

Assessment of ecosystem changes in response to freshwater inflow of the Kromme River Estuary, St. Francis Bay, South Africa: A network analysis approach

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Abstract

We present results on changes which occurred at the ecosystem level over a period of 10 years in the relatively pristine Kromme River estuary, St. Francis Bay, South Africa. Carbon flow models were constructed for the estuary based on data collected before 1984 and again during the period 1988 to 1992. The first data set was collected during a period of regular and substantial freshwater inflow (average of about $117 \times 10^6 \text{ m}^3 \text{ a}^{-1}$), and the second set after the impoundment of the river in 1984 and the resultant decrease in freshwater inflow to less than $2 \times 10^6 \text{ m}^3$ per annum. The salinity regime changed from one with gradient (35 to 15) to a homogenous one where the salinity remained virtually constant at 35 and higher since the construction of the dam in 1984. The flow models were analysed and global system properties, such as the total system throughput, the magnitude and structure of cycling, development capacity, ascendancy and relative ascendancy, were used to assess whether the system has undergone change due to reduced freshwater inflow rates since 1984. Results showed that while some of the biotic compartments increased in biomass and abundance, others declined. Based on the results we conclude that the estuary has changed from a plankton-dominated system to one dominated by submerged benthic vegetation and macrobenthic invertebrates in response to reduced freshwater inflows.

Introduction

The measurement and quantification of energy and material flows in natural ecosystems have received considerable attention (cf. Fasham, 1985; Longhurst, 1984; Baird and Ulanowicz, 1989). The description of the rate of flux between the living and non-living components of an ecosystem requires information on biomass, feeding ecology, energy relationships, predator-prey interactions, and primary and secondary production rates, which is necessary if the system is to be studied from a holistic, or ecosystem, point of view.

Detailed energy flow models have been described for a number of systems such as the Chesapeake Bay (Baird and Ulanowicz, 1989), the Baltic Sea (Wulff and Ulanowicz, 1989), and a salt marsh ecosystem (Asmus and McKellar, 1989). Flow models of South African estuaries and other marine ecosystems are limited to those of the Swartkops estuary (Baird, 1988; Baird et al., 1991), the Kromme estuary (Heymans, 1992; Heymans and Baird, 1995), and the Benguela upwelling system (Baird et al., 1991). In addition to the construction of flow models, the analysis of complex food web matrices by means of network analysis is receiving more and more attention (cf. Wulff et al., 1989; Baird and Ulanowicz, 1989, 1993). The application of network analysis allows not only an insight of the properties of the ecosystem, but also the comparison of different ecosystems (e.g. Baird et al., 1991; Baird and Ulanowicz, 1993), and the comparison of the same system on a temporal scale (Field et al., 1989; Baird and Ulanowicz, 1989).

Network analysis includes input-output, trophic and cycling analysis and the calculation of ecosystem indices such as total system throughput, development capacity, ascendancy and system overhead. Detailed reference to the basic concepts, theory

and methodology of network analysis is given by Ulanowicz (1986) and Kay et al. (1989), while Wulff et al. (1989) reviewed the methods and applications of network analysis in marine ecology.

As mentioned above, a very useful application of network analysis lies in the field of comparative ecosystem ecology. A particular ecosystem can thus be assessed at different times, say on a daily, seasonal, annual, or longer time scales. For example, Field et al. (1989) examined the succession of a planktonic community following an upwelling event, Warwick and Radford (1989) assessed seasonal changes in an estuarine benthic community, Baird and Ulanowicz (1989) and Baird et al. (1995) reported on the seasonal dynamics of carbon and nitrogen of the Chesapeake Bay respectively, all using network analysis techniques. The objective of this paper is to assess changes in biomass, in the rates of flow between the various living and non-living components, and in the system properties that may have occurred in the Kromme estuary, St. Francis Bay, during the past 15 years. In the years prior to 1984 a substantial amount of information was collected on the plant and animal communities. During 1984 a second large impoundment (the Impofu Dam) was completed in the catchment area about 16 km from the mouth of the estuary, substantially reducing the freshwater inflow into the estuary. Hypersaline conditions in the upper reaches and the virtual absence of a typical estuarine salinity gradient have been observed since then (Heymans, 1992). In order to assess possible changes in the abundance, productivity and diversity of the system in response to reduced freshwater inputs, an intensive quantitative sampling programme was conducted in the estuary during the period 1988 to 1992. We have compared the results from this period with those collected prior to 1984, using network analysis techniques in an attempt to illustrate changes that may have occurred at the ecosystem level.

Study site

The Kromme estuary (34:08'S, 24:51'E) discharges through a permanently open inlet into St Francis Bay, approximately 55 km

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