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# Talitrid orientation as bioindicator of shoreline stability: Protected headland-bays versus exposed extended beaches

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ABSTRACT

The behaviour of talitrids, being a local adaptation to beaches, is known to be related to environmental stability. The use of behavioural responses of resident populations as bioindicator of shoreline stability has been tested under various conditions, including after soft and hard engineering actions to stabilise eroded beaches. Port structures likely have impact on sediment longshore transportation and shoreline stability. The question was whether talitrid orientation behaviour could be proposed as bioindicator of impacts also for sandy bays of limited extension and highly used for recreation, such as those in the vicinity of touristic port structures. Orientation experiments were carried out on a set of sandy beaches of different extension and morphology, each of them in the vicinity of a touristic port, across the Mediterranean coasts. The protocol included field orientation tests of populations of talitrids, then analysed in terms of orientation precision seawards (considering sun compass orientation as the most locally adapted behavioural mechanism) in different seasons (before and after the touristic season) and times of day. The populations from more protected (either naturally or artificially) headland-bays showed a higher precision of orientation with respect to the shoreline direction than those from extended beaches, more subject to changes in longshore sedimentary transport as consequence of natural and human activities. The distance from the port and touristic pressure had no influence on talitrid orientation. An important stabilising factor for the sandy beach ecosystems, including talitrid populations and their behavioural adaptation, appeared to be the presence of seagrass banquette. The behavioural data point out that biotic information proceeding from local animal populations linked to beach sediments may complement sedimentology data and allow scaling the impacts occurring on a developed coastline. This becomes particularly relevant when considering interdisciplinary approaches to monitoring strategies.



## 1. Introduction

### 1.1. Talitrids: fine tuning to a changing environment

Sandy beaches host abundant and diverse arthropod communities in the intertidal and supra-littoral zones exploiting the wrack deposited by tides and waves (Schlacher et al., 2014). Within the mobile arthropod fauna communities, talitrids (Crustacea, Amphipoda, Talitridae) are keystone species that show peculiar behavioural adaptations tuned to the environmental features of sandy beaches (Scapini, 2006, 2014; Walsh et al., 2010). Talitrids inhabiting sandy beaches are night-active, but may express solar orientation seawards during the day in case of displacement by mechanical factors (e.g., waves, predators) or to face a dehydration risk while buried in the sand in the supra-littoral zone. This is particularly evident in Mediterranean microtidal beaches, where talitrids occupy a zone very close to the waterline (Scapini et al., 1997; Colombini et al., 2002; Fallaci et al., 2003). Differences in orientation capability, with the use of alternative mechanisms and cues, were found related to the stability of beaches (Scapini, 2006). On Italian shores, sun orientation was shown to be adapted to the

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shoreline direction and inherited on more stable beaches, while on changing shorelines a scatter toward various directions was observed in the samples (Scapini et al., 1995). The interpretation of these results, supported by population genetics data, was that stable beaches offered a longer time for behavioural adaptation to be fixed by natural selection and/or learning. The study of Scapini et al. (1995) was integrated by relating behavioural and genetic adaptation with the changes of shoreline through time (decades) as reported in the topographic maps of Italy (C.N.R.-M.U.R.S.T, 1997). These hypotheses remained indeed to be tested in a wider context, to avoid bias due to differences in coastline morphology, such as uneven presence of headlands, river mouths and rocky shores (see e.g. Barsanti et al., 2011, regarding Italian coasts). Later studies led however to similar conclusions: differences in orientation precision toward the shoreline were shown by populations from different points along the same continuous beach on the Tyrrhenian coasts of Italy, subject to different erosion/accretion dynamics (Scapini et al., 2005; Ketmaier et al., 2010). Also Bouslama et al. (2011) found a link between talitrid behaviour and environmental stability on two beaches of the Tunisian coasts comparing behavioural traits (orientation and locomotor activity rhythms). On the Atlantic coast of Uruguay, Fanini et al. (2009) compared the orientation of talitrids from beaches differing in morphodynamics and observed a more precise orientation on a reflective beach than on a dissipative one, due to the protected position of talitrid populations across the beach, where the wave energy is reflected by the beach slope (Habitat Safety Hypothesis, Defeo and Gómez, 2005). On the Pacific coasts, in Chile, on oceanic macrotidal intermediate beaches, a better adapted seaward orientation was observed on a protected beach than on an exposed one (Scapini and Dugan, 2008). Although the relation of talitrid behavioural adaptation/plasticity with respect to stable/changing shoreline was not clearly stated among the hypotheses to be tested, the relationship between population features and sandy beach ecology and morphology appeared clear from literature (Soares et al., 1999; McLachlan and Brown, 2006; Defeo et al., 2009). In summary, there is a consistent indication across geographical macro-areas, of talitrid adaptation (allowed by a high behavioural plasticity) to the stability of the shoreline inhabited by the populations. While the debate about the meaning of "shoreline stability" is still open (depending on the perspective of each discipline), the information provided by local talitrid populations can provide an integration of those features, which are relevant to the species-environment perspective.

### 1.2. Behaviour of talitrids and man-made structures: open questions

The MAPMED project (ENPI CBC-MED programme) aimed at characterizing port areas in the Mediterranean, to develop suitable monitoring tools that can sustain Port Authorities in managing these areas. Within the project framework, a suite of possible stabilizing/destabilizing factors were taken into account that may act on a shoreline. Port structures may impact on sediment longshore transport and sandy beach stability (Poulos and Chronis, 2001). These dynamics, generated by man-made hard structures, may act with faster time than the natural ones and severely impact beach ecosystem (Dugan et al., 2008; 2013). Behavioural experiments (etho-assays) were planned on beaches at different distances updrift or down-drift from the port structures to assess the effects of the port impacts on mobile macrofauna adaptation. Three port areas were selected across the Mediterranean, in the western Mediterranean Basin (Italy, Sardinia, Port of Cagliari), in the eastern one (Greece, Crete, Port of Heraklion) and on the southern coasts (Tunisia, eastern coast, Port of El Kantaoui) (Fig. 1a). The three localities were characterised by the presence of touristic infrastructures and similar seasonality of tourism (peaks in summer months); the direct impact of human trampling and other managements were consequently supposed to be similar. To each of the selected beaches an index of beach use (Recreation and Conservation, integrating in a final score both natural and human features of the beach-dune system) was assigned (McLachlan et al., 2013). The approach of this study was based on current models developed in coastal engineering regarding the concept of "static bay beach" (Hsu et al., 2010; Barsanti et al., 2011). According to this concept, a pocket beach would be stable, while an extended beach would be subject to longshore sediment transport depending on the dominant winds, currents and waves, and thus to changes as a consequence of human actions and man-made interruptions (Barsanti et al., 2011).

### 1.3. Hypotheses for behavioural tests on changing coastlines

Arthropod community features and orientation of talitrids to the shoreline had been used in similar contexts to monitor the stability of the beach ecosystem with respect to changed sedimentary dynamics caused by soft and hard engineering measures to stabilise beaches against erosion (Fanini et al., 2007; Bessa et al., 2013; Nourisson et al., 2014). Measurable changes in talitrid orientation parameters, such as the precision with respect to the shoreline direction, would provide a tool for a monitoring programme of the impact of man-made structures on the beach ecosystem (Scapini, 2014). In a complex system such as the touristic areas under analysis, it is relevant, first of all, to know to which of the above mentioned factors (direct tourism impact or effects of human made structures on the sedimentary transport) will respond the local talitrid population.

In this study current paradigms were considered, which summarize the stability condition of a sandy beach under the perspective of different disciplines, and were tested via the behaviour of local talitrid populations. It was assumed that on more stable beaches (in the present case on pocket beaches, eventually stabilised by the presence of wrack, Dugan et al., 2003, 2013) talitrids would show an orientation precisely adapted to the (stable) shoreline, while on beaches more exposed to winds, currents and waves, and stressed by changes in sedimentary longshore transport, talitrid orientation would be more scattered. The interference of port structures with longshore sedimentary drifts was expected to have a consequence on resident populations, likely detectable in behavioural adaptation.

Alternative not mutually exclusive hypotheses that have been considered by this study were:

(1). The intensity of recreation activities (expressed by the Recreation index, McLachlan et al., 2013) would have a negative impact on the mobile macrofauna.
(2). The vicinity of the port structure (distance from the port) would have a negative impact on the talitrid populations and their behavioural adaptation.
(3). The extension of the beach (pocket beach vs. extended beach) would affect the talitrid behavioural adaptation to the shoreline direction.
(4). The presence of dunes and wrack (Conservation index, McLachlan et al., 2013, or local ecological stabilisation) would positively impact on the behavioural adaptation.

## 2. Material and methods

### 2.1. Study sites choice and characterisation

Orientation tests on talitrids were carried out in 2012 in two replicates: one at the beginning of the touristic season (May–June)