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Appendix A from R. Patin et al., "Space Use and Leadership Modify Dilution Effects on Optimal Vigilance under Food-Safety Trade-Offs" (Am. Nat., vol. 193, no. 1, p. E15)

Summary and Discussion of Model Assumptions

This appendix presents (1) graphics showing the relationships between mean food gain and time spent vigilant and between the probability of dying from predation and time spent vigilant (fig. A1) as well as between the probability of dying from starvation and the nutritional state (fig. A2) and (2) a short discussion of one specific assumption: that vigilance decreases only the predation risk of the focal individual (no collective detection).

Functional Relationships Underlying the Model

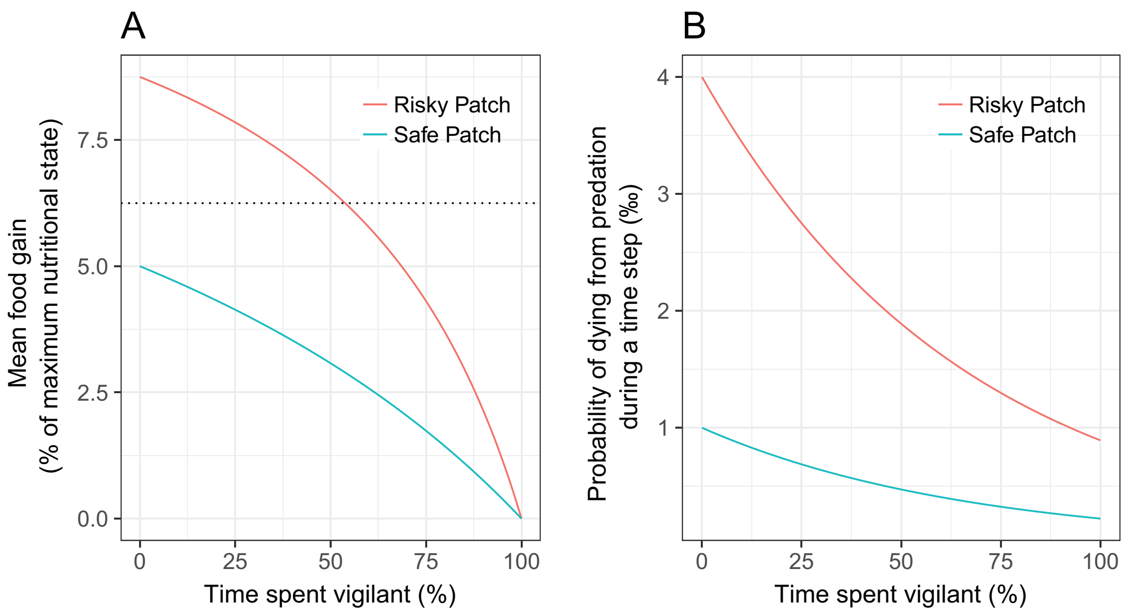

Figure A1: *A*, Relationship between the vigilance level of the individual and its mean resource gain when foraging in the risky (red line) or the safe (blue line) patch, under the default parameter values. The amount of resource lost (i.e., metabolic cost) at each time step is also shown (dotted line). Note that an individual cannot survive if it always remains in the safe patch. *B*, Relationship between the vigilance level of the individual and its probability of dying from predation when foraging alone in the risky (red line) or the safe (blue line) patch, under the default parameter values (see table 1). Probabilities are expressed as per mill.

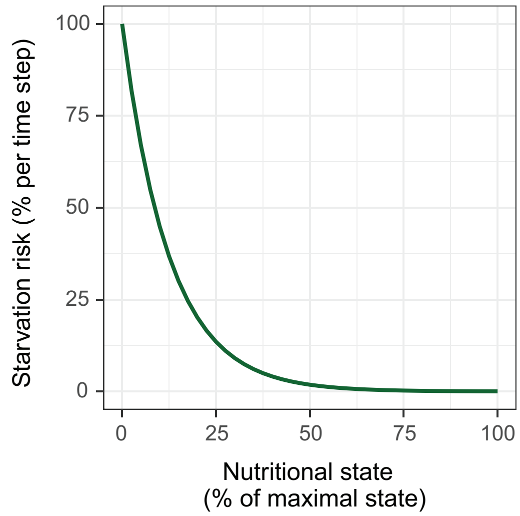

Figure A2: Relationship between the nutritional state of the individual and its probability of dying from starvation, under the default parameter values (see table 2).

Note on the Assumption That Vigilance Decreases Only the Predation Risk of the Focal Individual

As our focus was on the dilution effect, we did not model collective detection (also known as the detection effect or the "many eyes effect"; Lima 1995). Collective detection assumes that an individual may benefit from predator detection by other group members. One could test whether accounting for collective detection would change the predictions provided by our model. Including collective detection in an optimization framework would require the use of game theory through an evolutionary algorithm (as in Sirot 2012). We do not expect, however, that our results would be affected qualitatively, especially that vigilance and space use would vary monotonically if one accounted for collective detection. This inclusion should only make groups more efficient at detecting predators. One could argue that followers could rely more than leaders on collective detection, reducing their own vigilance more to minimize foraging costs, thereby reducing the differences in optimal vigilance between leaders and followers in response to predation risk. Collective detection would be beneficial only if predators do not target individuals with lower vigilance levels (Bednekoff and Lima 1998; situation modeled here). Further studies could investigate how relying on group vigilance when nutritional state is low could change the effects of group size and leadership on antipredator behaviors.

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Appendix B from R. Patin et al., "Space Use and Leadership Modify Dilution Effects on Optimal Vigilance under Food-Safety Trade-Offs" (Am. Nat., vol. 193, no. 1, p. E15)

Additional Information on Optimal Strategies (Convergence and Examples) and Initial Nutritional State in Simulations

This appendix presents (1) a check of the convergence of the dynamic programming algorithm and a comparison with the resulting life expectancy; (2) examples of optimal strategies for individuals using a single patch (fig. B3) and for leaders (fig. B4), followers (fig. B5), and followers without knowledge of long-term patch use (fig. B6) using two patches; and (3) information on the choice of the initial nutritional state for individuals in the simulation.

Check of Convergence and Comparison with Life Expectancy

Calculations of optimal strategies using the dynamic algorithm were made on 250 time steps. We used the last change in the calculated strategies as the convergence time. As we see in figure B1, strategies stopped changing after 20–40 time steps in most cases and after 100 time steps for the longest cases, still far from the 250 time steps of the algorithm. We can therefore conclude that the dynamic programming algorithm has converged.

We compared these convergence times to the resulting life expectancy of these strategies (see fig. B2 for the life expectancies). Life expectancies for individuals in a group were higher than 200 time steps most of the time. This shows that strategies are optimal on a shorter timescale than the timescale on which group size might change if individuals were to die without being replaced. In the riskier cases (small group size and very high risk in the risky patch), those timescales are closer, as follower vigilance in the risky patch converges around step 100 and life expectancy is slightly higher than 100 time steps. However, the strategies at convergence are very close to the strategies at step 70 (less than two changes in vigilance level).

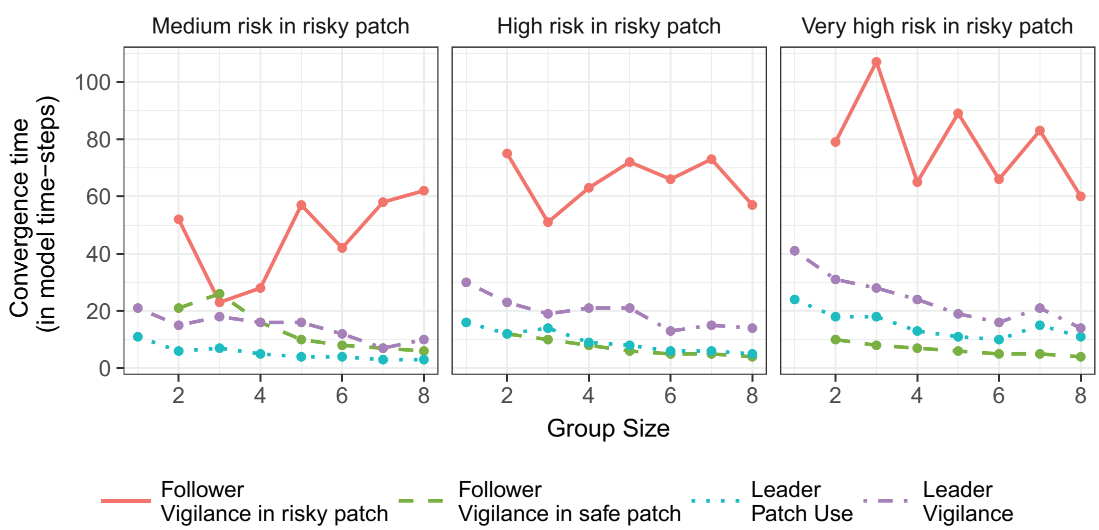

Figure B1: Relationship between the number of time steps required for convergence of the optimal strategy and group size for follower vigilance in safe (green) and risky (red) patches, leader vigilance (blue), and patch use (purple), in situations where the likelihood of meeting the predator is four (*left*), eight (*middle*), or sixteen (*right*) times higher in the risky patch than in the safe patch.

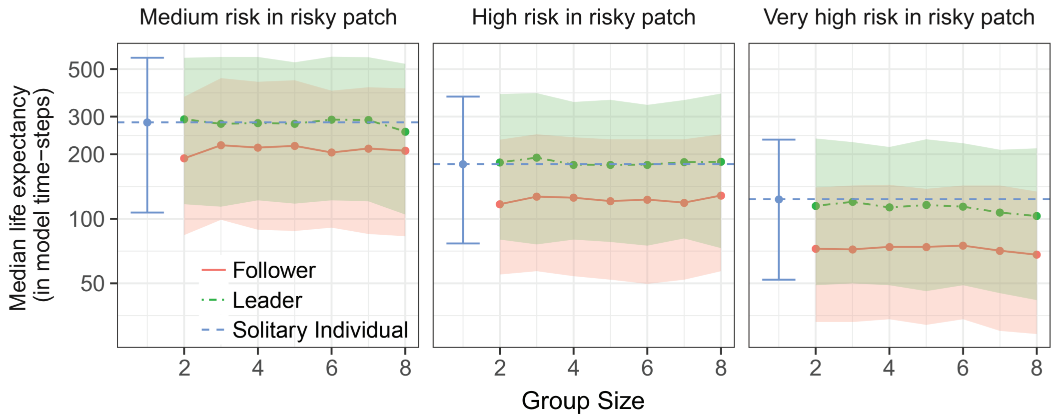

Figure B2: Relationship between life expectancy (in model time steps; median, lower and upper quartiles) and group size for leaders (green), solitary individuals (blue), or followers (red) in situations where the likelihood of meeting the predator is four (*left*), eight (*middle*), or sixteen (*right*) times higher in the risky patch than in the safe patch.

Examples of Optimal Strategies

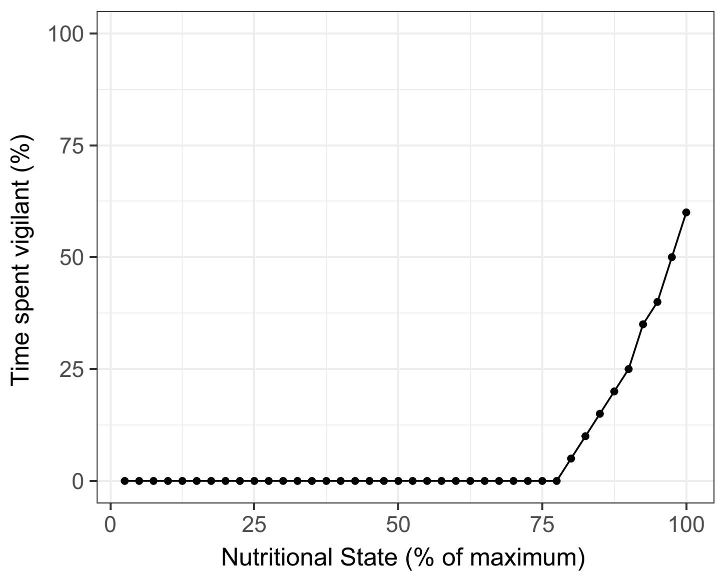

Figure B3: Optimal choice of vigilance given the nutritional state of an individual in a group of two individuals using only one patch. $k_0(\text{risky}) = 0.004$, $f = 0.2$, $k_2 = 0$, $a_2 = 0$.

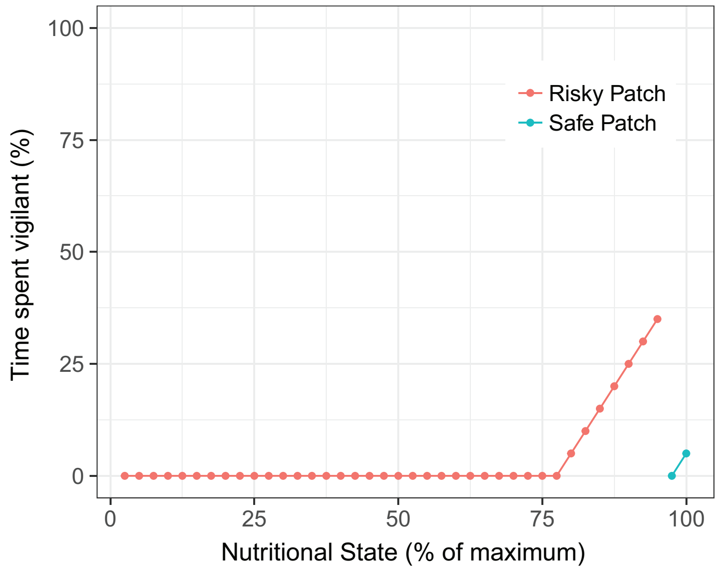

Figure B4: Optimal choice of vigilance and patch given the nutritional state of a leader in a group of two individuals. $f = 0.2$, $k_0(\text{risky}) = 0.004$, $k_2 = 0$, $a_2 = 0$.

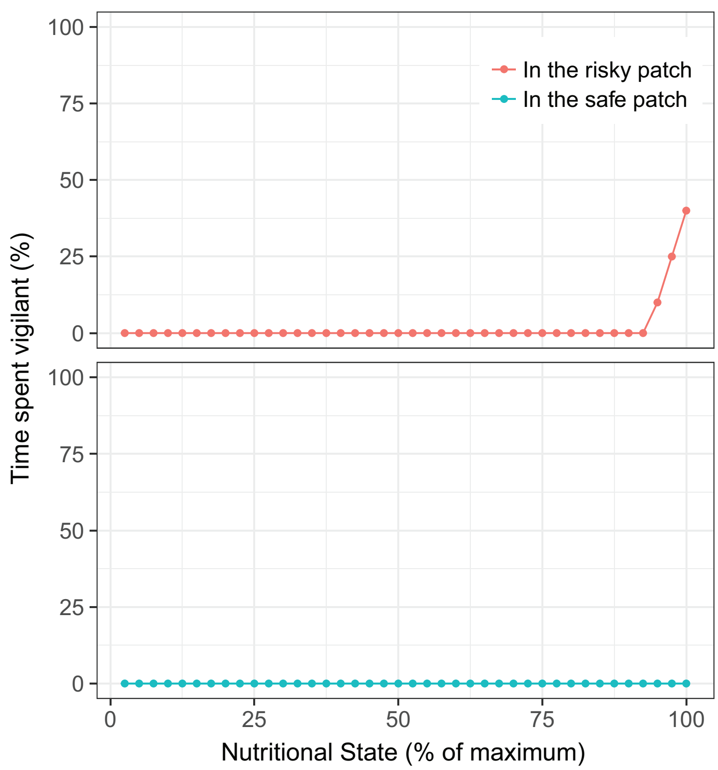

Figure B5: Optimal choice of vigilance given the nutritional state of a follower in a group of two individuals in the risky patch (*upper panel*) and in the safe patch (*lower panel*). $f = 0.2$, $k_0(\text{risky}) = 0.004$, $k_2 = 0$, $a_2 = 0$.

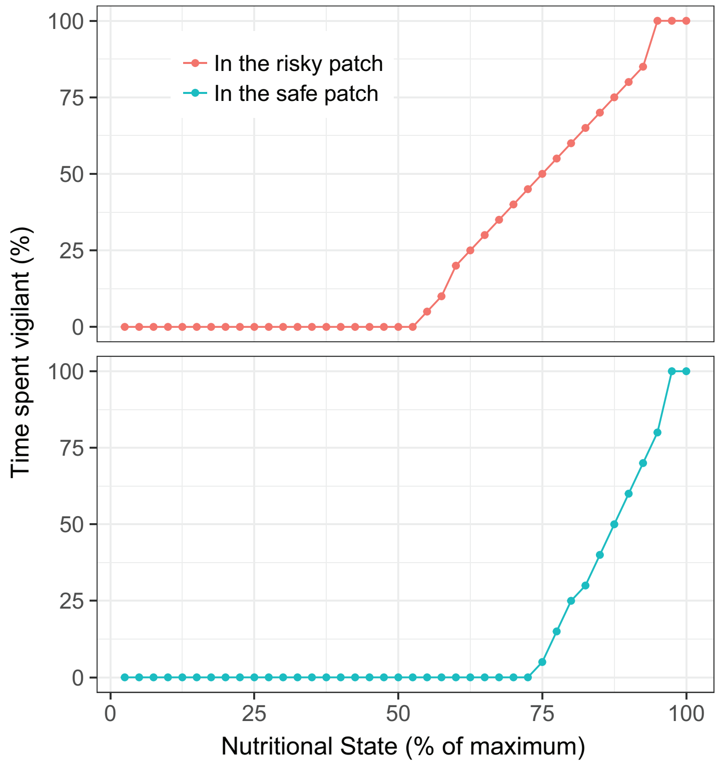

Figure B6: Optimal choice of vigilance given the nutritional state of a follower with no knowledge of long-term patch use in a group of two individuals in the risky patch (*upper panel*) and in the safe patch (*lower panel*). $f = 0.2$, $k_0(\text{risky}) = 0.004$, $k_2 = 0$, $a_2 = 0$.

Choosing the Initial Nutritional State for Simulations

We wanted to initiate an individual nutritional state with the point around which its state will fluctuate, that is to say, its mean nutritional state. However, this cannot be known without any simulations. Based on the optimal strategy only, we can nevertheless approximate such a state.

For leaders, once we know the optimal strategy, for each nutritional state we can calculate the mean food gain provided by this behavior (vigilance, patch choice). An example is shown in figure B7. We therefore use as the initial state the state below which behavior causes an increase in the nutritional state (gain larger than cost) and above which behavior causes a decrease in the nutritional state (gain smaller than cost). It is represented by a vertical dashed line in figure B7.

For followers, we can also calculate the mean gain associated with their behavior at a different nutritional state (fig. B8). We calculated an equilibrium state by simulating a leader's patch use along with a follower that would always get its mean food gain. The mean nutritional state obtained through this procedure was used to initiate the simulations.

The initial nutritional state that we calculated was used for initiating simulations. In addition, when a leader died during a follower's simulation, it was immediately replaced by a new leader in its initial state. Overall, the starting states were quite close to the maximum state (as seen by the very high mean nutritional state in fig. 3).

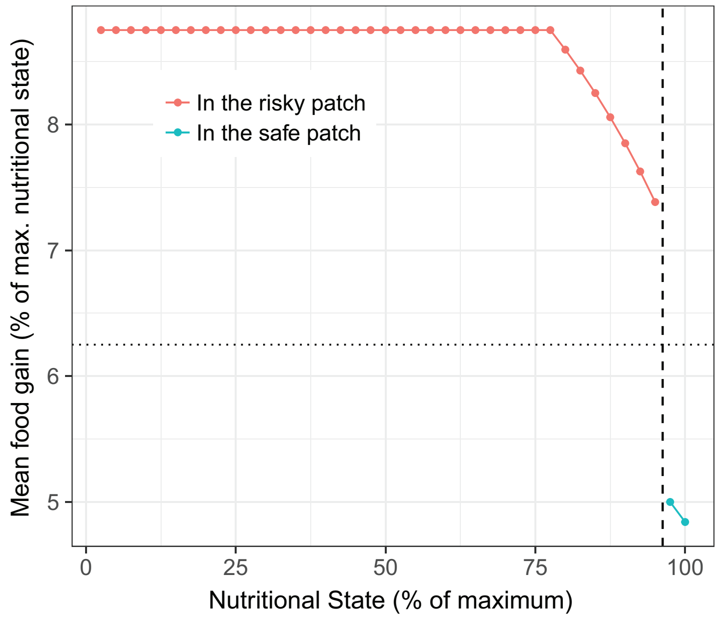

Figure B7: Mean food gain given the nutritional state of a leader in a group of two individuals. The horizontal dotted line shows the mean metabolic cost. The vertical dashed line shows the equilibrium state, above which behavior causes a state decrease and below which it causes a state increase. $f = 0.2$, $k_0(\text{risky}) = 0.004$, $k_2 = 0$, $a_2 = 0$.

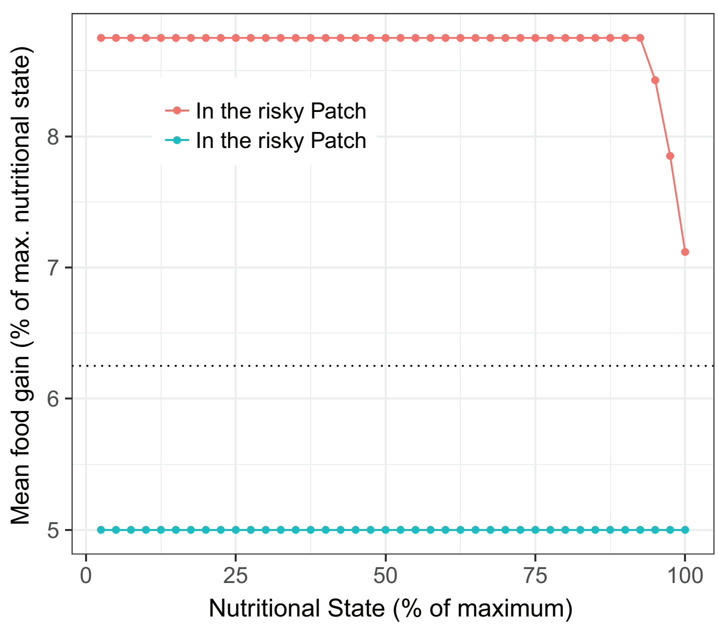

Figure B8: Mean food gain given the nutritional state and the occupied patch of a follower in a group of two individuals. The horizontal dotted line shows the mean metabolic cost. $f = 0.2$, $k_0(\text{risky}) = 0.004$, $k_2 = 0$, $a_2 = 0$.