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First record of the Indian meal moth *Plodia interpunctella* (Lepidoptera: Pyralidae) at a research station in Antarctica

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Abstract: We report the first formal record of the Indian meal moth *Plodia interpunctella* from a location within the Antarctic Treaty area, with the capture of a live adult male within the Brazilian Comandante Ferraz research station on King George Island, South Shetland Islands. This species is a well-known pest of stored products and is widely recorded in synanthropic situations such as food stores globally. No other adults or immature stages have been observed on the station. While there is no suggestion that *P. interpunctella* could survive or establish in the natural environment beyond the station, this observation highlights the ever-present threat of unintended anthropogenically assisted transfer of non-Antarctic species into human facilities on the continent, with some such species proving extremely difficult to eradicate if they successfully establish within these facilities.

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Introduction

Antarctica, considered under the Antarctic Treaty as all land and ocean south of the 60°S latitude parallel, houses some of the most pristine environments on Earth. The continent's ecosystems are characterized by some of the most extreme environmental conditions globally (Convey *et al.* 2014, Convey 2017). Along with the continent's geographical isolation, such conditions act as environmental filters preventing most organisms from colonizing and becoming established. Antarctica's native terrestrial diversity is relatively poor (Convey 2017). Only two native flowering plants are present, with vegetation primarily consisting of mosses and lichens, along with microbiota (Ochyra *et al.* 2008, Carvalho-Silva *et al.* 2021). Similarly, the terrestrial fauna comprises primarily micro-arthropods (mites and springtails) and micro-invertebrates and includes only two native insects: the chironomid midges *Parochlus steinenii* (Gerke 1889) and *Belgica antarctica* Jacobs, 1900, both restricted to the Maritime Antarctic (Convey & Block 1996).

The Antarctic Peninsula and Scotia Arc experienced the most dramatic warming in air temperature in Antarctica in the second half of the twentieth century (Turner *et al.* 2009). Since the turn of the century, this warming has paused and even reversed for a short period (Turner *et al.* 2016), but climate modelling predicts a resumption of the rapid warming through the remainder of the twenty-first century (Bracegirdle *et al.* 2020).

King George Island (KGI) is the largest of the South Shetland Islands (Fig. 1) with an area of 1150 km^2. It has a cold oceanic climate and an average annual temperature of -1.88°C to -1.68°C and a relative humidity of 89%, with three to four summer months typically having low positive monthly mean air temperatures. KGI is highly impacted by human presence, hosting national research stations representing nine countries (Argentina, Chile, China, Brazil, Peru, Poland, Russia, South Korea and Uruguay) and an aerodrome, as well as being visited by tourists.

One of the most concerning threats to Antarctic ecosystems and biodiversity, as is the case globally (Pyšek *et al.* 2020), is the introduction through anthropogenic assistance of new species (potentially including some providing new ecological functions) that may be able to become established in the region, with unknown and unpredicted consequences for the native biota (Frenot *et al.* 2005, Amesbury *et al.* 2017, Robinson *et al.* 2018, Convey & Peck 2019). Many examples of this already exist in the sub-Antarctic, with increasing numbers of records becoming available from

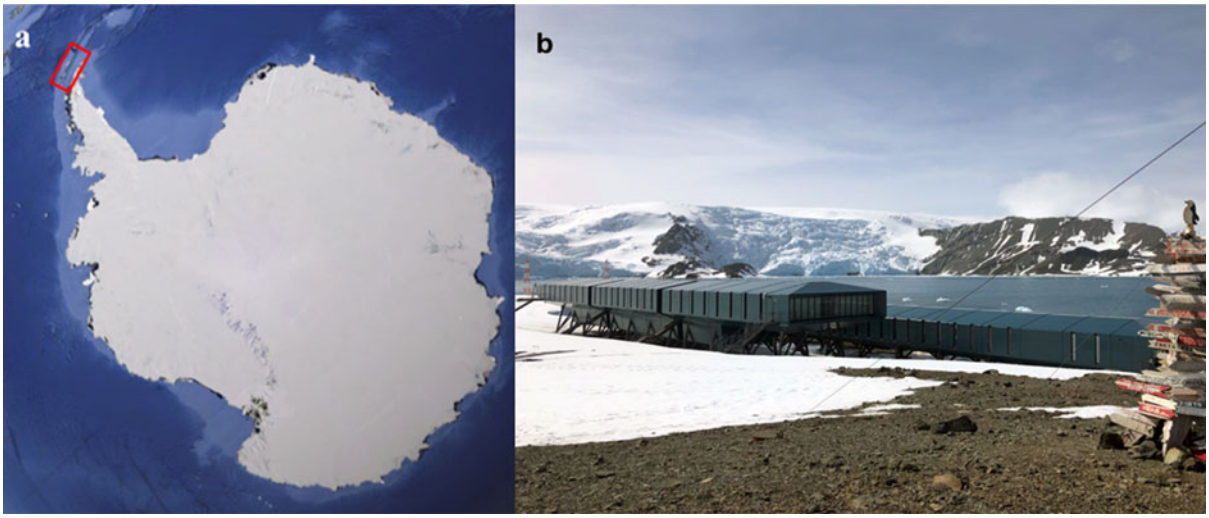

Fig. 1. a. Location of the South Shetland Islands indicated by the red square. **b.** The newly constructed Brazilian Comandante Ferraz research station on the Keller Peninsula, Admiralty Bay, King George Island.

the Maritime Antarctic (Frenot *et al.* 2005, Hughes *et al.* 2015). Some of these were clearly able to become established in parts of Antarctica under pre-warming or current conditions, but the predicted continued warming is likely to act in synergy with increasing levels of human activity to increase the risks of both transfer events and successful establishment (Convey & Peck 2019). It is also pertinent to note that, in the entire history of human contact with the Antarctic continent (one to two centuries) and the sub-Antarctic (two to three centuries), there are either no (continent) or a tiny proportion (sub-Antarctic; two of > 200 known species) of proposed instances of natural (non-human-assisted) dispersal and colonization events.

During the 2021/2022 summer, a microlepidopteran was captured inside a kitchen in the newly built Comandante Ferraz research station on KGI (Fig. 1). Here, we report the first record of *Plodia interpunctella* (Hübner, 1813) in Antarctica.

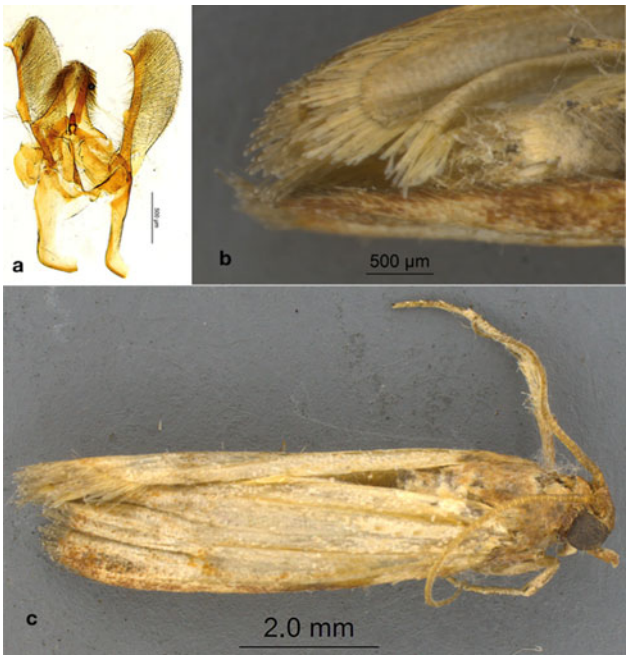

Fig. 2. *Plodia interpunctella*: **a.** male genitalia, **b.** wing scales and **c.** *habitus* (dorsal view).

Methods

Specimen capture and identification

A single microlepidopteran specimen was observed within a kitchen in Comandante Ferraz research station (62°05'07"S, 58°23'29"W) on 13 November 2021 and captured using a Falcon tube. The individual was frozen at Ferraz and transported to the University of Brasília, Brasília, DF, Brazil. Supplies to Ferraz are primarily transported by Brazilian navy vessels from the cities of Rio de Janeiro and Rio Grande. The station also receives cargo originating in Chile (Punta Arenas), and it has therefore not been possible to ascertain the specimen's origin. No direct evidence of the presence of adult moths or larvae has been apparent in the station's stored foods.

In preparation for dissection of its genitalia, the insect's abdomen was removed and placed in a vial containing 10% KOH solution, which was kept in a water bath at 50°C for 45 min. The abdomen was then washed in water and cleaned with a fine brush to remove the scales and other debris. After cleaning, the genitalia were removed and dehydrated in 90% ethanol. The genitalia were soaked in clove oil for 2 h and then mounted on a blade in Hoyer's medium for subsequent examination.

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P. interpunctella (Hübner) (Pyralidae) can be identified by the striking bicoloured pattern of the hindwings in living adults. The forewings of living specimens have lighter grey or tan colouration in the basal part and darker reddish-brown colouration in the apical part. Amongst stored product pest species, it is the only moth species that has pink or red copper scales on the hindwings (Fig. 2; Gorham 1991). In the absence of scales on the wing in worn specimens, the species can be differentiated from other moths of the subfamily Phycitinae by the forward-facing labial palps, small differences in the venation of the forewing and the presence of tufts of scales in the head region (Richards & Thompson 1932).

Results

Our specimen is a male and the morphology of the male genitalia is a diagnostic character of the species (Fig. 2). *P. interpunctella* differs from closely related species such as *Ephestia kuehniella* Zeller by the presence of an apical thorn on the valve rim (Richards & Thompson 1932).

Discussion

Insects feature highly amongst records of biological invasions in part due to the risk and ease of unnoticed transportation of individuals in stored foodstuffs (Liebhold & Tobin 2008). Microlepidoptera are amongst the most important pests of stored products. Among these, *E. kuehniella* Zeller, 1879 (Pyralidae) has been reported to have been accidentally transported on fresh foods to the Polish Arctowski station on KGI (Chwedorzewska *et al.* 2012). Many Lepidoptera can also disperse widely as part of their natural behaviour. Convey (2005) reported records of three potentially invasive Lepidoptera from sub-Antarctic South Georgia, including the migratory species *Agrotis ipsilon* (Hufnagel, 1766) (Noctuidae) and *Plutella xylostella* (Linnaeus, 1758) (Yponomeutidae) and the food pest *P. interpunctella* (Pyralidae). *P. xylostella* is already established on sub-Antarctic Marion Island (Chown & Language 1994). Living moths may also be accidentally transported into Antarctica as 'passengers' on vessels, to which they are easily attracted by the ships' lights, as recorded for the noctuids *Peridroma saucia* (Hübner, 1808) and *Pseudaletia adultera* (Schaus, 1894) (Barnes & Convey 2005). Here, we have confirmed the first formal record of *P. interpunctella* from any location within the Antarctic Treaty area.

P. interpunctella is cosmopolitan, being present on every continent except Antarctica (Mohandass *et al.* 2007). It is commonly associated with synanthropic food storage environments and is considered a storage pest of a wide variety of grains, flours, nuts, cereals and processed foods (Rees 2004, Mohandass *et al.* 2007). It is thought to have originated from India and its global dispersal has been facilitated by the transport of grains and other stored foods where its larvae develop (Mohandass *et al.* 2007). While being associated with food storage areas globally, it is generally not considered one of the most serious such pests (Johnson *et al.* 1992, Mohandass *et al.* 2007).

The life cycle of *P. interpunctella* is directly influenced by temperature. Under experimental conditions, optimal larval development and adult reproduction occur at between 20°C and 27°C (Defilippo *et al.* 2019). The minimum temperature threshold for development ranges from 16°C to 20°C, depending on diet, rearing conditions and geographical origin of the populations (Johnson *et al.* 1992, Mohandass *et al.* 2007, Defilippo *et al.* 2019). The insect can enter diapause, normally during the fifth larval instar, triggered by a combination of reducing photoperiod and temperature (Tzanakakis 1959). This diapause is usually ended when temperature conditions return to the minimum required for development (Wijayaratne & Fields 2012). At low environmental temperatures, as found in the sub-Antarctic, there is no evidence that individuals can develop or survive outside human settlements (Convey 2005). Experimental exposure of larvae or eggs at temperatures between 0°C and -10°C for 24 h provides an effective control measure and causes 100% mortality (Oh *et al.* 2022).

To our knowledge, this is the first report of *P. interpunctella* in Antarctica. Given its physiological temperature requirements, it is highly likely only to be capable of survival in synanthropic environments (i.e. within built and heated structures) in Antarctica, and there is no evidence that individuals can survive in the natural environment. However, although not reported commonly in the scientific literature, a number of examples exist of insect species being transported to and in some cases establishing synanthropically within research stations in Antarctica, where they can prove difficult or as yet impossible to eradicate (Hughes *et al.* 2005, Remedios-De León *et al.* 2021). It is possible that some species, such as the fly *Trichocera maculipennis* Meigen, 1818 (Trichoceridae), have been capable of moving from the synanthropic to the natural environment (Remedios-De León *et al.* 2021). Hence, even the synanthropic presence of new non-native species in Antarctica is a matter of concern. We suggest that the application of more rigorous control measures (e.g. freezing stored products for 24 h) should be employed to prevent the transportation and establishment of *P. interpunctella* and other similar species in human facilities on the Antarctic continent.

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Author contributions

PEASC performed fieldwork and collecting samples. PC, VAF, PHBT and JRPL performed the identification and dissecting. PEASC, PC and JRPL wrote the first draft of the manuscript. All authors contributed to the final version.

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