes i.e. Democratic Republic of the Congo (DRC), Burundi, Rwanda, Uganda, Kenya, Tanzania, Zambia, Malawi, Mozambique, and Ethiopia (source: United States Department of State, Diplomacy in action. About the Great Lakes Region, http://www.state.gov/s/greatlakes_drc/191417.htm, accessed on 27April 2016). The AGL (Fig. 1) were considered for their exceptional attributes that make them outstanding, not only in AGL region or Africa but globally (Table 1).

EwE (Polovina, 1984; Christensen and Pauly, 1992; Pauly et al., 2000; Christensen et al., 2008), which has been described as one of the top ten breakthroughs of NOAA in 200 years (http://celebrating200years.noaa.gov/breakthroughs/ecopath/welcome.html), is a precursor of EBFM and the most widely used aquatic ecosystem modeling platform in the world (Christensen and Walters, 2005; Aydin et al., 2007; Heymans et al., 2014; Colléter et al., 2015). More recent and with only about a decade of application, Atlantis (http://atlantis.cmar.csiro.au/) is a platform designed to support EBFM through fostering the understanding of coupled social and natural dynamics of aquatic ecosystems to guide appropriate and model-tested management decisions (Fulton et al., 2011a).

Scientific publications applying EwE and Atlantis on the AGL were searched using relevant search terms, such as ecosystem modeling for Lake Victoria (or any other AGL), from web-based libraries such as Google Scholar, Online Access to Research in the Environment (http://www.fao.org/agora/en/; OARE) and Access to Global Online Research in Agriculture (http://www.fao.org/agora/en/; AGORA). EwE archives publications that have applied the platforms in a publicly available data base, EcoBase (http://sirs.agrocampus-ouest.fr/EcoBase/), which was also searched for prevalence of the scientific publications. The publication year, authorship, and affiliation were recorded for each selected publication. A closer look was undertaken on the published models to obtain information including their location (country), lake, model area, model period, and other features for the models. Basing on Christensen and Walters (2005), we present the trend in publications applying EwE on the AGL as indicators of how active ecosystem modeling is on the lakes.

As of August 2016, there was no single published Atlantis model on the AGL, with only one model indicated to be under development on Lake Victoria (http://atlantis.cmar.csiro.au/www/en/atlantis.html). The absence of publications applying Atlantis modeling framework on the lakes is surprising because, Atlantis has been in place for more than 10 years, which is a long time for a modelling framework with moderate data requirements to be adopted by fisheries scientists anywhere. Indeed, it has been applied in about 30 systems throughout the world (http://atlantis.cmar.csiro.au/www/en/atlantis.html), including the North American Great Lakes for management and for understanding invasive species, climate and acidification. Given that the AGL are among the most stressed inland lakes in the world (Welcomme et al., 2010), thus requiring EBFM supported by ecosystem modeling, absence of Atlantis model publications indicates inactive ecosystem modeling research activities in the region. This is a great concern because it demonstrates that fisheries management in the AGL region is predominantly limited to singles species management solutions, which have largely failed (Njiru et al., 2007).

The search for publications applying EwE on the AGL revealed 14 publications, including one thesis, published from 1988 to 2012, a period spanning 25 years (Table 2). This publication frequency over the period implies a publication rate of 0.6 papers per year, a dismal publication rate, and consequently limited application of EwE ecosystem modeling platform on the AGL in the last three decades, about the same period EwE has been used (Steenbeek et al., 2014). The rate further drops to 0.5 papers per year if the period is extended to cover up to 2015. Over the publication period (1988–2012), 16 of the years (64%) had no publications each; 6 years (24%) had one publication each, while 1993 had the highest number of publications, with four (Fig. 2). A closer look at the publications indicates that seven of the 14 publications (50%) were published within the first decade (1988–1997), since 1988, the year of publication for the first retrieved