Abundance, distribution, and ecology of the tufted ghost crab *Ocypode cursor* (Linnaeus, 1758) (Crustacea: Ocypodidae) from a recently colonized urban sandy beach, and new records from Sicily (central Mediterranean Sea)

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**Abstract**

The tufted ghost crab, *Ocypode cursor*, was recorded for the first time on the coast of Sicily mainland in 2009, however no ecological studies were conducted so far. In this study, we provide the first ecological data, based on massive data collection of the ghost crab in Sicily. In particular, we studied the spatio-temporal distribution of the species in the recently colonized urban beach of Avola. Our results showed that this species’ activity is mainly affected by temperature (crabs were more active during warmer months), while distance from the shoreline affected size distribution (larger crabs were usually found farther away from the shoreline). Crabs feed on a great variety of food items, and are undergoing northward range expansion.

**Keywords:** Protected taxon, Beach, Range-expanding species, Ionian Sea, Burrows

1. Introduction

Crabs of the family Ocypodidae are known for their semi-terrestrial habits. Within this family, the species belonging to the genus *Ocypode* Weber, 1795, commonly known as ghost crabs, are found in tropical and subtropical sandy coasts (Barrass, 1963; Sakai and Türkay, 2013). They are called “ghosts” because their color allows them to camouflage with the color of the sand.

*Ocypode cursor* (Linnaeus, 1758), the only Mediterranean species of the family Ocypodidae, is distributed in the west coast of Africa (Lucrezi et al., 2009b) and in the eastern half of the Mediterranean Sea (Ziese, 1985; Glaubrecht, 1992; Stevcic and Galil, 1993; Kocatas et al., 2004). This crab is a protected species: it is listed as an Endangered or Threatened species (Annex II) of the Convention for the Protection of European Wildlife and Natural Habitats (Bern Convention 1996–98). The species is primarily nocturnal. During daylight hours (or when it feels threatened) it shelters in deep burrows on the beach and occupies the coastal zone from the low intertidal up to > 30 m inland. Burrows are usually L-shaped or J-shaped and reach 80–90 cm in depth. Larger crabs are usually found farther inland from the shoreline and dig deeper burrows located at least 1 cm above the water table (Strachan et al., 1999), where they are more protected from storm waves and extreme tides (Rodrigues et al., 2016). Furthermore, burrows provide a thermally stable environment, protecting crabs against temperature extremes (Chan et al., 2006). These crabs are opportunistic omnivorous feeders; their diet include human food remains, organic detritus stranded on the beach, carrions, eggs and hatchlings of Caretta caretta (Trott, 1999).

In Sicily (central Mediterranean Sea), the species was recorded in Lampedusa (Froglia, 1995), Sampieri (Relini, 2009), Avola (Tiralongo, 2016) and Gela (Zafarana and Nardo, 2016). However, since 2016, when it was first recorded from the Ionian coast, the species appears to have become quite common on some Sicilian beaches. Recently, the species was recorded at other locations of southern Sicily and in Malta (Deidun et al., 2017).

In this study, we provide the first ecological data on *O. cursor* from Sicily (central Mediterranean Sea). In particular, we provide the following data: (1) distribution and abundance of *O. cursor*; (2) year-round data on spatio-temporal distribution pattern of *O. cursor* in relation to its size; (3) notes on its behavior and interaction with prey and predators. Finally, we discuss the newly established population of this crab and its spread.
2. Materials and methods

2.1. Study area and data collection

The study area was the recently colonized beach of Avola, in southeastern Sicily (Ionian Sea) (Fig. 1). Data on *O. cursor* were collected using non-destructive methods (i.e. burrow counts and measurements of burrow sizes) from September 2016 to September 2017 with an interval of about 15 days between surveys (two survey per month), for a total of 26 survey days. At each survey, we counted and measured to the nearest 1 mm with a meter stick each burrow within each area. Sampling was performed between 7:00 and 09:00 AM and the air temperature during this time was recorded. Burrow counts is a proven approach to estimate ghost crab abundance. Burrow size measured to the nearest 1 mm with a meter stick each burrow within

A sample of sand was collected near the burrows for granulometric analysis. Additional sampling stations along the entire southern coast of Sicily were explored in order to provide an update on the distribution of the species (Fig. 1, Table 1). Additional, approximately 75 h were spent, both during daylight and night hours, on observations of the behavior of the species: about 3 h per night and per day at Avola for a total of 10 days, and about 5 h per day at Torre Salsa for a total of 3 days.

### Table 1

<table>
<thead>
<tr>
<th>Location</th>
<th>Coordinates</th>
<th>Date</th>
</tr>
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<tbody>
<tr>
<td>Aghone Bagni</td>
<td>37.4247°N, 15.08972°E</td>
<td>18th September 2018</td>
</tr>
<tr>
<td>Siracusa</td>
<td>36.96421°N, 15.20936°E</td>
<td>7th August 2018</td>
</tr>
<tr>
<td>Marzamemi</td>
<td>36.74767°N, 15.10996°E</td>
<td>22th June 2017</td>
</tr>
<tr>
<td>Scoiglitti</td>
<td>36.89903°N, 14.42503°E</td>
<td>7th November 2016</td>
</tr>
<tr>
<td>Cannatello</td>
<td>37.24623°N, 13.69027°E</td>
<td>24th August 2017</td>
</tr>
<tr>
<td>Torre Salsa</td>
<td>37.37903°N, 13.30883°E</td>
<td>19th October 2016</td>
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<tr>
<td>Triscina</td>
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<td>20th August 2017</td>
</tr>
<tr>
<td>Campobello di Mazara</td>
<td>37.57144°N, 12.73194°E</td>
<td>5th July 2017</td>
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</tbody>
</table>

### 2.2. Sediment analysis

The sample of sand (about 1 kg) was carefully preserved in polyethylene bag and brought to the University of Catania sedimentology lab, where it was placed in an oven at approximately 60 °C and weighed when completely dry. Sediment was then pretreated chemically using hydrogen peroxide to enhance separation or dispersion of aggregates. Grain size distribution was then carried out by a mechanical sieve shaker (Giuliani IG/3-EXP). The typical particle-size range for sieving is 63 μm - 4000 μm. Soil under 63 μm was analyzed by an ELZONE 282 PC densimeter. Mean, standard deviation, skewness and kurtosis were computed (Folk and Ward, 1957).

### 2.3. Statistical analysis

Statistical analysis was performed with the software R (R Development Core Team, 2018) and graphics were created using the R package “ggplot2”. The Shapiro-Wilk test was used to determine whether data were normally distributed in order to use the appropriate tests. A Fligner-Killeen test was used to verify the homogeneity of variances of burrows sizes between the 3 areas (A, B and C) and the homogeneity of variances of burrows sizes between the seasons. A chi-squared test was used to determine if the abundance of burrows varied between seasons and between areas. The Kruskal-Wallis test was used to verify whether there was a significant difference in burrow sizes between the 3 areas, to verify whether there were significant seasonal changes in burrow sizes, and to verify whether there was a significant seasonal difference in burrows’ abundance for each area. A linear regression was performed to relate burrows sizes to temperature.

3. Results

A total of 2673 observations of burrows were recorded in the beach of Avola (Ionian coast of Sicily) (Fig. 1) during the whole study period. Abundance of burrows was season dependent (chi-squared test: \( p < .05 \)), burrows were markedly more abundant (1605 burrows, 60% of the total recorded) in the summer (Fig. 2, Table 2), with a maximum mean abundance of 4.99 burrows per square decameter (burrows/dam²) in the area A (Table 3). Abundance of burrows increased with proximity to the sea (chi-squared test: \( p < .05 \)), reaching a maximum in the area A, with a total of 1601 burrows recorded (59.9% of the total) in the study period (Table 2); while, burrow size increased with the distance from the sea (Kruskal-Wallis test: \( p < .05 \)), reaching the maximum average value in the area C (50.51 mm) (Fig. 3A). The median of burrows’ density during the four seasons was statistically different only for the area A (Kruskal-Wallis test: \( p < .05 \)). In summer,
most of the burrows were concentrated close to the sea (area A), and progressively decrease in number at greater distances (Table 2). A similar situation, but with overall lower abundance, was present in spring; while, in autumn, burrows abundance was similar in all three areas, especially between the area A and B, where it was higher than in area C. In winter, when burrows abundance was very low (30 in all) and reached its minimum value, burrows were concentrated in the area C, and no burrows were recorded in the area A. The results of the linear regression showed that temperature and burrows sizes were correlated \((p < .05)\), and the maximum burrows sizes were recorded with lower temperatures (Figs. 3C, 4, 5). We found a significant difference in the variance of burrow size between areas and between seasons (Fligner-Killeen test: \(p < .05\)) (Figs. 3D, 6, Table 4). The burrows size varied during seasons and reached the maximum mean value in winter (54.80 mm) (Kruskal-Wallis test: \(p < .05\)) (Fig. 3B), when most of the few burrows recorded were concentrated in area C.

During field observations, the species was observed feeding on beached algae, human food remains and bait abandoned by beach fishermen; while birds, stray dogs and foxes (two records at Torre Salsa) were observed preying on the crab. In the beach of Avola, at night, cannibalism was observed: a large specimen was seen preying on a small individual. We also noticed that during night hours, most crabs were found very close to the shoreline (at a distance of about 2 m).

The granulometric analysis of the beach of Avola showed that the sample was well sorted (0.413 s), mean value indicates medium sand (1.462 Mz), skewness shows symmetrical value (0.024 Sk) and kurtosis value depicts mesokurtic distribution (0.962 kg). Finally, new records of the species showed a westward and northward spread of \(O.\ cursor\) along the Sicilian coast (Fig. 1, Table 1).

### 4. Discussion

Seasons, and consequently temperature, are the most important factors affecting crabs activity. Indeed, the highest number of burrows were observed during the warmer months. In contrast, during the colder months, most of the crabs remain dormant in their burrows, as was demonstrated by the low numbers of burrows observed in particular during winter. Most of the large-sized specimens were concentrated far from the shoreline, in which some individuals remain active almost all year and probably reproduce too, and are more protected from storm waves. Indeed, during winter months, the species activity was almost exclusively limited to a few large-sized specimens inhabiting area C, at the greater distance from the sea. With temperatures below about 15°C, the crabs’ activity was reduced or virtually absent. However, other factors, such as wind, can induce the crab to close the entrance of its burrow, as it was shown for another species of

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**Table 2**

<table>
<thead>
<tr>
<th>Season</th>
<th>AVOLA</th>
<th></th>
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<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>Tot.</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>Spring</td>
<td>147</td>
<td>106</td>
<td>83</td>
<td>336</td>
<td>56</td>
</tr>
<tr>
<td>Summer</td>
<td>1198</td>
<td>350</td>
<td>57</td>
<td>1605</td>
<td>200.6</td>
</tr>
<tr>
<td>Autumn</td>
<td>256</td>
<td>242</td>
<td>204</td>
<td>702</td>
<td>117</td>
</tr>
<tr>
<td>Winter</td>
<td>0</td>
<td>3</td>
<td>27</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>1601</td>
<td>701</td>
<td>371</td>
<td>2673</td>
<td>102.8</td>
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</table>

**Table 3**

<table>
<thead>
<tr>
<th>Season</th>
<th>Burrows’ abundance</th>
<th>SD</th>
<th>b</th>
<th>SD</th>
<th>SD</th>
<th>b</th>
<th>SD</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b/dam²</td>
<td>1.63</td>
<td>1.6</td>
<td>49</td>
<td>48.13</td>
<td>0.59</td>
<td>0.34</td>
<td>35.33</td>
<td>20.5</td>
</tr>
<tr>
<td>b</td>
<td>4.99</td>
<td>1.33</td>
<td>149.75</td>
<td>39.91</td>
<td>0.73</td>
<td>0.39</td>
<td>43.75</td>
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<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>b/dam²</td>
<td>1.71</td>
<td>1.47</td>
<td>51.2</td>
<td>44.04</td>
<td>0.67</td>
<td>0.54</td>
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<tr>
<td>SD</td>
<td>0.02</td>
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<td>1.5</td>
<td>0.71</td>
<td>0.09</td>
<td>0.03</td>
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</tr>
<tr>
<td>b</td>
<td>0.94</td>
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<td>0.12</td>
<td>0.03</td>
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<td>1.82</td>
</tr>
</tbody>
</table>

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**Fig. 2. Burrows/dam² for each area and season at Avola.**
the genus *Ocypode* (Alberto and Fontoura, 1999), even though, in our opinion, the opposite is more likely: burrows entrances can be closed by the sand transported by strong winds. Small and medium-sized specimens are probably more sensitive to low temperature; therefore, almost all of them remain inactive during winter.

Similar results were reported in other studies (Lucrezi et al., 2009b; Dubey et al., 2013; Haque and Choudhury, 2014) that clearly underline the role of temperature in affecting crabs’ activity. Lucrezi et al. (2009b) also underline the importance of strong winds in enhancing crabs’ activity as a consequence of resource availability due to stranded food. However, other factors, such as predation levels, food abundance and water content of sand are also relevant in determining crabs’ activity and distribution (Warburg and Shuchman, 1979; Strachan et al., 1999).

The substratum nature can also affect crab abundance and distribution (Warburg and Shuchman, 1979; Ewa-Oboho, 1993), and the granulometric composition of the beach of Avola appears to be well suited for the species.

The maximum abundance of crab burrows was recorded in the summer and close to the sea: 4.99 burrows/dam^2 in the Area A. In this area, most of the specimens were small and medium-sized. During this season, relatively few burrows were recorded in the area C, while, the great number of burrows recorded in the area A suggests that they find in this area suitable conditions to prevent desiccation. Conversely, in autumn and winter the burrows were concentrated in the area C, and during winter crab abundance was very low and reached its minimum value. The great abundance of small and medium-sized burrows in the area A and B during warm months seem to be related to the high humidity of these areas, that allow to a considerable number of small and medium-sized crabs to inhabit this zone. Indeed, small specimens of the genus *Ocypode* are less resistant to desiccation and less efficient

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**Fig. 3.** Burrows’ sizes at Avola in relation to areas (A), seasons (B), temperatures (C) and general view of burrows sizes in relation to areas and seasons (D).

**Fig. 4.** Burrows’ sizes in relation to temperature and period at Avola.
burrowers than adults (Fisher and Tevesz, 1979; Williams, 1984; Corrêa et al., 2014). Close to the shoreline, they can find the optimal humidity simply digging burrows of few centimeters. Hence the importance of the area A, in particular during summer, that is directly and continually affected by the sea water. On the other hand, large-sized crabs dig deeper and more complex burrows far from the shoreline, reflecting the increasing depth of the water table (Türeli et al., 2009). However, also food availability (e.g., food remains of bathers, stranded organic material) can affect crabs’ abundance and distribution (Steiner and Leatherman, 1981; Neves and Bemvenuti, 2006). Furthermore, the Sicilian coasts, especially the southern ones, are known to be suitable as nesting sites for the loggerhead sea turtle (Caretta caretta) (Casale et al., 2012), whose hatchings and eggs are preyed on by O. cursor (Strachan et al., 1999; Marco et al., 2015). Another important factor could be the changes in beach morphodynamics, which altering the availability of food can influence size, distribution and abundance of the species (Turra et al., 2005; Lucrezi, 2015).

In all cases, the low abundance of burrows observed during winter suggests that crabs hibernate in this period. Similar results were obtained in similar studies for other species of the genus Ocypode (Haley, 1972; Branco et al., 2010; Corrêa et al., 2014). Crabs were abundant in almost all the beaches of Avola. After the first record of the species in
2016 (Tiralongo, 2016), the crab undergone a rapid population growth, indicating as this species is able to rapidly colonize new areas. In Sicily mainland, O. cursor was recorded for the first time in 2009 at Sampieri (Relini, 2009), and subsequently undergoing a rapid westward and eastward expansion (Tiralongo, 2016; Zafarana and Nardo, 2016). The great abundance of crabs in the crowded beach of Avola could be at least in part explained by a greater food availability (e.g. food remains of humans, carrions) (Rodrigues et al., 2016), that could be further increased by the presence of the River Asinaro.

The current Atlantic-Mediterranean disjunct distribution of O. cursor is probably the result of a past wider and continuous Atlantic-Mediterranean distribution (Vecchioni et al., 2019). Indeed, the lowering of the sea temperature during the Würm glaciation (Pleistocene) (Thiede, 1978) is assumed to be the cause of the fragmentation of the species range, reestablishing this thermophiles species to the warmer African Atlantic and Levantine Mediterranean coasts as consequence of its local extinction from the temperate Atlantic Ocean and the western Mediterranean Sea. Currently, as demonstrated by this study, the spread of this species continues northward: along the recently colonized Ionian coast and along the west area of Sicily. Furthermore, very recent records from the Salento Peninsula (Italy) and Tunisia emphasize the fast spread rate of the species in the Mediterranean Sea (Karaa et al., 2019; Mancinelli et al., 2019).

The ongoing increase in sea temperature can be the main, or one of the main, facilitating factor for the spread of the species (Pastor et al., 2017; Sacco et al., 2017). Hence, sea warming could lead to a secondary contact between the Atlantic and Mediterranean subpopulations (Bianchi, 2007). However, the habitat discontinuity represented by the long stretches of rocky coast in the northern Sicily could represent a barrier for the dispersal of the species in other Italian locations, even though marine currents should play an important role to overcome these barriers and, consequently, for secondary colonization of other beaches, for example through rafting on floating objects (e.g. detached macroalgae, seagrasses, wood) or through dispersion of the larvae (Peña-Toribio et al., 2017). Furthermore, the use of citizen science is a suitable method for monitoring the spread of the species in the Mediterranean Sea (Tiralongo et al., 2019) and should be implemented at international level. Indeed, O. cursor is an easily recognizable and detectable species.

Although anthropogenic impacts are considered to have negative effects on crab abundance, and some authors have used ghost crabs as ecological indicators (Neves and Benvenuti, 2006; Lucrezi et al., 2009b; Lucrezi et al., 2009a; Schlacher et al., 2011; Noriega et al., 2012; Jonah et al., 2015), the massive presence of O. cursor in Sicily urban beaches suggests that the species is rather tolerant to human presence, and may even benefit from food supplementation due to human presence. This tolerance can be explained by the nocturnal habits of the species. Indeed, during daylight hours, in particular during the summer months, beaches are typically crowded and crabs remain inside their burrows. Furthermore, on 19th October 2016, at the natural area of the Nature Reserve of Torre Salsa, along a stretch of beach with low human presence that extended for about 300 m and was > 30 m wide, were recorded only 16 burrows. Notwithstanding the minimal anthropogenic disturbance, the species abundance was low, and this is probably due, at least in part, to lack of human food remains. Also, the daily mechanical cleaning of urbanized beaches seems not to cause great disturbance: mechanical means removal of only a few superficial centimeters of sand that cover the burrow does not seem to have apparent effects on crabs. Furthermore, this operation was carried out in the early morning, when crabs are usually inside the burrows, several decimeters below the surface. The crabs opened the burrow entrances a few minutes after the beach cleaning or at sunset. However, considering the legal status (protected) of the species, the impact of human activities on O. cursor needs to be explored in more detail. Therefore, data on abundance and distribution of the species, such as those provided in this study, provide base line information useful for policy making and management of the species. For example, in some areas in which the crabs are particularly abundant, the mechanical cleaning and/or access may be limited or prohibited. Other protection measures, such as ban of construction for bathing facilities, or the construction of particular low impact structures, should be adopted to achieve protection objectives.

This study provides the first ecological data of O. cursor in Sicily based on massive data collection, providing useful information for possible future actions. The species showed a nocturnal activity, from sunset to sunrise, when it comes out from its burrow in search of food and prey. During those hours, we observed most of the specimens feeding very close to the shoreline, on wet sand. However, we observed that in Scoglitti the species can be found out of the burrow also during daylight hours; while it was very rare to observe active crabs during daylight hours at Avola. However, several aspects of the biology and ecology of the species remain unclear (e.g., reproduction, the impact on other species, the role usually ascribed to ghost crabs has been that of scavengers (Taylor, 1971), they are also predators (Wolcott, 1978). Furthermore, their digging behavior enhances oxygenation in the ground soil and facilitates the decomposition of organic materials and nutrient recycling (Dubey et al., 2013).

From our results, the spatial and temporal distribution, as well as the size distribution of O. cursor in Sicily appear well defined. The crabs’ activity decreases from warm to cold seasons, while crab size increases with distance from the sea. In contrast, during the warmer months, the crabs abundance decrease with its distance from the sea. However,
several factors such as temperature, food availability, predators and changes in beach morphodynamics can locally and temporarily alter the general pattern of the species abundance and distribution.

Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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We are grateful to the two anonymous reviewers for their helpful comments.

References

La始于 2015年，根据其提供的数据，我们发现了一种名为_neuromorphic_systems_的海洋生态系统。其中含有多种生物，如小螃蟹（Ocypode spp.）等，它们对环境的高敏感性导致了显著的生态变化。这不仅影响了海滩的生物多样性和分布，且对海鸟等物种的迁徙模式产生了重要影响。

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