Join effects of nutrients and contaminants on the dynamics of a food chain in marine ecosystems

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During the last decades coastal waters have been exposed to growing anthropogenic pressures represented not only by the increase on the input of nutrients and contaminants, but also by the exploitation of coastal areas for aquaculture, fishing and tourism. Release of pollutants derived from urban, agricultural and/or industrial effluents and domestic sewage may reach the coastal waters from watersheds, but also atmospheric transport (dry and wet deposition and air-water exchange) can be a major contributor.

The interactions between nutrient enrichment and the cycling of contaminants at ecosystem level may be important for assessing the fate of contaminant in the aquatic environment, their bioavailability, and their effects on the impacted ecosystem[1]. Impacts of contaminants in the aquatic ecosystem are both direct and indirect[2] from acute and/or chronic toxicity on sensitive species to disruption in the food web structure, with long-term effects as bioaccumulation and biomagnification. Furthermore, they can have instantaneous effects as massive killings after an accidental contaminant release.

We consider the Canale's chemostat model (CC) which is an extension of the tri-trophic food-chain Rosenzweig-MacArtur model (RMA), which has been extensively studied in theoretical ecology[3,4].we analyze the joint effect of the presence of contaminants and of nutrient loading on population dynamics of marine food chains by means of bifurcation analysis[5]. Contaminant toxicity is assumed to alter mortality of some species with a sigmoidal dose-response function. Counterintuitive effects arising from indirect effects are described.

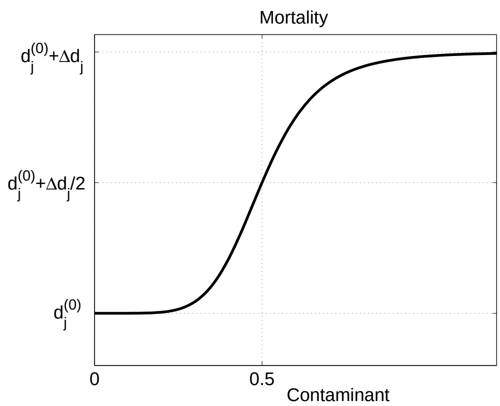

Figura 1. Sigmoidal response of mortality to the concentration of the toxic contaminant.

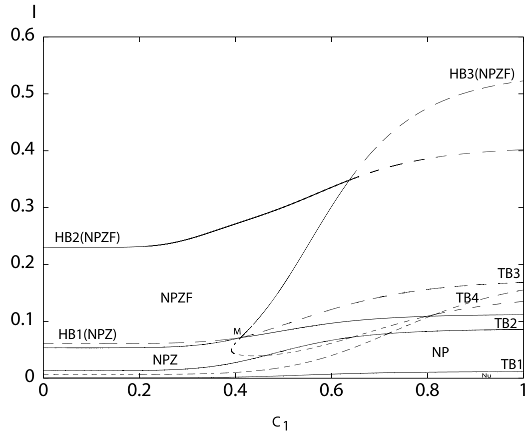

Figura 2. Some of the bifurcations occurring as a function nutrient input I and contaminant C_1 affecting phytoplankton, where TB is the notation to transcritical bifurcatons, HB is the Hopf bifurcations. The variables N, P, Z, F represent the nitrogen concentration in the different compartments of the system (nutrient, phytoplankton, zooplankton and fish) expressed in units of mg N/l. NPZF is the region where there is the coexistence among all species.

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1. Gunnarsson, J. S., Broman, D., Jonsson, P., Olsson, M. and Rosenberg, R. (1995) Interactions between eutrophication and contaminants: towards a new research concept for the European aquatic environment. Ambio 24: 383-385
2. Fleeger, J.W., Carman, K.R. and Nisbet, R.M. (2003). Indirect effects of contaminants in aquatic ecosystems. The Science of the Total Environment 317: 207-233
3. Scheffer M. and Carpenter S.R. (2003). Catastrophic regime shifts in ecosystems: linking theory to observation. Trends in Ecology and Evolution. 18 (12) 648-656.
4. Gragnani, A., De Feo, O., Rinaldi, S. (1998). Food chains in the chemostat: Relationships between mean yield and complex dynamics. Bulletin of Mathematical Biology 60:703-719.
5. Gugenheimer an Holmes (1983). Nonlinear oscillations, dynamical systems and bifurcations of vector fields. Applied mathematical sciences, (Springer-Verlag New York inc)v.42