

Sexually dimorphic melanization patterns in Pierid butterflies: Effects of time and geographic distribution on variation

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BACKGROUND

Wing pattern melanization has been shown to occur across a wide range of butterflies, and it has been especially studied in butterfly species of the Pieridae family. In fact, one of the most well studied examples of insect thermoregulation is found in the seasonal polyphenism of wing melanization patterns in pierid butterflies (Kingsolver & Wiernasz, 1987; Stoehr and Goux, 2008). While thermoregulation is an important factor influencing wing melanization, sexual selection and intersexual communication have also been shown to play an important role in butterfly wing pattern evolution (Ellers & Boggs, 2003; Robertson & Monteiro, 2005; Wiernasz, 1995). For example, in Pieris rapae, the spots in the dorsal forewing express different levels of sexual dimorphism. The upper spot varies in in size between males and females, whereas the second spot is usually present only in females (Figures 1 and 2). This second spot has been shown to be involved in male-female recognition (Stoehr et al., 2016). Thus, the evolution of sexually dimorphic wing patterns in pierid butterflies might be determined by an interaction between the selective pressure of thermoregulation on one hand, and sexual selection or sexual communication pressures on the other (Stoehr & Goux, 2008). This potential interaction between ecological and sexual selection in sexually dimorphic wing patterns, the fact that individuals also include different levels of sexual dimorphism in the wing patterns, and the large numbers of digitalized images in museum collections, make pierid butterflies an excellent group for the investigation of how tradeoffs between sexual and ecological selection influence wing pattern variation across geographic ranges, and across time.

Pieris rapae

The small cabbage white butterfly is originally from the Old World. It was introduced to North America and Australia in the 1860s, where it is a major pest of vegetables in the family Brassicaceae, such as cauliflower, broccoli, and cabbage (Scott, 1986). This species now occupies a large range of North America, and thus, it encounters many different thermal environments. Moreover, *P. rapae*'s first introductions in North America are well documented, making this species a model system for the study of wing pattern melanization (Stoehr & Goux, 2008).

Sexual selection and intersexual communication

Sexual dimorphism in wing patterning is common in Lepidoptera, and can be related to presence-absence, degree of coloration, ultraviolet reflectance, or melanization of the wing pattern or eyespot. Studies show that wing pattern melanization can play a role in sexual selection as well as intersexual communication. In *Pieris occidentalis*, females prefer males with highly melanized dorsal forewing

margins (Wiernasz, 1989). This melanization pattern is also used by male and female *P. occidentalis* to discriminate against other closely related sympatric species such as *Pieris protodice* (Wiernasz & Kingsolver, 1992; Wiernasz, 1995). In *P. rapae*, both males and females use sexual dimorphism of melanic patterns in the dorsal forewing to discriminate among conspecifics and adjust the time they spend interacting with them (Stoehr et al. 2016).

Thermoregulation

In many Pieris butterflies, the ventral hindwing and parts of the forewing can become heavily melanized with a decrease in temperature and change in photoperiod. In colder temperatures, darker ventral hindwings convert more sunlight to heat while the butterflies bask with wings folded over their body. Thus, ventral hindwing melanization has been shown to vary with season, latitude and elevation (Kingsolver & Wiernasz, 1987; Ellers & Boggs, 2002). In addition to the ventral hindwing, pierids also show environmentally influenced melanization in the basal portion of the dorsal forewing (Wasserthal, 1975; Stoehr & Goux, 2008), and this basal portion is thought to also contribute to heating of the body via solar absorption. Melanization of the distal portion of the dorsal forewing, however, might function in a different way. In Pieris, the distal portion of the dorsal forewing may be used in reflectance basking (Kingsolver, 1985), whereby a highly reflective (white) distal wing surface reflects light to the body and the melanized basal wing area. For this specific section of the wing, less melanization translates into increased thermoregulation. Therefore, colder temperatures should be associated with more melanization in the ventral hindwing and the basal area of the dorsal forewing, and less melanization of the distal area of dorsal forewing. While males of *P. rapae* in southern CA follow this prediction, females do not follow this pattern, especially in the distal dorsal forewing spots (Stoehr & Goux, 2008), suggesting that sexual dimorphism has the potential to change the level of variability for melanized wing patterns.

Potential research questions

Depending on the data (and time) we might be able to investigate one of these questions:

- (1) Do wing patterns with different levels of sexual dimorphism vary across different sites of North America (east versus west coast or low versus high latitudes)?*
- (2) Do wing patterns with different levels of sexual dimorphism vary between the native and introduced range?*
- (3) How much do wing patterns with different levels of sexual dimorphism change across time?

*For questions (1), and (2) it is important to note that there will be a need to control for season and compare only one season across sites. This will decrease the number of images available.



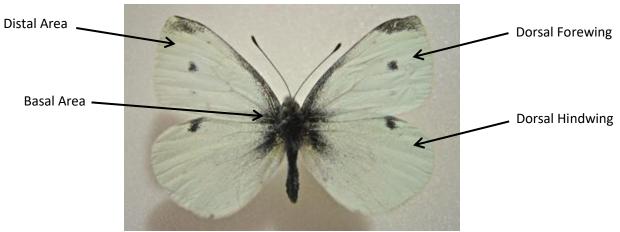


Figure 1. Male *P. rapae* **butterfly.** By Ypna - Own work, CC BY-SA 3.0. https://commons.wikimedia.org/w/index.php?curid=16445170

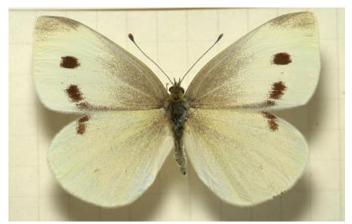


Figure 2. Female *P. rapae* **butterfly.** By Sarefo - Own work, CC BY-SA 3.0. https://commons.wikimedia.org/w/index.php?curid=2905370

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