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First measurements of the scope for growth (SFG) in mussels from a large scale survey in the North-Atlantic Spanish coast

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HIGHLIGHTS

► Wild mussel SFG was determined to check seawater quality.
► First SFG data on a large spatial scale (>1000 km) along Spain's Atlantic coast.
► Negative relationships between organochlorine compounds and SFG.
► Pollution effect on SFG was lower than condition or age (confounding factors).
► SFG biomarker needs corrective strategies to avoid effect of confounding factors.

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ABSTRACT

SFG and physiological rates were measured in wild mussels from the Spanish Marine Pollution monitoring program (SMP) in order to determine seawater quality. It consists of 41 stations, covering almost 2500 km of coast, making the SMP the widest-ranging monitoring network in the Iberian Peninsula's Atlantic region. Results of the 2007 and 2008 surveys when 39 sites were sampled: (20 in 2007 and 19 in 2008, being 8 sites sampled both years) were presented. Chemical analyses were carried out to determine the relationships between physiological rates and the accumulation of toxic compounds. Data presented are the first to become available on the use of SFG as a biomarker of the marine environment on a large spatial scale (>1000 km) along Spain's Atlantic seaboard.

SFG values enable significant differences to be established between the areas sampled and between the two years surveyed. The integration of biological and chemical data suggests that certain organochlorine compounds, namely chlordanes and DDTs, may have a negative effect on SFG, although such an effect is of a lesser magnitude than that associated with certain biological parameters such as condition index and mussel age. These variables act as confounding factors when attempting to determine the effect of chemical compounds present in the marine environment on mussel SFG. Further research is therefore needed on the relation between these confounding factors and SFG in order to apply the relevant corrective strategies to enable this index to be used in monitoring programs. The effect of these confounding factors is more clearly revealed in studies that cover a wide-ranging spatial and time scale, such as those carried out within the SMP. These results do not invalidate the use of biological data in monitoring programs, but rather point to the need to analyze all the factors affecting each biological process.

1. Introduction

Marine pollution monitoring programs are principally based on the spatio-temporal monitoring of the concentration of chemical contaminants in various marine matrices: water, sediment and biota (Soriano et al., 2006, 2007; Bellas et al., 2011a). One of the most commonly-used organisms in pollution studies is the mussel *Mytilus galloprovincialis* due to its sedentary nature, its widespread geographical distribution, its great capacity for accumulating contaminants and its ease of sampling (Goldberg et al., 1978; Widdows and Donkin, 1992; Sericano et al., 1995; Besada et al., 2011a, 2011b). Various bodies and institutions responsible for environmental management (e.g. OSPAR, ICES) have been demanding to identify the nexus between contaminant concentrations and harmful effects on the living resources of coastal ecosystems through the application and standardization of biological techniques that make it possible. Thus, in recent years monitoring programs have included the analysis of the biological effects caused by chemical components in the organisms exposed to them, the final objective being to integrate both sets of data, chemical and biological, in order to determine marine environmental quality (Thain et al., 2008).

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The exposure to environmental contaminants produces a variety of adaptation responses in the organisms as a means of counteracting the negative effect of contaminants on their functioning. If such exposure is maintained over time and the organisms' defense mechanisms fail to neutralize it, the functioning of their biological systems can be affected, resulting in toxic effects that may impact on their growth, reproduction and survival.

Structural alterations occurring in organs affected by pollution have an influence on the way they function, thus converting the measurement of an organism's functional activity into a tool for environmental assessment. One of these biological tools, which itself is the result of a variety of vital functions (filtration, ingestion, absorption and respiration), is scope for growth (SFG), a technique involving the calculation of the energy available for growth under standardized laboratory conditions. The determination of growth in organisms is one of the most sensitive methods available for detecting, quantifying and identifying changes over time and space to the water quality of marine ecosystems, since growth is the result of a combination of different physiological processes involved in energy acquisition and consumption. It is, therefore, a non-specific, highly sensitive, comprehensive and ecologically relevant response of organism to the presence of a contaminant. In short, it consists of evaluating the energy acquired by an organism after absorbing the food it has ingested, and that lost in the respiratory and excretory processes being the difference the energy the organism has available for production (growth and reproduction). The presence of contaminants in the marine environment alters this energy balance, making SFG a marker for toxic stress (Widdows and Johnson, 1988; Widdows and Donkin, 1989, 1991). In summary, SFG is a biomarker at the individual/whole organism level of biological complexity with a high level of ecological relevance and for this reason is very applicable for biomonitoring programs (SIME, 2007).

The calculation of SFG has been successfully applied in programs monitoring chronic pollution (Widdows et al., 1995; Cotou et al., 2002; Widdows et al., 2002; Toro et al., 2003a; Halldórsson et al., 2005), acute pollution associated with a spill (Larretxea and Pérez Camacho, 1996; Fernández et al., 2010), and in laboratory contaminant exposure studies (Widdows and Page, 1993; Kraak et al.;, 1997; Sobral and Widdows, 1997; Wang and Chow, 2002). SFG values were used in all these situations to calculate the toxicity of most marine environmental contaminants and determine their effect on an organism's energy balance. Additionally, SFG values in bivalves have been shown to correlate with biodiversity metrics of the benthic communities they inhabit (Crowe et al., 2004), meaning that SFG can be considered a good marker of pollution not only for individual organisms but also for the population as a whole.

In 2007 the Spanish Marine Pollution monitoring program (SMP) from the Spanish Institute or Oceanography (IEO) added SFG as an environmental assessment technique to be integrated with the chemical parameters. The study area (Fig. 1) covers more than 2500 km of coastline along the N–NW Iberian Peninsula, and is included in the OSPAR Region IV (OSPAR Comission, 2010). This area can be divided into two different oceanographic regions, the Atlantic coast, where the Galician rías are located, and the Cantabrian coast, included within the Bay of Biscay. This coastal area is composed of highly productive ecosystems, with high complexity and biodiversity, and is often rich in living resources. Moreover, the area is of particular importance from a socio-economic point of view: there are many activities such as tourism, fishing, shell-fishing, etc. All these activities require both a suitable environmental quality and a sustainable development. In general, Galician rías present a low degree of pollution, restricted to certain areas located in their inner part which, besides a lower water renewal rate, support the main riverine inputs and are located close to the main urban and industrial areas (e.g. Prego and Cobelo-Garcia, 2003). The Cantabrian coast contains diverse industry that discharges contaminants into the surrounding waters and/or atmosphere. This industrial activity is usually located close to the main cities and ports (Avilés, Gijón, Santander or Bilbao). In general, concentrations of trace metal, PAH and PCB levels are higher in the Cantabrian than in the Atlantic coast (OSPAR Comission, 2010).

The purpose of this study was to evaluate water quality on a large scale along the Spanish coastline (the North Atlantic and Cantabrian region) by measuring physiological stress responses (SFG) and contaminant concentrations in mussel tissues, as well as to determine

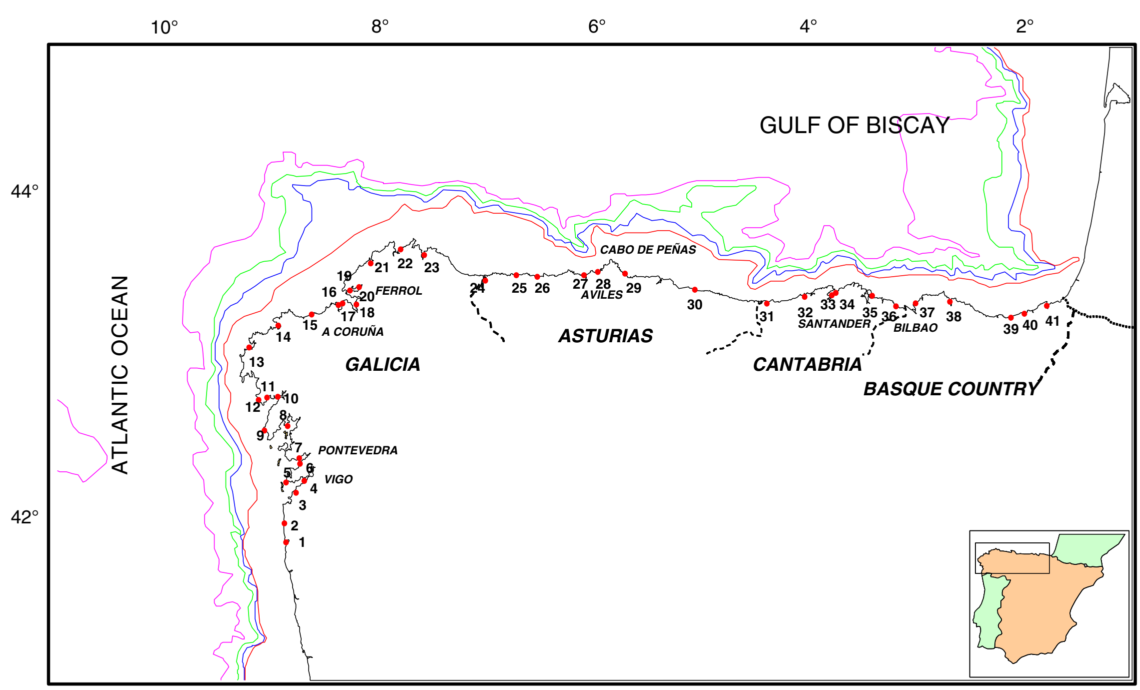

Fig. 1. Geographical situation of the 41 sites of the Spanish Marine Pollution (SMP) monitoring program in the North-Atlantic coast.