Research Article

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Functional flower morphology and entomophilous pollination syndromes in Cape Kaliakra Nature Reserve (North Black Sea coast, Bulgaria)

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Abstract: The complex of entomophilous plants in Cape Kaliakra Nature Reserve (08E1 Western-Pontic petrophytic steppes Natura 2000 habitat) was classified according to the functional morphology of their "blossoms" (flower or compact inflorescence) in the following basic classes: 1) "dish/bowl" - free access to the nectar and pollen, 2) "bell" and "funnel" - more or less hidden nectar, 3) "flag" (sternotribic pollination) and "gullet" (nototribic pollination). Entomophilous pollination syndromes are discussed and medicinal plants from the area are assessed regarding this point of view. This classification roughly predicts the pollinators. Although high percent of the flora of Cape Kaliakra Nature Reserve is wind pollinated related to the specific steppe character, significant is the insect pollination. Many plants have "dish/bowl" "blossoms". Pollinators should be generalists – short tongued small bees, wasps, flies and beetles.

Key words: blossoms, pollinators, generalists, medicinal plants.

Introduction

Specific steppe communities are preserved nowadays in the area along Black Sea coast between the towns of Shabla and Balchik (Bondev 1991, Kozuharov et al. 2001, Tzonev et al. 2006, Făgăraş et al. 2010). There is a significant diversity of the medicinal plants in the northern part of Black Sea Coast floristic region: 593 species of vascular plants from 357 genera and 96 families shown by a recent review of the studies (Zahariev et al. 2016). This represents 80,2% of all medicinal plants recognized by the Medicinal Plant Act (2000) in Bulgaria.

The aims of this paper were to analyze the pollination syndromes of the flora of Cape Kaliakra Nature Reserve: 1) to classify entomophilous plants according to the functional morphology of their "blossoms" (flower or compact inflorescence), and particularly to assess from this point of view the medicinal plants in the area, and 2) to predict the pollinators.

Material and methods

For this study floristic list was filled in during field investigations conducted in 1996 and during the period 2011-2014 at ten study sites in the area of Cape Kaliakra Nature Reserve. We analyzed the biological types as they provide information about breeding systems. The entomophilous plants were classified according to the functional morphology of their "blossoms". The term „blossom" in this study refers to both individual flowers and compact inflorescences that function as a single flower (capitula of Asteraceae and Dipsacaceae) (Faegri & van der Pijl 1970). Medicinal plants were denoted after Medicinal plant act 2000. Descriptive statistics was used to analyze the data obtained.

Results

During the study we recorded 417 species of terrestrial plants. Herbaceous plants dominated significantly

(89,2%) over woody plants (10,8%) and within herbaceous plants perennials (64,4 %) dominated over annuals (35,5%). Spore and gymnosperm plants were poorly presented in the flora of Cape Kaliakra Nature Reserve (4 species, 1,0%, Fig. 1). Wind pollinated plants were rather abundant plants in the area (79 species, 19,0%, Fig. 1): grasses, *Artemisia* sp. div., *Thalictrum minos* L., etc. The analysis of the functional flower morphology revealed that dish/bowl blossoms dominated in the area with 148 species (35,6%, Fig. 1): *Adonis vernalis* L., *Adonis wolgensis* Stev., *Agrimonia eupatoria* L., *Asphodeline lutea* (L.) Rchb., *Conium maculatum* L., *Galium verum* L., *Gypsophila trichotoma* Wend., *Malva sylvestris* L., *Paeonia peregrina* Mill., *Paeonia tenuifolia* L., *Rosa canina* L., *Ruta graveolens* L., *Sambucus ebulus* L., *Sambucus nigra* L., etc. These blossoms presented free access to the nectar and pollen. The blossom symmetry was radial. Different insects (including short tongued bees, flies and even beetles) could be pollen vectors. The second group of the most abundant plants were with dish/bowl+funnel tube blossoms (64 species, 15,4%, Fig. 1). These also had radial symmetry of the blossom (capitulum), in which the individual flowers were tubes or funnels with nectar and pollen more or less accessible (Fig. 1): *Achillea* sp. div., *Centaurea* sp. div., *Onopordon acanthium* L., etc. Their pollen vectors needed to possess short proboscis and pollinators were mainly bees. Funnel blossoms had more or less hidden nectar and the depth of the corolla tube restricted the pollinators. In the area of Cape Kaliakra Nature Reserve funnel shallow blossoms were well presented and much more numerous than funnel deep blossoms (41 plant species 9,9% versus 2 plant species 0,5%, Fig. 1). Funnel shallow blossom was characterised by hidden nectar, narrow but short corolla tube, radial symmetry to slight zygomorphy, where nectar was accessible to short tongued insects like wild and honey bees and bee flies. Funnel deep blossom was characterised by hidden nectar, with narrow and deep corolla tube, radial symmetry to slight zygomorphy. Nectar was accessible to insects with long proboscis like butterflies and moths, long tongued bees (e.g. some species of bumblebees). Specialization in pollination syndromes was expressed in flag and gullet syndromes. They usually required as pollen vectors large enough bees - e.g. *Megachile* sp. div., *Andrena* sp. div., *Osmia* sp. div., bumblebees and honey bees, which were usually generalists and polylectic. These syndromes were almost equally represented in the flora of Cape Kaliakra Nature Reserve (37 species, 8,9% flag syndrome and 39 species, 9,4% gullet syndrome, Fig. 1). Flag syndrome was characterized by zygomorphy (bilateral symmetry) with sexual organs in the lower part, with pollen deposited on the abdominal side of the insect and the pollination was stemotribic: *Astragalus* sp. div., *Chamaecytisus* sp. div., *Medicago* sp. div., *Vicia* sp. div., etc. Gullet syndrome was characterized by zygomorphy (bilateral symmetry) with sexual organs restricted to the functionally upper side, pollen deposited on the dorsal side of the insect and upper part of the head, more or less hidden nectar, nototribic pollination: *Acinos suaveolens* (Sm.) G. Don fil., *Ajuga* sp. div., *Balota nigra* L., *Consolida regalis* S. F. Gay, *Digitalis ferruginea* L., *Digitalis lanata* Ehrh., etc. Few of these plants with flag or gullet pollination syndromes were annuals adapted to self-pollination. Bell blossom was characterized by more or less hidden nectar, wide corolla tube, radial symmetry to slight zygomorphy. Few plant species in the studied area possesed this syndrome (Fig. 1): *Campanula sibirica* L., *Ecbalium elaterium* (L.) A. Rich. These blossoms presented both food and shelter for their pollinators (small bees or flies).

Totally 134 medicinal plant species were found in the area of Cape Kaliakra Nature Reserve, which represented 18,1% of all medicinal plants recognized by the Medicinal Plant Act (2000) in Bulgaria. When medicinal plants recorded in the area of Cape Kaliakra Nature Reserve were classified according to their blossom morphology a pattern of pollination syndromes similar to the entire flora was observed. Dish bowl blossoms dominated over wind pollinated and funnel flowers (Fig. 2). The only difference was recorded in the ratio gullet/flag syndromes.

Discussion

The high percentage of wind pollinated plants of Cape Kaliakra Nature Reserve was in accordance with the steppe character of the flora and vegetation, described earlier (Bondev 1991, Kozuharov et al. 2001, Tzonev et al. 2004, 2006, Anastasiu et al. 2008, Făgăraş et al. 2008, 2010). Nevertheless, plants with entomophilous syndrome dominated over wind pollinated plants. The biological type indicated possible breeding systems – annuals were often capable for spontaneous self-pollination. Perennials were often cross-pollinated but they might also have additional compensatory reproductive mechanisms – facultative ability for spontaneous self-pollination or apomixis including vegetative propagation (Richards 1997). Although many of these plants were annuals and they possibly spontaneously self-pollinated, perennials were bigger group expected to require insect pollen vectors.

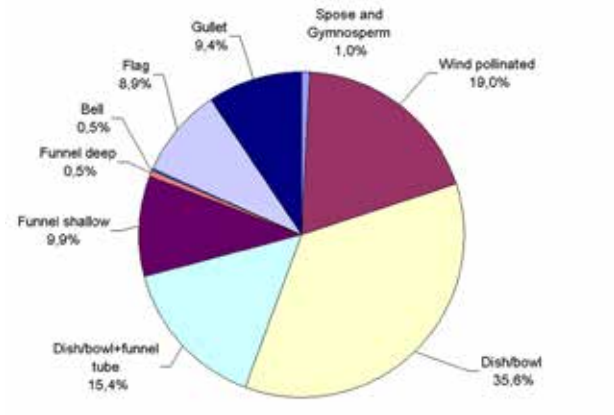

Fig. 1. Plant species of Cape Kaliakra Nature Reserve classified according to the functional morphology of their "blossoms" (flower or compact inflorescence).

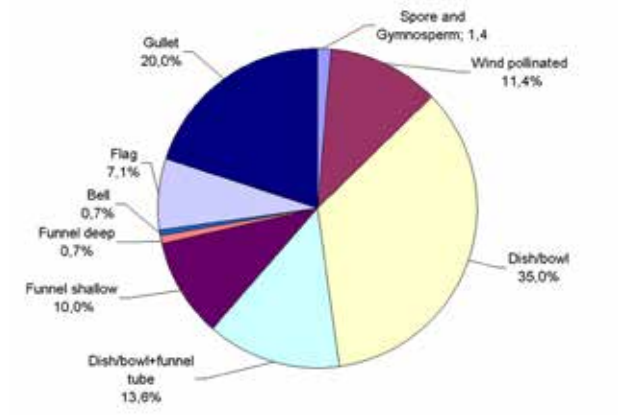

Fig. 2. Medicinal plant species of Cape Kaliakra Nature Reserve classified according to the functional morphology of their "blossoms" (flower or compact inflorescence).

The dish/bowl and dish/bowl+funnel tube blossom types dominated. These two types were more or less similar and were usually put together (Faegri & van der Pijl 1970). Therefore, it could be stated that in the flora of Cape Kaliakra Nature Reserve dominated plants with nectar and pollen accessible to short tongued pollinators (such as small bees, wasps, anthophilous flies and beetles). The results of the pollination syndromes analysis were in accordance with the floristic analysis. The presence of Submediterranean and Mediterranean geoelements (Kozuharov et al. 2001) suggested pollination system similar to that in the Mediterranean ecosystems. The most important pollinators in the Mediterranean are solitary (small) bees (Petanidou & Ellis 1993, Petanidou & Lamborn 2005, Potts et al. 2006, Lázaro et al. 2016). Pollination of the flora of Cape Kaliakra Nature Reserve was orientated towards generalists and only few were specialists (e.g. *Ficus carica* L.). Reviews of plant–pollinator mutualistic networks showed that generalization was a common pattern in this type of interaction (Bascompte et al 2003). There's a long-standing idea in biology that ecological specialisation is an evolutionary "dead end" from which species can never emerge. (de Brito et al. 2017). In addition, specialization leads to vulnerability of both components in the system plant-pollinator (Stefanaki et al. 2015). Regarding the pollination syndromes of medicinal plants in the studied area we can predict that at least of 50-60% of the medicinal plants in the area need pollen vectors for their reproduction. These should be generalists – wild bees, honey bees, as well as flies, beetles and butterflies.

The relative importance of pollinating honey bees, *Apis mellifera,* versus other species is debated for more than 20 years and the role of wild bees in the pollination process should not be neglected (Ollerton et al. 2012). Recent concept of mutualistic networks has practical conservation aspects. Survival of the mutualistic networks depends on the conservation of the aggregation of all interacting taxa (Thébault & Fontaine, 2010, Fortuna et al. 2010, Hegland & Totland 2012). Therefore, it is not enough to focus only on the plant object to protect particular endemic or rare plant species but is necessary to develop conservation strategy for the whole mutualistic networks.

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