Figures

Figure 1. Conceptual hierarchy of individual movement spanning (1) fine, (2) intermediate, and (3) coarse time and space scales. Each section (Displacement, Dispersal, Migration) represents the common processes at each scale and the width and height represent the time and space scale, respectively. The central individual unit i with its internal state and dynamic energy budget DEB fluctuates with basic energy requirements, costs, and gains (i_{DEB}), ultimately linked to individual fitness. At each scale, thicker, coloured arrows represent emerging processes, boxes represent the end processes from movement, and plus signs denote dominant complementary behaviours or processes.

Figure 2. Stylised conceptual diagram of direct and indirect movement costs in time and space across the individual life cycle. Circles represent individual body mass of offspring, juvenile, and adult. Direct movement costs (A, green) form a proportion of somatic maintenance costs (B, blue) across growth. Indirect movement costs (C, pink) change as the individual interacts with its environment over time due to increasing movement trade-offs associated with different behaviour, such as foraging, mating, and defending. Hatched polygon represents points in time and space where the individual may anticipate how indirect movement costs influence performance, i.e. consciously change strategy in response to previous maladaptive behaviour, where E_H^P signifies the shift in maturity from offspring to juvenile and the onset of adaptive movement, e.g. dispersal events. Numbers represent different behavioural events (described in main text).

Figure 3. Examples of contrasting landscape and habitat structures that animals must negotiate in space and time. Top: Light Detection and Ranging (LIDAR) data of an arid, terrestrial environment in South Australia (139º21'E, 33º55'S) highlighting A) large vegetation in contrast to B) available small vegetation for the same site that acts as available refuges for animals throughout the day. Middle: Examples of simulated model landscapes showing C) low and D) high resource (food and shade) density to emulate the conditions seen in A) and B). Insets show simulated animal movement paths using a spatial movement framework that incorporates the i_{DEB} primer. Bottom: Field images of the study site in A) and B) showing the visible differences between E) low and F) high resource density within a habitat.

Figure 4. Schematic of data and model inputs of the IDEBM model. Examples of weather data: monthly to annual temperatures microclimate; Microclimate: local solar and infrared radiation temperature, ground and air temperature (Table 4); DEB model: See Tables 3 and 6; Heat budget model: See Table 4; Habitat data: food and shade patches (Table 5). The DEB and heat budget models update with the time steps of the decision-making IBM to form feedback loops. All weather and habitat data are modelled on the sleepy lizard habitat (139º21'E, 33º55'S). Animal data are for the adult sleepy lizard.

Figure 5. Schematic of decision-making IBM simulation runs. Solid boxes are processes, dashed boxes are individual decisions, and ellipses are individual actions. Searching refers to either searching for food, shade, or socialising, depending on the

current thermal or metabolic state or movement strategy of the animal. Hungry refers to whether the gut fullness threshold is <75%.

Figure 6. (A) Distributions of home range area (km^2) of real (pink) and seeded simulated optimising (orange) and satisficing (blue) movement strategies under dense resource distribution (food and shade). Home range polygons in space showing overlap of seeded simulated (B) satisficing and (C) optimising individuals and (D) real individuals. Home ranges in (D) appear more scattered due to different starting locations of real animals, whereas (B) and (C) have seeded starting locations in the centre of the landscape. The vegetation layer in (D) is generated from LIDAR data of the habitat site, showing the thermal mosaic of the landscape.

Figure 7. Activity budget for all optimising and satisficing animals throughout the breeding season showing proportion of time spent (A) feeding, (B) searching, and (C) resting, as well as (D) proportion of number of transitions between activity states. Radius = time spent in activity state; circumference = days throughout the breeding season. Black arrows indicate a 5-day period where environmental conditions were not conducive to activity, so animals spent this time resting in shade.

Figure 8. Movement path and home ranges of real versus simulated sleepy lizards. (A) Individual #11885, a real sleepy lizard showing active movement and (B) individual #11533, a real sleepy lizard showing passive movement, throughout the breeding season. (C) A random simulated optimising individual representing the maximum potential movement and (D) a random simulated satisficing individual representing the minimum movement necessary throughout the breeding season based on its physiological limits. (C–D) green = food patches, black = shade patches, and polygons represent home ranges. Patch size in simulations represents time elapsed on patch.

Figure 9. Energetic outputs showing differences in maximum (optimising) and minimum (satisficing) potential movement. (A) Cumulative movement costs (kJ) for a random simulated optimising (orange) and satisficing (blue) individual throughout the breeding season. (B) Difference in mean structural volume (g^{-1} cm^3; green), wet mass storage (g; blue), converted food mass (g; black), and reproductive organ wet mass (g; pink) between optimising and satisficing movement strategies throughout the breeding season.

Figure 10. (A) Hourly T_b for individual #11885 (orange), a real sleepy lizard showing active movement and individual #11533 (blue), a real sleepy lizard showing passive movement, throughout the breeding season. (B) Hourly T_b for a simulated optimising animal (orange) and satisficing animal (blue). (C) Example of daily T_b profile for the same optimising animal during the hottest (orange curve) and coldest (blue curve) day of the breeding season. Dashed horizontal lines show thermal limits of activity period (26ºC–35ºC) and black graphics atop (A) represents the sun cycle.

Figure 11. Distribution of mean home range area against mean mass of simulated adults and juveniles. A) Adults and juveniles under high resource density; B) juveniles under low resource density; C) adults under low resource density.

Figure 12. Kernel utilisation distribution of simulated home ranges under high resource density. Top panel: A) Optimising and B) satisficing adults (green). Bottom panel: C) optimising and D) satisficing juveniles (blue).

Figure 13. Kernel utilisation distribution of simulated home ranges under low resource density. Top panel: A) Optimising and B) satisficing adults (green). Bottom panel: C) optimising and D) satisficing juveniles (blue).

Figure 14. Mean rate of T_b (ºC) change against mean T_b (ºC) of simulated adults (left) and juveniles (right) for A) optimising and B) satisficing movement strategies under high resource density and C) optimising and D) satisficing movement strategies under low resource density. Vertical dashed blue, orange, and red lines represent basking temperature (14ºC), lower activity range temperature (T_{lower}, 26ºC), and upper activity range temperature (T_{upper}, 35ºC), respectively.

Figure 15. Example of T_b (ºC) in the morning (09:00 hours) throughout the breeding season comparing simulated adults and juveniles under high resource density. A) Optimising adult, B), optimising juvenile C), satisficing adult, and D), satisficing juvenile. Horizontal dashed blue, orange, and red lines represent basking temperature (14ºC), lower activity range temperature (T_{lower}, 26ºC), and upper activity range temperature (T_{upper}, 35ºC), respectively.

Figure 16. Example of T_b (ºC) in the morning (09:00 hours) throughout the breeding season comparing simulated adults and juveniles under low resource density. A) Optimising adult, B), optimising juvenile C), satisficing adult, and D), satisficing juvenile. Horizontal dashed blue, orange, and red lines represent basking temperature (14ºC), lower activity range temperature (T_{lower}, 26ºC), and upper activity range temperature (T_{upper}, 35ºC), respectively.

Figure 17. Time simulated optimising A) adults and B) juveniles take to reach their activity range (T_{lower}, 26ºC) from 06:00 AM (orange) and 09:00 AM (blue) throughout the breeding season. As a comparison, C) and D) show the time adults and juveniles, respectively, take to reach activity range throughout the breeding season when surrounding microclimate conditions are near optimal (12:00 PM; purple).

Figure A1. Distributions of home range area (km^2) of real animals (pink) and simulated optimising (orange) and satisficing (blue) movement strategies under (A) dense and (B) sparse resource distribution (food and shade). Insets (L–R): Home range polygons in space showing overlap of simulated satisficing (blue) and optimising (orange) movement strategies, and examples of (upper) dense and (lower) sparse resource distributions in the study site.

Figure A2. Rates of T_b change (ºC 2 min^{-1}) comparing (A) observed active (orange; #11885) and passive (blue; #11533) movement and (B) simulated optimising (orange) and satisficing (blue) movement for the morning hours (heating period; 06:00–12:00). (C) Observed active (orange) and passive (blue) movement and (D) simulated optimising (orange) and satisficing (blue) movement for the afternoon hours (cooling period; 12:00–18:00) throughout the breeding season. Animal graphics represent the most probable activity state of the animal (from Fig. 5).