A behavior-predictive model based on thermoregulatory behavior of the desert locust in Africa

There is an urgent need to develop better forecasting capacities so we can anticipate how species of economic importance will respond to environmental change. Pest insects are one of the most economically important groups of species requiring forecasting capacity. Any efforts to predict environmental constraints on the behavior, distribution, and abundance of terrestrial ectotherms such as insects must adequately capture how environment and behavior interact to determine body temperature, because virtually all biological processes are temperature-dependent. This is a significant challenge due to the complex, nonlinear responses of heat exchange between organisms and their microclimates, but it is possible to compute such responses from first principles using techniques in biophysical ecology.

The desert locust, *Schistocerca gregaria*, is one of the world's most destructive pest insects. Sometimes, desert locust populations grow explosively, forming swarms and causing locust plagues. A plague can affect up to 20% of the earth's surface across Africa, the Middle East, and Southwest Asia. Desert locusts can potentially damage the livelihoods of a tenth of the world's population. The preventive approach seeks to monitor and spray locust breeding areas. However, this is difficult in practice as many of the principal breeding zones are located in remote areas and are difficult to reach. We have been studying the locust and are developing efficient and sustainable control measures with due consideration to environmental well-being. For example, we have found that gregarious nymphs actively migrate during the day (Fig. 1), while they remain on relatively large plants during night under fluctuating thermal conditions. If we can understand these behavioral patterns and thermoregulatory behaviors, we can develop a predictive model. To obtain these ecological information and to develop a predictive model, we have taken temperature data on desert locusts doing different activities and their circumstances in the Mauritanian fields.

Using a thermal infrared camera in the field, we showed that gregarious nymphs altered their microhabitats as well as their postural thermoregulatory behaviors to maintain a relatively high body temperature (nearly 40°C) (Figs. 1 & 2). We used our data (Table 1) to successfully parameterize a general biophysical model of thermoregulatory behavior that could capture hourly body temperature and activity at our remote site using globally available environmental forcing data (Fig. 3).

This modelling approach provides a stronger basis for forecasting thermal constraints on locust outbreaks under current and future climates. Our technique may prove especially useful if it contributes toward developing forecasting capacity and preventive control, both short-term in response to weather events and long-term in response to climate change.

(K.O. Maeno,
P. Cyril [The French Agricultural Research Centre for International Development (CIRAD)],
M. R. Kearney [The University of Melbourne])
S. Ould Mohamed [The Mauritanian National Anti-Locust Centre (CNLA)]

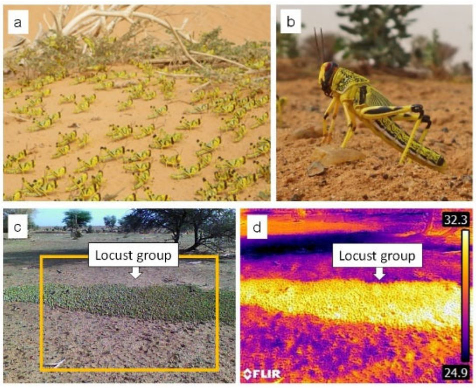


Fig. 1. Behaviors of gregarious nymphs of the desert locust

a: marching as a group, b: stilting behavior, and c: basking in the cool morning. Photo d shows thermal image of the basking locusts.

Description	Value
lethal maximum body temperature	50℃
lethal minimum body temperature	1℃
thermoregulation target body temperature	40℃
maximum foraging body temperature	43℃
minimum foraging body temperature	25℃
minimum basking temperature	15℃
minimum temperature for movement to basking site	15℃

Table 1. Parameters used in the model for the desert locust hoppers

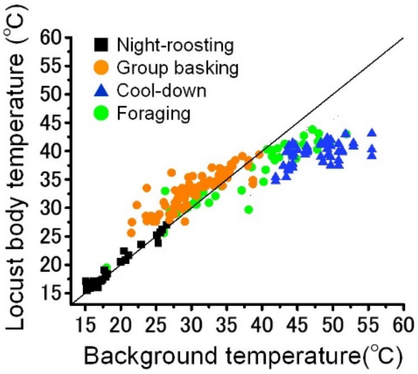
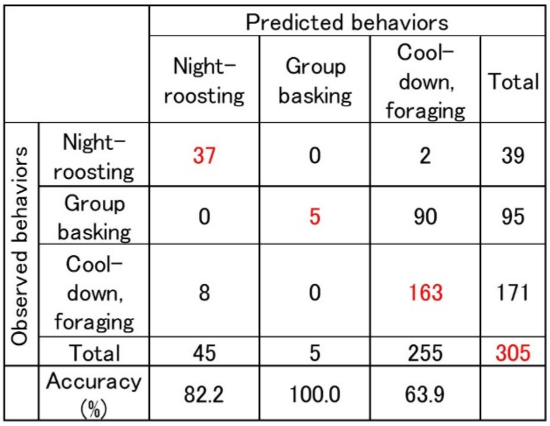


Fig. 2. Relationships between background temperature and locust body temperature when locusts displayed various behaviors such as roosting on plants at night, group basking, cooling-down, and foraging



		Predicted behaviors			
		Night-roosting	Group basking	Cool-down, foraging	Total
Observed behaviors	Night-roosting	37	0	2	39
	Group basking	0	5	90	95
	Cool-down, foraging	8	0	163	171
	Total	45	5	255	305
	Accuracy (%)	82.2	100.0	63.9	

Fig. 3. Confusion matrix of the observed vs. predicted behaviors of hoppers with the ectotherm-microclimate model