Collective behaviour

Evolving composite tactics

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018

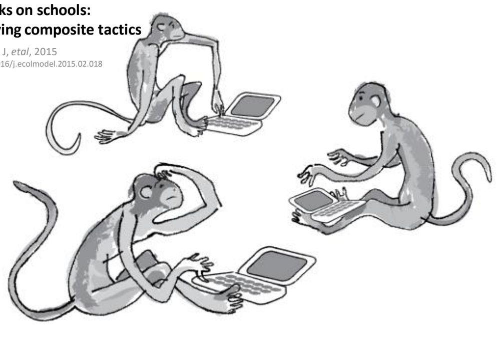
attack isolated
attack nearest
attack centre

predators in nature?

goshawks (*Accipiter gentilis*)
peregrine falcons (*Falco peregrinus*)
sparrow hawks (*Accipiter nisus*)
african wild dogs (*Lycaon pictus*)
alpomado falcons (*Falco femoralis*)
bottlenose dolphins (*Tursiops truncatus*)
killer whales (*Orcinus orca*)
swordfish (*Xiphias gladius*)

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018



goo.gl/nLtkEM

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018

Table 2
Values for the parameters used in our experiments.

Parameter	Description	Default value
Δt	Time step	1 s
T	Duration of the evaluation phase per predator	600 time steps
N_a	Number of groups attacked by predators of one generation	5
N_g	Number of generations	500
m_r	Mutation rate	2%
m_f	Mutation factor ("intensity of mutations")	20%
n_a	Number of prey individuals in the group	100
n_p	Predator population size	100
D	Initial predator's distance from the centre of the prey group	200 BL
S	Initial area of the prey group	100 BL^2

Simulated predator attacks on schools: evolving composite tactics

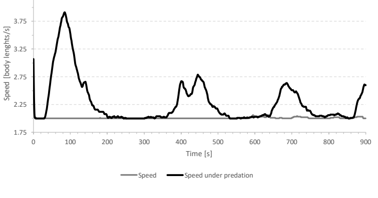
Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018

Table 1
Values for zone radii, weights and other parameters of our model.

Parameter	Description	Default value	Tested value
Prey			
v_m	Maximum speed of prey	4 BL/s	
v_c	Cruising speed of prey	2 BL/s	
ϕ	Prey's field of view	300°	
r_s	Zone radius for the separation drive	5 BL	
r_a	Zone radius for the alignment drive	25 BL	
r_c	Zone radius for the cohesion drive	100 BL	
r_e	Zone radius for the escape drive	100 BL	50 BL
w_s	Weight for the separation drive	5.0 s^{-2}	
w_a	Weight for the alignment drive	0.3 s^{-1}	
w_c	Weight for the cohesion drive	0.01 s^{-2}	
w_e	Weight for the escape drive	5.0 s^{-2}	12.0 s^{-2}
a_m	Prey's maximum acceleration	2.0 BL/s^2	
L	Body length (BL)	0.2 m	
Predator			
L_p	Predator body length (PBL)	6 BL	
v_{mp}	Maximum speed of the predator	6 BL/s	
v_{cp}	Cruising speed of the predator	3 BL/s	
r_h	Zone radius for the hunt drive	400 BL	
r_{co}	Confusability radius	25 BL	0 BL
a_h	Hunting acceleration	2.5 BL/s^2	
d_c	Catch distance	1 PBL (6 BL)	
t_h	Handling time	30 s	
t_r	Refocus time	30 s	

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018



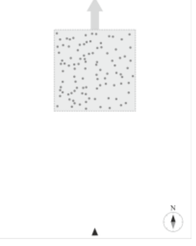
Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018

$$P_{success} = \frac{1}{|N_{co}|}; N_{co} = \{j \in A;\ j \neq p;\ \|\vec{d}_j\| \leq r_{co}\},$$

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018



Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015
doi: 10.1016/j.ecolmodel.2015.02.018

Mixture of simple tactics

$$\vec{P}_i = \frac{1}{|G|} \sum_{j \in G} \hat{d}_j ; G = \{j \in A;\ j \neq i; j \neq p;\ \|\vec{d}_j\| \leq r_c\},$$

$$t_n = t;\ \|\vec{d}_t\| = \min_{j \in T} \|\vec{d}_j\|;\ T = \{j \in A;\ j \neq p;\ \|\vec{d}_j\| \leq r_h\}.$$

$$t_m = t;\ \|\vec{P}_t\| = \min_{j \in T} \|\vec{P}_j\|;\ T = \{j \in A;\ j \neq p;\ \|\vec{d}_j\| \leq r_h\}.$$

$$t_p = t;\ \|\vec{P}_t\| = \max_{j \in T} \|\vec{P}_j\|;\ T = \{j \in A;\ j \neq p;\ \|\vec{d}_j\| \leq r_h;\ \hat{d}_j \cdot \hat{P}_j > 0\}.$$

Parameter	Description	Interval	Initial value
p_n	Target the nearest prey probability	[0,1]	Random
p_m	Target the most central prey probability	[0,1]	Random
P_p	Target the most peripheral probability	[0,1]	Random

$$t = \begin{cases} t_n & \text{iff } \xi \in (0, p_n] \\ t_m & \text{iff } \xi \in (p_n, p_n + p_m] \\ t_p & \text{iff } \xi \in (p_n + p_m, 1], \end{cases}$$

Simulated predator attacks on schools: evolving composite tactics

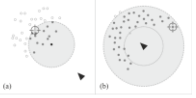
Demšar J, *etal*, 2015

doi: 10.1016/j.ecolmodel.2015.02.018

Dispersing tactic

1. chase central prey of the nearest group of prey
   (nearest individual + neighbors inside its cohesion zone)
2. when close enough lock on isolated individual

Parameter	Description	Interval	Initial value
d_l	Lock-on distance	[0,400 body lengths]	Random
r_l	Lock-on zone radius	[0,400 body lengths]	Random



Simulated predator attacks on schools: evolving composite tactics

Demšar J, etal, 2015

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015

doi: 10.1016/j.ecolmodel.2015.02.018

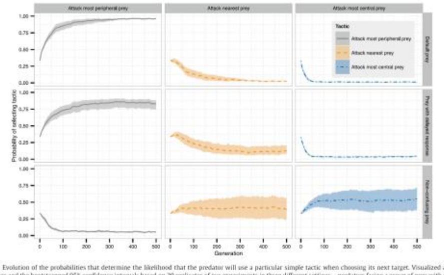


Fig. 3. Evolution of the probabilities that determine the likelihood that the predator will use a particular simple tactic when choosing its next target. Visualized are the averages and the bootstrapped 95% confidence intervals based on 20 replicates of our experiments in three different settings – predators facing a group of prey with default parameters as in Table 1 (default prey), predators facing a group of prey with a delayed response, and predators with confusability radius set to 0 (non-confusing prey).

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015

doi: 10.1016/j.ecolmodel.2015.02.018

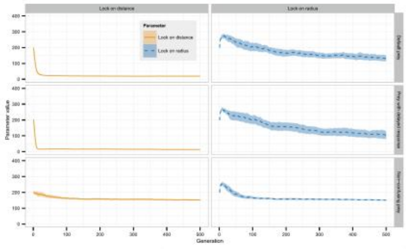


Fig. 4. Evolution of the lock-on distance and lock-on radius in the case of the dispersing predator. Visualized are the averages and the bootstrapped 95% confidence intervals based on 20 replicates of our experiments in three different settings – predators facing a group of prey with default parameters as in Table 1 (default prey), predators facing a group of prey with a delayed response, and predators with confusability radius set to 0 (non-confusing prey).

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015

doi: 10.1016/j.ecolmodel.2015.02.018

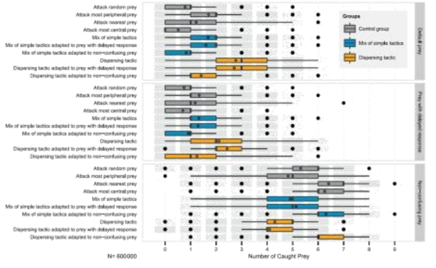


Fig. 5. Results of a direct competition between the individual predators that emerged from the 20 replicates of each of our experiments and a control group consisting of predators that attack exclusively the most peripheral prey, exclusively the nearest prey, exclusively the most central prey, or a random individual. Presented are the distributions, boxplots and averages of the distributions of the number of caught prey per tactic per specific setting.

Simulated predator attacks on schools: evolving composite tactics

Demšar J, *etal*, 2015

doi: 10.1016/j.ecolmodel.2015.02.018

A direct competition between the evolved predators (instances of tactic parameters adapted to specific settings) of 600,000 simulations revealed that attacking the nearest prey or the most central prey is the best tactic when confusability is not at play, while simply attacking a random individual is not far behind (with only a 17% lower success rate than attacking the nearest prey). The competition results suggest that confusability might play an important role in the evolution of target selection/hunting tactics and/or prey evasion tactics. The competition results show that the dispersing tactic is the best tactic when confusability is at play. Additionally, the results suggest that advanced evasion tactics, like a delayed response (Partridge,1982), are from the prey's point of view successful as they generally reduce the number of caught prey, but also that the dispersing tactic is capable of adapting to at least partially counter the effect. The adaptation is simply diving deeper into the group of prey before selecting the final target.