Hydrocomplexity: New Tools for Solving Wicked Water Problems
Kovacs Colloquium, July 2010 (IAHS Publ. 338, 2010)

International Centre for Coastal Ecohydrology – applying the Ecohydrology approach for the sustainable functioning of coastal ecosystems

LUIS CHÍCHARO[1,2], RADHOUAN BEN-HAMADOU[1,2], ANA AMARAL, PEDRO RANGE, CARMEN MATEUS, DAVID PILÓ, RUTE MARQUES, PEDRO MORAIS & MARIA ALEXANDRA CHÍCHARO

1 *International Centre for Coastal Ecohydrology – ICCE, Solar do Capitão mor, Horta das figuras, EN125. 8005-815 Faro, Portugal*
lchichar@ualg.pt

2 *Centro de Ciências do Mar – CCMAR, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal*

INTRODUCTION

Coastal areas are among the most sensitive and productive ecosystems around the world, providing for the subsistence of large numbers of people, particularly in developing countries.

Human pressure on coastal areas has dramatically increased during the last decades and climate changes will pose new threats to these areas, as expected from sea-level rise and the decrease in freshwater discharges from rivers (Chicharo *et al*., 2009).

The International Centre for Coastal Ecohydrology (ICCE) a newly approved centre under the auspices of UNESCO, in October 2009, is located in the Algarve region (south Portugal). The centre acts as a facilitator and synergetic structure by providing the articulation of different scientific and institutional stakeholders at national and international levels. ICCE aims are to contribute scientific knowledge, capacity-building, educational and dissemination activities to support, design and implement adaptation and mitigation strategies and policies for coastal zones, including the impacts of climate change, addressing the goals of the Strategic Plan of the 7th Phase of UNESCO-IHP, the Millennium Development Goals (UN-MDGs) and the key themes for the United Nations Decade of Education for Sustainable Development (UN-DESD), particularly in African and Mediterranean regions.

The Ecohydrology concept (Zalewski, 2000) was developed and defined within the framework of the strategic plans for the 5th and 6th phases of the International Hydrological Programme (IHP-V: 1996–2001 and IHP-VI: 2002–2007, respectively). This approach considers the integration of hydrology and biology to achieve a sound understanding of ecosystems functioning and provide tools for the sustainable management of water resources (EH PROGRAM, UNESCO IHP).

Actual scientific knowledge allows the design of solutions for the existing and expected scenarios of change to coastal ecosystems. However, the remedial measures currently proposed are generally based on engineering and technological fixes, which are not likely to restore the ecological processes of a healthy, robust coastal system and, as such, will not reinstate the full beneficial functions and services of estuarine ecosystems. The successful management of estuaries and coastal waters requires an ecohydrology-based, basin-wide management approach. Indeed the coastal ecohydrology approach and solutions have been applied in different countries worldwide, such as Australia, Romania, Croatia, Portugal, Argentina, Greece, Philippines, among several others, and have been particularly focusing on how to adapt, mitigate and restore functioning of estuaries and coastal areas impacted by dams and climatic changes.

RESULTS AND DISCUSSION

Estuarine and coastal ecosystems regulated by dams suffer modifications to their natural regimes of freshwater discharge, both in volume and timing, affecting their functioning, productivity, biodiversity and related uses (e.g. coastal fisheries). In fact, several studies demonstrated the contribution of river freshwater discharge to coastal planktonic production (Cunha, 2001), to fisheries landings (Chícharo *et al.*, 2002; Erzini, 2005), and even to continental slope productivity (Santos *et al*., 2004; Ribeiro *et al.*, 2005). These aspects were analysed, from the ecohydrology perspective, at the Guadiana estuarine and adjacent coastal areas. Results show that the interplay between organisms and hydrological factors is key for improving water quality and sustaining biodiversity and the good ecological status of the estuarine ecosystem.

The volume of the Guadiana River water stored upstream in dams and reservoirs has been increasing since 1950. This disturbance in the freshwater outflow causes several impacts in the downstream ecosystems, including modifications in river inflow. The river inflow regime plays a determinant role in estuarine and coastal ecosystems since it is the provider of nutrients and sediments. Also, the reduction of the freshwater flow decreases the ability of the river and estuary to conduct self-purification by exporting excess nutrients to the ocean, which increases the potential risk of eutrophication.

Modifications in the river discharge were responsible for changes in the abundance and distribution of fish species with economic importance, and contributed to the increasing presence of invasive species in the estuary, such as the bivalve clam (*Corbicula fluminea*) (Chicharo *et al.*, 2006a). Reduced outwelling from the estuary is visible in the decrease of the coastal area that is influenced by the river plume. The river plume is used by small pelagic fish species, like the anchovy, as an indication of the proximity of estuaries (Chícharo, 2001; Chicharo *et al*., 2002; Lloret *et al*., 2004). This has consequences for the survival of the eggs and larvae and affects the future size of fisheries' with the consequent social and economic impacts (Chicharo *et al*., 2006b). The results of the ecohydrology model provide information about the threshold densities of *Corbicula fluminea* to be supported in the system for controlling water quality and ensuring sustainable biodiversity. Moreover, freshwater pulses increase system stochasticity (Roelke, 2003), making it more difficult for alien species to colonise the area and, therefore, can also be used for sustaining biodiversity in the Guadiana estuary.

The reduction in flow discharge and the upstream trapping of nutrients affects the N:P:Si ratio impact on the ability of diatoms to form their exoskeleton and, therefore, to grow and multiply, and also provokes a decrease in the productivity of the area, affecting all the food web and, more directly, the planktivorous fish species, like the anchovy and sardine.

Sustaining coastal ecosystems' ecological and social functions requires a holistic approach that considers the role of human society, both as a cause of impacts and users of aquatic coastal ecosystems, and the interplay between surface and groundwater hydrology with biota and ocean dynamics (Chícharo *et al*., 2009). Particular and isolated actions may provide solutions for water quality degradation. However, a synergetic harmonization of several ecohydrology solutions can maximise the benefits for more long term sustainable solutions for coastal ecosystems.

Acknowledgements The Guadiana Demosite in Ecohydrology was supported by Ecohydrology IHP UNESCO 2005 (contract no. 4500039232). A special thanks is due to ICNB-Reserva Natural do sapal de Castro Marim (Dra Anabela Resende and Dra Maria José Pitta Groz).

REFERENCES

Chícharo, L., Chícharo, M. A., Esteves, E., Andrade, P. & Morais, P. (2002) Effects of alterations in fresh water supply on the abundance and distribution of *Engraulis encrasicolus* in the Guadiana Estuary and adjacent coastal areas of south Portugal. *J. Ecohydrology & Hydrobiology* **1**(3), 195–200.

Chicharo, L., Chicharo, M. A. & Ben-Hamadou, R. (2006a) Use of hydrotechnical infrastructure (Alqueva Dam) to regulate planktonic assemblages in the Guadiana estuary: basis for sustainable water and ecosystem services management. *Estuarine, Coastal and Shelf Science* **70**, 3–18.

Chícharo L., Ben-Hamadou, R., Amaral, A., Range, P., Mateus, C., Piló, D., Marques, R., Morais, P. & Chícharo, M. A. (2009) Application and demonstration of the Ecohydrology approach for the sustainable functioning of the Guadiana estuary (South Portugal). *Ecohydrology & Hydrobiology* **9**, 55–71.

Chícharo, M. A., Chícharo, L., Galvão, H., Barbosa, A., Marques, M. H, Andrade, J. P, Esteves, E., Miguel, C., Gouveia, C. & Rocha, C. (2001) Status of the Guadiana estuary (South Portugal) during 1996–1998: an ecohydrological approach. *Aquatic Ecosystem Health and Management* **4**, 73–90.

Chicharo, M. A., Chicharo, L. & Morais, P. (2006b) Inter-annual differences of ichthyofauna structure of the Guadiana estuary and adjacent coastal area (SE Portugal/SW Spain): before and after Alqueva dam construction. *Estuarine, Coastal and Shelf Science* **70**, 39–51.

Cun Ha, M. E. (2001) Physical control of biological processes in a coastal upwelling system: comparison of the effects of coastal topography, river run-off and physical oceanography in the northern and southern parts of western Portuguese Coastal Waters. PhD Thesis. Faculdade de Ciências da Universidade de Lisboa, Portugal.

Erzini, K. (2005) Trends in NE Atlantic landings (southern Portugal): identifying the relative importance of fisheries and environmental variable. *Fish. Oceanogr.* **14**(3), 195–209.

Lloret, J., Palomera, I., Salat, J. & Sole, I. (2004) Impact of freshwater input and wind on landings of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in shelf waters surrounding the Ebre (Ebro) River delta (north-western Mediterranean). *Fisheries Oceanography* **13**(2), 102–110.

Ribeiro, I., Peliz, A. & Santos, M. (2005) A study of the response of chlorophyll-a biomass to a winter upwelling event off Western Iberia using SeaWiFS and in situ data. *J. Marine Systems* **53**, 87–107.

Roelke, D. L., Augustine, S. & Buyukates, Y. (2003) Directing the fall of Darwin's "grain in the balance": manipulation of hydraulic flushing as a potential control of phytoplankton population dynamics. *Texas Water Resour. Inst.* **245**, 1–13.

Santos, A. M. P., Peliz, A., Dubert, J., Oliveira, P. B., Angelico, M. M. & Re, P. (2004) Impact of a winter upwelling event on the distribution and transport of sardine (*Sardina pilchardus*) eggs and larvae off western Iberia: a retention mechanism. *Continental Shelf Research* **24**, 149–165.