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Buff-tip (*Phalera bucephala* L.) – a potential pest in energy plantations and agroforestry. Literature review from selected Internet sources

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Abstract. *Phalera bucephala* belongs to the moth of Notodontidae family. The food plant list of its larvae covers many tree and shrub species, including those used in energy crops and agroforestry. The aim of this study was to collect and organise the information available in selected online literature databases on the buff-tip, taking into account scientific articles published in the last decade. In addition to a description of the insect's appearance, the review covers issues concerning its occurrence, development, feeding mode, behaviour and relationship with other organisms. The summary also assesses the usefulness of the web sources used to characterise the species in question.

Keywords: Lepidoptera, moth, tree pest, Google Scholar, literature databases.

INTRODUCTION

The buff-tip (*Phalera bucephala* L.) belongs to the moth of the Notodontidae moth family. It is a polyphagous insect, mainly associated with forests. Its larvae also feed on trees and shrubs grown for energy in short rotations of several years (e.g. willow, poplar) and those used in agroforestry systems (e.g. birch, sessile oak, apple, mountain ash, hazel, lime, walnut) (Wójcik et al., 2021). The buff-tip is not currently ranked as one of the most dangerous pests of such crops, but it tends to increase rapidly in population size and in the 20th century significant damage to tree foliage caused by the feeding of its caterpillars was recorded locally. The biology and thus the importance of this species, may be modified by climate change. In addition, the presence of the buff-tip in field ecosystems may affect the appearance and activity of more economically important insects. Knowledge of the species involved in such interactions may be of considerable practical importance in the cultivation of trees and shrubs in energy plantations or in agroforestry, where the possibility of intervening conservation treatments is limited for ecological or technical reasons (Borek et al., 2021; Remlein-Starosta, Mrówczyński, 2013).

A very extensive and recently most used source of information is the Internet and, for researchers, articles collected in bibliographic databases. Of particular importance, due to the potentially largest audience, are the publications offered in the open access option. The aim of this paper is to review information on *Phalera bucephala*, taking into account recent scientific articles, and to assess the content of selected bibliographic online sources in this respect.

DATA SOURCES

The study uses data from three bibliographic sources offered in the open access option (Table 1). Google Scholar is a free search engine for working with databases containing scientific articles. The international SCOPUS database includes tens of thousands of scientific journals and is given as one of the reference databases of the Polish ministry of education and science. Biblioteka Nauki (The Science Library) is an aggregator of scientific databases covering Polish scientific articles in six fields. Publications directly related to the subject of the study were selected from the entire resource. Articles in which buff-tip is mentioned only as a species caught in the study area were omitted. In addition, information available on professional entomological websites, plant protection textbooks and several review publications outside the time range covered by the search were included.

OCCURRENCE

Phalera bucephala is a Palearctic species. It is found in Europe, the Caucasus, Central Asia, Siberia, Iran, the Far East (Korea and China), and North Africa. There are 4 subspecies: *bucephala, bucephalina, persica, tenebrata,* related to geographical regions. Moths are found up to an altitude of 2200 m (Schintlmeister, 2008). Morimoto and Pietras (2000) suggested the possibility of expansion of *P.*

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Table 1. Internet sources used in the study.

Search description	Bibliographic source		
	SCOPUS	Google Scholar	Biblioteka Nauki
Enquiry	all records from the query „Phalera bucephala” under the full institutional access option	all records from the query „Phalera bucephala”	all records from the queries „Phalera bucephala” and „narożnica zbrojówka”
Time range	unlimited	2012-2022	unlimited
Total number of records	4	607	5
Number of records included in the study	4	114	3

bucephala using new food plants, both into new areas and into higher mountain altitudes. In Poland, buff-tip occurs throughout the country and is a frequent species (https://www.ior.poznan.pl ...).

Information on the environmental preferences of the buff-tip identified in various studies is inconclusive. For example, it was included among the 19 species of Lepidoptera considered most dangerous to greenery in the city of Donetsk (Martynov et al. 2019), while in Yekaterinburg it did not occur on trees in central parts of the city and city parks at all (Bogačeva, Zamšina, 2017), and it was not found in street environments and parks of Kharkiv (Kukina et al., 2021). According to data cited by Ogris and Kavčič (2021), *P. bucephala* is associated with open habitats and the edges of deciduous forests. In contrast, in a German study (Mestdagh, 2021), it appeared to be the only species that occurred deep in the forest and was not recorded at forest edges. Such variation is understandable, as the results are influenced by local conditions, the abundance of the moth population, the timing and methods of trapping or the representativeness of the sample. It is generally considered that the buff-tip is associated in nature with widespread forests (Tyler 2020), occurs at the interface between forest and meadow biotopes (Růžička, 2013), but can also occur in cities (Sidorova, 2014): in parks, botanical gardens (Muhina et al., 2016), in squares, on vegetation near buildings, in alleys, along streets (Ponomarëva, Bessonova, 2016). Port and Thompson (1980) describe its outbreak of several years on beech trees growing along a traffic route. The authors explained this by the high N content in the substrate affecting the condition of host plants, not limited by predation pressure in the area. *Phalera bucephala* is also recorded in shelterbelts protecting fields and in agroforestry crops (Gribust, Belickaâ, 2020), in energy crops (Wrzesińska, Wawrzyniak, 2012) and even in orchards (Fryer, 2015). Adult moths were also caught to light in meadows (Šumpich, Konvička, 2012).

According to most European reports, *P. bucephala* is a species with a consistent occurrence. For example, Moraal and Jagers OpAkkerhuis (2013), on the basis of an analysis of data since 1964, classified it as one of 18 tree pest species with this characteristic. Also Wagener (2001) found that it was not recorded in the border areas between Germany and the Netherlands in only six years between 1921 and 1974. Also Laussmann et al. (2022), on the basis of data from 1907 to 2019, found this species to be consistently frequent, with a rating of 4 on a scale of 0 (not present) to 8. In contrast, in a paper on the forests of Ukraine, *P. bucephala* is cited as an example of a pest whose last outbreak were recorded in the 1940s and 1950s and whose importance is now lower (Meshkova, 2022). The author links this to the impact of chemical forest protection on insect community relationships (Meshkova, 2000). Also, Kardash (2020), who considered the buff-tip as a species capable of outbreaks, found that such occurrences were less frequent in Kharkiv in 2017–2020 than in the 1960s.

DESCRIPTION

The appearance of the individual developmental stages of the armyworm is constant, and photographs and drawings are of the greatest informative value in their description. These can be found on professional websites containing entomological data, for example: Butterflies of Europe/Lepidoptera Mundi, Lepiforum e.V., the website of the Institute of Plant Protection – National Research Institute in Poznań, Les Pages Entomologiques d'André Lequet, Forest Research, Plant Parasites of Europe. Photographs included in the text are from personal resources. The same information on appearance and development is reproduced in many different sources, so only examples of publications are given when discussing particular traits and phases. Buff-tip is an easy species to determine by appearance. In cases where morphological determination is not possible, barcodes available in gene banks can be used to identify the genetic material of *P. bucephala* (Huemer, Hebert, 2012, 2015).

Egg

Eggs are laid in groups, in a single layer, usually up to a few tens of eggs in a bed (Fig. 1), close together. They are large, measuring 0.8–0.9 mm (Marčenko, 2015), weighing about 2.1–2.3 mg (Denisova et al., 2014). The upper part of the egg is bright and convex. In its centre is a dark, round, depressed spot. This is the site of sperm penetration (Sourakov, Chadd, 2022). The lower part of the egg is dark green or beige. The base of the egg is flat, which increases adhesion to the leaf surface (Sourakov, Chadd, 2022). The chorion is finely ribbed (Dolinskaya, 2016).

Larva (caterpillar)

The appearance of the larvae changes as they grow older. The body is yellow and the dark pattern visible on it changes as they develop. Initially these are different sized blackish brown oval spots arranged in lines along the body, then longitudinal black and white stripes with yellow or orange rings on individual segments (Fig. 2). The body is hairy, the long greyish-white hairs being best visible just after moulting.

The head is black, only freshly moulted light yellow. From the 4th larval instar onwards, the mark of a yellow inverted Y is well visible (Fig. 3).

The thoracic legs and prolegs are black. The last, fifth, pair of prolegs has developed into short, black forked appendages, without feet but with preserved original hair (Dolinskaya, Pljushch, 2003).

The caterpillars reach 50–60 mm in length, weighing then about 1.2–1.5 g (Denisova et al., 2014). Detailed descriptions of the first-stage larvae and the distribution, number, size and shape of the larval cranial setae and their changes as the insect develops can be found in the literature (Dolinskaya, 2013; Dolinskaya, Pljushch, 2003).

Pupa

The pupa is initially green, then darkens, starting from the abdomen, and finally the whole becomes purple-brown, dull. It is about 30 mm long (Marčenko, 2015) and weighs about 0.9 g (Denisova et al., 2014). The cremaster is flat, split and branched (Zinčenko, Suchomlìn, 2012).

Imago

The wingspan of the moths is 50–68 mm, body length 25–35 mm. Individuals from the Far East are usually larger than European individuals (Schintlmeister, 2008). Larger butterflies are also found in urbanised areas (Merckx et al., 2018)

The thorax of the butterfly is reddish from above, grey-brown on the sides, the abdomen beige. The front wings are grey with a large, light yellow, partly dark-contoured spot near the apex. The bands are narrow and dark. The light spot on the transverse vein is faintly visible. The hind wings are light beige, with indistinct grazing. The butterflies of this species are characterised by a large variation in colouration; in addition to typical specimens, there are both very light, almost white specimens (usually from xerothermic habitats) and very dark specimens with a contrasting yellow pattern on the front wings (Schintlmeister, 2008). The ultraviolet reflectance of the wings of *P. bucephala* is 0.38 (Cane et al., 2018).

In the buff-tip moth there is no clear sexual dimorphism, but females tend to be larger and have thicker abdomen before laying eggs, and they also differ slightly from males in the shape of the antennae (Fryer, 2015).

Sitting with folded wings, the moths both in colour, pattern and shape resemble a broken branch of a birch or other tree with light bark (Fig. 4).

DEVELOPMENT

Phalera bucephala is considered to be a univoltine species (https://www.ior.poznan.pl), only Dolinskaya (2012) cites information from 1897 about the occurrence of a 2nd generation.

Moths emerge from pupae from mid-May (https://lepidoptera.eu; https://www.ior.poznan.pl) and fly until August, with a maximum in abundance in July. The sex ratio is approximately 1:1 (Denisova et al., 2014). Copulation occurs soon after flight and females quickly proceed to lay eggs, which is characteristic of species that as adults do not take food and rely on reserves accumulated during the larval stage. Eggs are laid in clusters of about 20 to nearly 100 in one. One female lays an average of 250 eggs (Marčenko, 2015). According to most authors, she places them on the underside of the leaves (e.g. https://www.ior.poznan.pl ..., Marčenko, 2015), according to https://lepidoptera.eu: on the upper side, and Fryer (2015) also gives a possible location on the shoots. Embryonic development lasts from about 10 days (https://www.insectes-net.fr ...) to 2 (https://www.ior.poznan.pl ..., Marčenko, 2015) and even 3 weeks (Forest Research), its length is influenced by temperature (https://www.insectes-net.fr ...). The caterpillars go through 5 developmental stages, the early moults take place synchronously. Initially they stay together, from the 3rd larval stage they start to divide into smaller groups (Marčenko, 2015). Full larval development lasts about 40–45 days (Marčenko, 2015), its length depending, among other things, on the type of food (Dikovič, 2017). According to Marčenko (2015), the descent of caterpillars into the soil lasts from July to September, according to Tomalak (https://www.ior.poznan.pl) from August to October. Pupae form at a depth of 3–6 cm, only some deeper, up to 15 cm (Marčenko, 2015), in a small cavity prepared by the caterpillar (https://www.ior.poznan.pl ...) or under fallen leaves (Fryer, 2015). Some authors claim that the pupa is naked (Denisova et al., 2014), others that the larva forms a loose cocoon (Dolinskaya, 2012). The developmental cycle is not regulated by photoperiod (Lees, 1955), but is influenced by vitamin metabolism (Liu et al., 2022).

FEEDING MODE, HARMFULNESS

According to Sourakov and Chadd (2022), larvae immediately after hatching partially eat the egg casing, while Lequet (https://www.insectes-net.fr ...) noticed that they

Figure 1. Egg cluster of *Phalera bucephala* on willow leaf

Figure 2. Mature caterpillar of *Phalera bucephala*

Figure 3. Y-mark on *Phalera bucephala* caterpillar head

Figure 4. Moth of *Phalera bucephala* with folded wings

Figure 5. Feeding of young caterpillars of *Phalera bucephala*

Figure 6. Willow leaf gnawed by a group of *Phalera bucephala* caterpillars

do not show this behaviour. Young caterpillars feed in clusters, lined up close together in a single row. Initially, they scrape only the crumb (Fig. 3), then gnaw the leaves through the entire thickness (Fig. 4). According to Iszczuk (2017), they also feed on buds. As they grow, they begin to separate into smaller groups, eventually feeding separately. The outgrown larvae eat the entire leaf blades, leaving only the thickest nerves (Łabanowski, Soika, 2012; https://www.ior.poznan.pl ...). It has been calculated that during the entire development a caterpillar feeding on an oak tree eats about 20 leaves (10–12 g of biomass) (Marčenko, 2015). Adults do not take food.

Compounds have been detected in the faeces of larvae feeding on plants containing salicylates (black poplar), indicating that the caterpillars use different methods to detoxify the plant material they eat (Boeckler et al., 2016). It has also been found that caterpillars can effectively feed on weakened plants, such a condition in laboratory studies was achieved by cutting twigs and keeping them in the dark for 24–48 hours. Both developmental parameters and food utilisation were even better in such combinations than in control treatments (Denisova et al., 2014; Dikovič, 2017). In two experiments, the best efficiency of biomass utilisation by caterpillars was found in oak. In the first experiment, it decreased successively for hazel, raspberry, rowan and elm (Denisova, 2020), and in the second experiment for birch, apple, rowan and cherry (Denisova, Sedlovskaâ, 2020).

Feeding *P. bucephala* caterpillars with genetically modified birch leaves, which had the chitinase gene from sugar beet incorporated into its genome, had no significant effect on the larval development parameters studied. The different result from *Orgyia antiqua* is explained by the authors by the different structure or composition of the peritrophic membranes (Vihervuori et al., 2013; Vihervuori, 2015).

The host plant range of the buff-tip is wide (Table 2). Foraging by young larvae causes yellowing and drying of leaves, older larvae can lead to complete defoliation (https://www.forestresearch.gov.uk ...; https://www.ior.poznan.pl ...), as well as shoot drying (Ogris, Kavčič, 2021). However, as the caterpillars' active period is in the second half of the summer, long-term adverse effects of damage are unlikely to occur unless the feeding affects young plants (https://www.forestresearch.gov.uk ...; Grečkin, 2020; Ogris, Kavčič, 2021).

The amount of damage also depends on the number of insects. The abundance of *Phalera bucephala* can periodically increase significantly. Based on literature sources, for example, mass occurrence in forests was described in 1875, 1893–1894, 1941–1942, 1945–1946, 1953–1954, 1958–1959, 1962, 1966, 1968, 1972 (Beleckij, Stankevič, 2018). Selikhovkin et al. (2018) recall such phenomena in 1937, 1938, 1947 and report that also in 2008 in St. Petersburg 30–60% of trees, mainly birch and elm, were attacked and the loss of leaf area was very high. Also Grečkin (2020) describes a *P. bucephala* outbreak in birch forests in the 1950s, which covered more than 100 ha. It was estimated that the tree crowns were 60% damaged. In monoecious moths, such as the buff-tip, an increase in abundance occurs when the following year's spring is warm after a hot, dry summer (Bogačëva et al., 2018, quoted after Gorlenko, Pan'ko).

INSECT BEHAVIOUR

The moth are active at night; during the day they can be found sitting on trunks (https://lepidoptera.eu ...). When at rest, they are difficult to spot because they are deceptively similar to a fragment of a broken twig. If disturbed, they spread their wings slightly – in which case the bright spots on their tips can be recognised as eyes, the spacing of which suggests to a predator the presence of a much larger animal (Craik, 2018). Blyth (2015) notes the similarity of the buff-tip to the barred owl. Moths have tympanic organs that enable them to avoid in-flight attacks by some bat species (Zhemchuzhnikov et al., 2014; Arrizabalaga-Escudero, Merckx, 2019).

Other defensive behaviours are displayed by caterpillars. These are variously described: from raising the front of the body (https://lepidoptera.eu ...), to bending the body into a U-shape and returning the food content when a threat is mounting (Despland, 2013, quoted after Costa). These behaviours are synchronised and can spread rapidly throughout a group of caterpillars, suggesting the possibility of communicating threat information (Despland, 2013). Schaefer (2012) also mentions the strong odour emitted by cornered larvae. There are reports in the popular literature of the irritating effect of the body hairs of *P. bucephala* caterpillars, but there is an explanation on the website of the Natural History Museum in London that they are harmless and the information about their harmfulness is the result of confusion with the properties of similar caterpillars of the oak processionary moth *Thaumetopoea processionea* (Pavid, 2018).

In many monitoring studies, *P. bucephala butterflies* have been shown to arrive at standard light traps. Nowinszky et al. (2022) found that traps emitting only ultraviolet, not visible light, were more effective. Truxa and Fiedler (2012) showed that even weak sources of artificial light (UV fluorescent tubes, 2 × 15 W) are sufficient for trapping, making it possible to conduct such studies even without professional equipment. Šumpich and Konvička (2012) draw attention to the correctness of the interpretation of results when trapping for light. In their study conducted in meadows in the Czech Republic, more individuals were captured on mown than unmown sites, but this may have been due to better visibility and ease of reaching the traps, not the environmental preferences of the insects. Also Nowinszky and Puskás (2015) emphasise that the results of this kind of study tell only about the susceptibility

Table 2. Host-plants of armyworm corner (example sources).

Host plant		Source
English common name	Latin name	
Maple	*Acer* sp.	Morimoto, Pietras, 2020
Horse chestnut	*Aesculus hippocastanum*	Thomas et al., 2019; Meier et al., 2012
Alder	*Alnus glutinosa*	Bianco et al., 2014
Birch	*Betula costata*	Turova, 2009
	Betula davurica	Turova, 2009
	Betula pendula (lab.)	Denisova, Sedlovskaâ, 2020
Hornbeam	*Caprinus* spp.	https://www.forestresearch.gov.uk
Chestnut	*Castanea* spp.	Ferracini, 2020; Núñez, 2020
Hazel	*Corylus avellana*	Hicks, 2022
Beech	*Fagus* spp.	Jung, Schmitz, 2022
	Fagus sylvatica	Packham et al., 2012; Belov, 2013
Ash	*Fraxinus excelsior*	https://bladmineerders.nl ...
Goldilocks	*Laburnum* spp.	https://bladmineerders.nl ...
Apple tree	*Malus* spp.	Fryer, 2015
	Malus palustris (lab.)	Denisova, Sedlovskaâ, 2020
Poplar	*Populus tremula*	Volf, 2012
	Populus balsamifera	https://bladmineerders.nl ...
	Populus nigra	https://bladmineerders.nl ...
Cherry	*Prunus avium*	https://bladmineerders.nl ...
Plum	*Prunus* spp.	Fryer, 2015
	Prunus spinosa	https://bladmineerders.nl ...
Oak	*Quercus mongolica*	Barma, 2015
	Qereus robur (lab.)	Denisova, Sedlovskaâ, 2020
	Quercus petraea	https://bladmineerders.nl ...
	Quercus pubescens	https://bladmineerders.nl ...
	Quercus rubra	https://bladmineerders.nl ...
Currant	*Ribes alpinum*	Morimoto, Pietras, 2020
Gooseberries	*Ribes uva-crispa* (lab.)	Morimoto, Pietras, 2020
Rose	*Rosa canina*	Łabanowski, Soika, 2012
	Rosa glauca	https://bladmineerders.nl ...
Willow	*Salix alba*	https://bladmineerders.nl ...
	Salix aurita	https://bladmineerders.nl ...
	Salix caprea	Iszczuk, 2017; Volf, 2012
	Salix cinerea	Iszczuk, 2017;Volf, 2012
	Salix ledebouriana (?)	Morozov et al., 2016
	Salix triandra	Iszczuk, 2017
	Salix tenuijulis (?)	Morozov et al., 2016
	Salix lapponum	https://bladmineerders.nl ...
	Salix phycilifolia	https://bladmineerders.nl ...
	Salix turanica (?)	Morozov et al., 2016
	Salix viminalis	Wrzesińska, Wawrzyniak, 2012; Volf, 2012
Linden	*Tilia* spp.	Meier et al., 2013; Sidorova, 2014
	Tilia cordata	https://bladmineerders.nl ...
	Tilia platyphyllos	https://bladmineerders.nl ...
Elm	*Ulmus* spp.	Selikhovkin et al., 2018; https://www.forestresearch.gov.uk ...
	Ulmus laevis	Denisova, 2020
	Ulmus procera	https://bladmineerders.nl ...
Viburnum	*Viburnum* spp.	https://bladmineerders.nl ...
Rowan	*Sorbus aucuparia* (lab.)	Denisova, Sedlovskaâ, 2020
Cherokee	*Padus racemosa* (lab.)	Denisova, Sedlovskaâ, 2020
Raspberry	*Rubus idaeus*	Tan et al., 2022
Black locust	*Robinia* spp.	Bragard et al., 2021

lab. – in laboratory studies; (?) – based on captures of adults of butterflies to light attraction, not about the status of the whole population. In their experiments, the proportion of *P. bucephala* males in traps was 98%, while the sex ratio in this species is equal (Denisova et al., 2014). The authors explain this by the lower mobility of females related to their greater mass and the greater activity of males, which have to search for mates.

The odour of an unfertilised enclosed female attracts males but is undetectable to humans (Jacobson, 1972). The olfactory organs of *P. bucephala females* have a very simple structure and are located between the eighth and ninth segments of the abdomen (Jacobson, 1972, quoted after Urbahn).

Phalera bucephala has been found to be one of the most mobile moth species, with average travel distances reaching 550 m (Merckx, Macdonald, 2015). However, Slade et al. (2013) consider that it is inferior in mobility to species of similar size and structure closely associated with forests. Buff-tip did not flock to the light traps located at the top of the wind turbine, about 100 m from the ground, although it was caught in the reference trap on the ground at the same time (Trusch et al., 2020).

Esposito et al. (2017) observed the pollinaria transfer of *Platanthera bifolia* and *P. chlorantha* by nocturnal butterflies, and, based on light trapping in areas colonised by these orchids, they selected potential other pollinators from this group. They also considered the buff-tip, but its contribution to pollination is unlikely because the adults do not feed on the flowers.

ANATOMY

In the resource searched, few papers deal with the anatomy of *Phalera bucephala*; information on its internal structure usually appears as a supplement to data describing other species. Primary source papers are not available free of charge in electronic form.

Insect brain structures that are probably responsible for odour discrimination and memory have been studied. In *P. bucephala, the* position of the neuroblast relative to the Kenyon cell group in the mature caterpillar has been described (Panov, 2018).

The main structures responsible for cocoon formation are the silk glands, which are modified labial glands. They interact with small paired formations called Filippi's glands. Their function is not well understood. They are thought to have an auxiliary role in fibre formation (lumbricate production, synthesis of fatty acids and fats, solution transport). In *Phalera bucephala,* their structure is complex, they are located near the subesophageal ganglion, have the shape of well-developed lobes and are connected by tubules to the silk glands. In species that do not produce cocoons, the secretions of the silk glands may have a different function (Sehadova et al., 2021).

Zhemchuzhnikov et al. (2014) studied the structure of the tympanic apparatus in species of the Noctuidae family of moths. For comparison, they cited literature data on these organs in *P. bucephala*.

RELATIONSHIPS WITH OTHER ORGANISMS

Many insects in the Diptera and Hymenoptera orders are parasitic of the buff-tip (Table 3), with eggs, larvae and pupae attacked. The first attempts at mass reproduction of small vasps of the genus *Trichogramma* were made precisely using the eggs of *P. bucephala* (de Almeira, Cruz, 2013, quoted after Flanders)

In the sources used in the study, most of the information on *P. bucephala* parasitoids is citations from other works, only a few are original. Segreeva and Dolmonego (2013) investigated the possibility of using the hymenopteran *Chouioia cunea* in forest protection, also against *P. bucephala*. In the experiment, 19 out of 43 pupae were parasitised, with up to 857 insects emerging from a single pupa. According to the authors, 80–90% parasitisation can be expected in breeding facilities, but under natural conditions it can reach at most 30%.

Larvae are also attacked by fungi, bacteria and viruses. The fungus *Cordyceps militaris* parasitizes larvae and pupae (Shrestha et al. 2016). Nužanov (2019) cites a report that the potentially pathogenic fungus *Scopulariopsis brevicaulis* (Sacc) Bain was found on larvae and adults of beetles and butterflies, including *P. bucephala.*

The bacterium *Serratia marcestens* (Gouli et al. 2020) can be dangerous to the buff-tip, and biological insecticides based on the bacterium *Bacillus thuringiensis* var. *Kurstaki* (https://www.ior.poznan.pl ...) are used in the control of *P. bucephala*. Buff-tip larvae can also be infected by both nuclear (Gouli et al. 2020) and cytoplasmic polyhedrosis viruses (Poinar, Thomas, 2012). The microsporidium *Nosema phalerae* was also found in the fat body of buff-tip larvae (Sokolova et al., 2018). Marčenko (2015) reports that breakdowns in outbreaks are due to fungal and other diseases, which can kill up to 90% of older larvae. Hein et al. (2022) found that control of the oak processionary moth *Thaumetopoea processionea* using the nematode Steinernema feltiae does not affect *P. bucephala* abundance. However, they emphasised that the treatments were carried out in spring, when there were no buff-tip caterpillars on the trees yet.

Insect predators that prey on *P. bucephala* include the bug *Picromerus bidens* L. (Volkov et al. 2021). Marčenko (2015) reports that birds do not eat the buff-tip, while Malchevskij (2012, 2022) considers it part of the oriole's diet, and Denerley et al. (2019) – the cuckoo. Arrizabalaga-Escudero et al. (2019) found that butterflies are caught by the bat *Rhinolophus euryale*, mainly in May and usually by adults.

Nakajima and Ogura (2022) report that *P. bucephala* was used as a human food in China. Denisova et al. (2014) found that caterpillars fed on oak leaves in the last developmental stage contained 6.41% protein in d.m., pupa 9.25,

Table 3. Insect parasites of *Phalera bucephala* (cited in original form).

Diptera		Hymenoptera	
species	source	species	source
Blondelia nigripes (Fallén, 1810)	Tschorsnig, 2017	*Aleiodes albitibia*	Shaw, 2016; Van Achterberg,
Carcelia gnava (Meigen, 1824)	Tschorsnig, 2017	*Barylypa longicornis* Bravus	Marčenko, 2015
Compsilura concinnata (Meigen, 1824)	Almeida et al., 2017; Herting, 2017; Tschorsnig, 2017	*Cales noacki*	Gerber, Schaffner, 2016; Mottern et al., 2012
		Chouioia cunea	Sergejev, Dolmoni, 2013
Drino imberbis (Wiedemann, 1830)	Akın, Kürşat, 2021; Tschorsnig, 2017	*Coclichneumon singularis* Bert. ##	Marčenko, 2015
Drino inconspicua (Meigen, 1830)	Marčenko, 2015; Tschorsnig, 2017	*Cotesia tibialis* (Curtis, 1830)	Abdinbekova et al., 2017; Žikić et al., 2015
Exorista fallax (Meigen)	Marčenko, 2015	*Dusona falcator* (Fabricius, 1775)	Choi et al., 2012; Shaw et al., 2016
Exorista larvarum (Linnaeus, 1758)	Tschorsnig, 2017	*Enicospilus ramidulus* (Linnaeus, 1758)	Coruh, Çalmaşur, 2016; Kiraç, Gürbüz, 2020; Kolarov, Coruch, 2022; Kolarov et al., 2020
Exorista rossica Mesnil, 1960	Tschorsnig, 2017		
Exorista segregata (Rondani, 1859)	Aytar et al., 2021; Uysal, Atay, 2021	*Enicospilus touznicri* Voll. ##	Marčenko, 2015
Nilea hortulana (Meigen, 1824)	Tschorsnig, 2017	*Goedartia alboguttata* (Gravenhorst 1829	Lungu-Constantineanu, Constantineanu, 2014
Pales pavida (Meigen, 1824)	Tschorsnig, 2017	*Meteorus colon* (Haliday, 1835)	Lee et al., 2017
Senometopia excisa (Fallén, 1820)	Tschorsnig, 2017	*Syspasis alboguttatus* Grav. #	Marčenko, 2015
Senometopia lena (Richter, 1980)	Tschorsnig, 2017	*Telenomus brevis* Thoms.	Marčenko, 2015
Senometopia separata (Rondani, 1859)	Tschorsnig, 2017	*Telenomus mayti* Kieff.	Marčenko, 2015
Sturmia bella (Meigen, 1824)	Tschorsnig, 2017	*Trichogramma evanescens* Westwood, 1833	Polaszek et al., 2012
Tachina magna (Giglio-Tos, 1890),	Seyyedi-Sahebari et al., 2019; Tschorsnig, 2017		
Winthemia cruentata (Rondani, 1859)	Tschorsnig, 2017		
Zenillia libatrix (Panzer, 1798)	Tschorsnig, 2017		

on the Fauna Europaea website (https://fauna-eu.org/): *Syspasis alboguttata*
no records on the Fauna Europaea website (https://fauna-eu.org/)

eggs 3.36, fat 9.47, 24.03, 23.74%, respectively. Carbohydrates in the haemolymph of 5-th instar caterpillars were 19.64 mg per ml, and glycogen in pupae was 12.69% d.m. Research has also looked at more complex multi-element systems. Van Dijk et al. 2020 studied the effects of feeding by the aphid *Tuberculatus annulatus*, *P. bucephala* and infection by the fungus *Erysiphe alphitoides* on the growth of pedunculate oak seedlings and the relationship between the insects and the fungus. They found that feeding of *P. bucephala* on leaves occupied by powdery mildew reduced larval survival and prolonged larval development, and caterpillar growth was also lower when the buff-tip was feeding on plants previously colonised by aphids. The feeding of *P. bucephala* larvae also affected the relationship between powdery mildew and aphids. Van Dijk et al. (2022) showed that the soil microbiome additionally influenced these relationships.

Morimoto and Pietras (2000), who observed *P. bucephala feeding* on *Ribes alpinum*, discussed the potential negative impact of the buff-tip on the butterfly *Euhyponomeutoides ribesiella*, which feeds only on plants of this genus and occurs in the same area.

Relationships between *P. bucephala* and other organisms became apparent, for example, in Portugal between 1945 and 1958. Forest spraying with DDT targeting *Lymantria dispar was* followed by a outbreak of other pests, including precisely the buff-tip (Ceia, 2016). Tan et al. (2022) discussed the ways in which *Phalera bucephala* feeding on raspberry bushes may influence virus infection through different types of relationships with the organisms that carry them.

SUMMARY

In the material selected on the basis of the criteria described in the Data sources chapter, there is little new information on *Phalera bucephala*. The articles published in the last decade mostly deal with faunistic data – findings of the presence of the species in the study area. They do not tell us much about the biology of the species, as they usually refer to a short period, the capture of mobile adults, and lack a detailed description of the status of the moths, habitat conditions and the presence of other organisms. Most of the information on parasitoids is quoted from old publications that are not available on the web, may contain errors due to repeated copying and needs to be verified. Primary source publications on biology and anatomy are not freely available online. Large resources of information, although not always factually correct, can be found on private and institutional websites.

Phalera bucephala is not an economically important species, as indirectly evidenced by the low number of records devoted to it in the Scopus and the Biblioteka Nauki databases. Interest in the buff-tip may increase as a result of wider use of its host plants, in energy biomass production or in agroforestry. Information on its defense mechanisms, methods of selecting food plants, determinants of outbreaks or interactions with other organisms may be important.

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