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From fish physiology to ecosystems management: Keys for moving through biological levels of organization in detecting environmental changes and anticipate their consequences

Angel Pérez-Ruzafa[a,*], María Pérez-Marcos[b], Concepción Marcos[a]

[a] Departamento de Ecología e Hidrología, Facultad de Biología, Campus de Espinardo, Universidad de Murcia, Campus de Excelencia Internacional Mare Nostrum, 30100 Murcia, Spain

[b] Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario (IMIDA), C/Mayor, s/n. La Alberca, E-30150 Murcia, Spain

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ABSTRACT

Tackling environmental problems not only requires the detection of harmful agents or the drivers that induce changes in ecosystems and their effects, but also knowledge of their action mechanisms and the processes involved in order to design solutions, recover the damaged systems and, above all, prevent any deterioration before it occurs. In recent years conservation physiology has been proposed as a discipline that could play an important role in this context. However, the main problem in generalizing physiological indicators in order to assess ecological status is the leap in scale from the internal physiology of an individual to its relevance for ecosystem functioning. In this paper, we propose that the study of the physiological bases and epigenetic mechanisms that determine the allocation of energy resources, in the context of Dynamic Energy Budget theory, can be the hinge that allows us to pass from the physiology of the individual to the scale of population dynamics, the structure of populations and ecosystems. This proposal is based on the strong relationship shown by the parameters of the life story of individuals, such as body growth rate, maximum size, life expectancy or generation time, with the parameters that determine population growth and the ecological strategies of the species. There is growing evidence that the relationship between these parameters is not completely fixed and does not only respond to evolutionary scales, but may be flexible within certain limits throughout ontogeny and the life of individuals, producing consequences in populations in response to environmental conditions, environmental stress and, in the case of fish, the effects of fishing.

Lay summary: Biological index to detect environmental impacts can be applied from cell to ecosystem scale. However, at lower levels, although they give important information on the mechanisms involved it is difficult to infer the real consequences of the detected changes on the ecosystems. The review of the regularities existing in ecological guilds relationships of fishes suggests that the study of the physiological and epigenetic bases that determine the allocation of energy resources in the context of Dynamic Energy Budget theory can be the hinge that allows us to pass from the effects on the physiology of the individual to the scale of population dynamics and ecosystems when modelling the consequences of changes in environmental stress.

1. Introduction/context

Tackling environmental problems requires multidisciplinary efforts. It is not sufficient to detect harmful agents or the drivers that induce changes in ecosystems and their effects. We also need to know how they act on the processes taking place and how to correct any deviation from good functioning through remediation and the management of recovery actions. But above all, we need to anticipate these changes before they occur, modelling connections between drivers, processes and consequences.

After publication of the Water Framework Directive in the European Union (2000), there was a huge increase in the use of classical biological indicators and in the number of new ones proposed to characterize the ecological status of aquatic ecosystems (Salas et al., 2006; Gamito, 2008; Birk et al., 2012). Although most of them focus on species and community structure, the negative effects of human impact and climatic change have consequences for all biological levels of organization (Lloyd, 1991; van der Oost et al., 2003; Sánchez and Porcher, 2009).

In recent years, conservation physiology has focused on conservation problems, applying physiological concepts and knowledge to

* Corresponding author.
E-mail address: angelpr@um.es (A. Pérez-Ruzafa).

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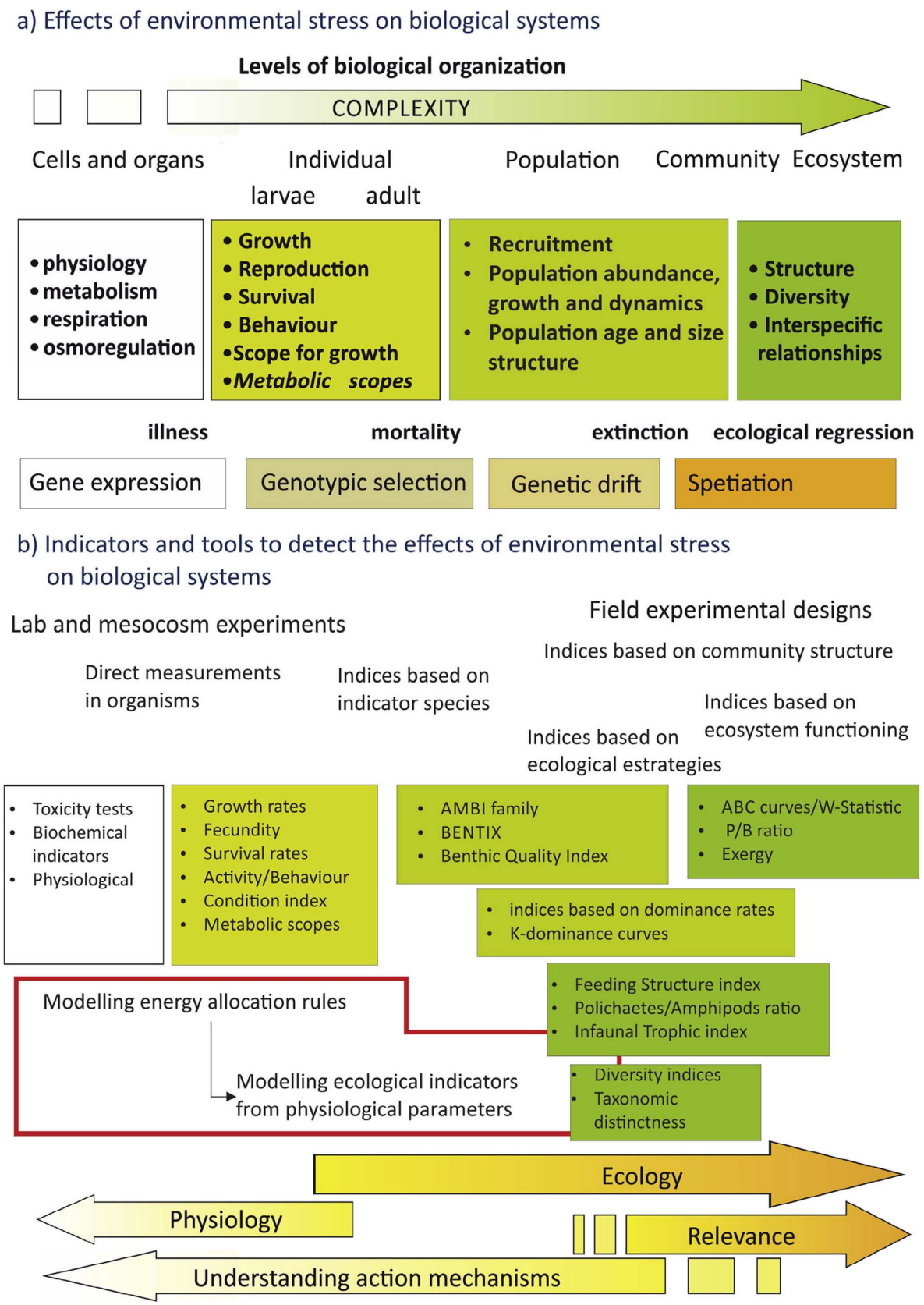

Fig. 1. a) Effects of environmental stress and pollutants on the different biological organization levels (from cells to ecosystem) and biological and ecological processes involved; b) main approaches, tools and types of bio-indicators that can be used to detect deterioration at the different levels. The research at lower levels allows us to better understand the mechanisms of action on the physiology and function of living things. In contrast, analysis of the upper levels is more relevant for understanding the real impact on the biosphere. AMBI: AZTI Marine Biotic Index; BENTIX: Bentix index (Simboura & Zenetos, 2002); ABC: Abundance Biomass Curve; P/B: Production/Biomass.