Ecological Modelling 222 (2011) 1209–1221

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Modelling the effects of eutrophication, mitigation measures and an extreme flood event on estuarine benthic food webs

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ARTICLE INFO

Article history:
Received 30 June 2010
Received in revised form 8 December 2010
Accepted 11 December 2010
Available online 21 January 2011

Keywords:
Ecological model
Food web
Eutrophication
Management
Flood
Ecopath
Mondego estuary
Portugal

ABSTRACT

Human-mediated and natural disturbances such as nutrient enrichment, habitat modification, and flood events often result in significant shifts in species composition and abundance that translate into changes in the food web structure. Six mass-balanced models were developed using the "Ecopath with Ecosim" software package to assess changes in benthic food web properties in the Mondego estuarine ecosystem (Portugal). Field, laboratory and literature information were used to construct the models. The main study objective was to assess at 2 sites (a *Zostera* meadow and a bare sediment area) the effects of: (1) a period of anthropogenic enrichment, which led to excessive production of organic matter in the form of algal blooms (1993/1994); (2) the implementation of mitigation measures, following a long period of eutrophication (1999/2000); and (3) a centenary flood (winter 2000/2001). Different numbers of compartments were identified at each site and in each time period. In general, the *Zostera* site, due to its complex community, showed a higher number of compartments and a higher level of system activity (i.e. sum of consumptions, respiration, flow to detritus, production, total system throughput, net primary production and system omnivory index). The differences at the two sites in the three time periods in the breakdown of throughput were mainly due to differences in the biomass of the primary producers (higher primary production at the *Zostera* site). Consumption, respiration and flow to detritus were dominated by the grazers *Hydrobia ulvae* and *Scrobicularia plana* at the *Zostera* and bare sediment sites respectively. At both sites, after recovery measures were implemented there was an increase in *S. plana* and *Hediste diversicolor* biomass, consumption, respiration and flows to detritus, and a decrease in *H. ulvae* biomass and associated flows, which increased again after the flood event. The mass-balanced models showed that the trophic structure of the benthic communities in Mondego estuary was affected differently by each disturbance event. Interestingly, in our study a high system throughput seems to be associated with higher stress levels, which contradicts the idea that higher system activity is always a sign of healthier conditions.

1. Introduction

Estuaries are among the most productive, diverse, and economically important ecosystems on earth (Hobbie, 2000; Paerl, 2006). With the high population densities and increasing socioeconomic demands typical of coastal areas, estuarine ecosystems are subjected to multiple anthropogenic stressors. These do not usually operate independently, but rather interact to produce combined impacts on biodiversity and ecosystem functioning (Vinebrooke et al., 2004; Dolbeth et al., 2007; Cardoso et al., 2008).

Nutrient enrichment is one of the widespread stressors. Estuaries, which are critical habitats for nutrient recycling and ecosystem productivity, often receive large nutrient inputs derived from human activities and agricultural discharges, which are generally followed by severe eutrophication events (Valiela et al., 1997; Cloern, 2001; Bode et al., 2006; Lotze et al., 2006). Eutrophication severely impacts the diversity of primary producers and consumers, which leads to alterations in the food web structure, ecosystem productivity and functioning. One of the most important aspects of this type of disturbance is the proliferation of fast-growing macroalgae that may replace slow-growing macrophytes and significantly decrease the areal extent of seagrass meadows, which decreases the ecological value of the entire estuary (Short and Wyllie-Echeverria, 1996; Howarth, 1988; Bricker et al., 1999; Valiela, 2006; Patrício et al., 2009).

In addition to the impact of organic loading, estuarine ecosystems are also influenced by natural perturbations, such as extreme

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doi:10.1016/j.ecolmodel.2010.12.010