I Introduction

Adaptive dynamics is about evolution.

More precisely:

Adaptive dynamics is a conceptual framework for the formulation and analysis of mathematical models of evolution by mutation and natural selection in complex ecological systems.

Examples

Predator-prey coevolution, competitive interactions, virus-host coevolution, mutualism.

Adaptive dynamics.

Adaptation in a Darwinian sense: • Mutation (generation of new strategies) • Selection (elimination of less "fit" individuals)	Change (over time) of heritable traits or "strategies" of individuals E.g. behavior, morphology, physiology!

Adaptation $\Longrightarrow$ Dynamics.

Simulation experiment

$x_1, \dots, x_k$ strategies

$n_1, \dots, n_k$ corresp. pop. densities.

Lotka-Volterra competition model:

$$(1) \quad \dot{n}_i = r(x_i)\, n_i \left(1 - \frac{\sum_{j=1}^{k} a(x_i, x_j)\, n_j}{K(x_i)}\right)$$

for $i = 1, \dots, k$.

Population dynamics ⇒ Selection:

Some strategies decline in number while others increase.

When the pop. dens. of a given strategy gets below a certain threshold, the strategy is removed (i.e., the corresponding equation is removed from the system)

Mutation.

Now and then (at random points in time) a new strategy is added at a low initial pop. density (i.e., a new equation is added to the system)

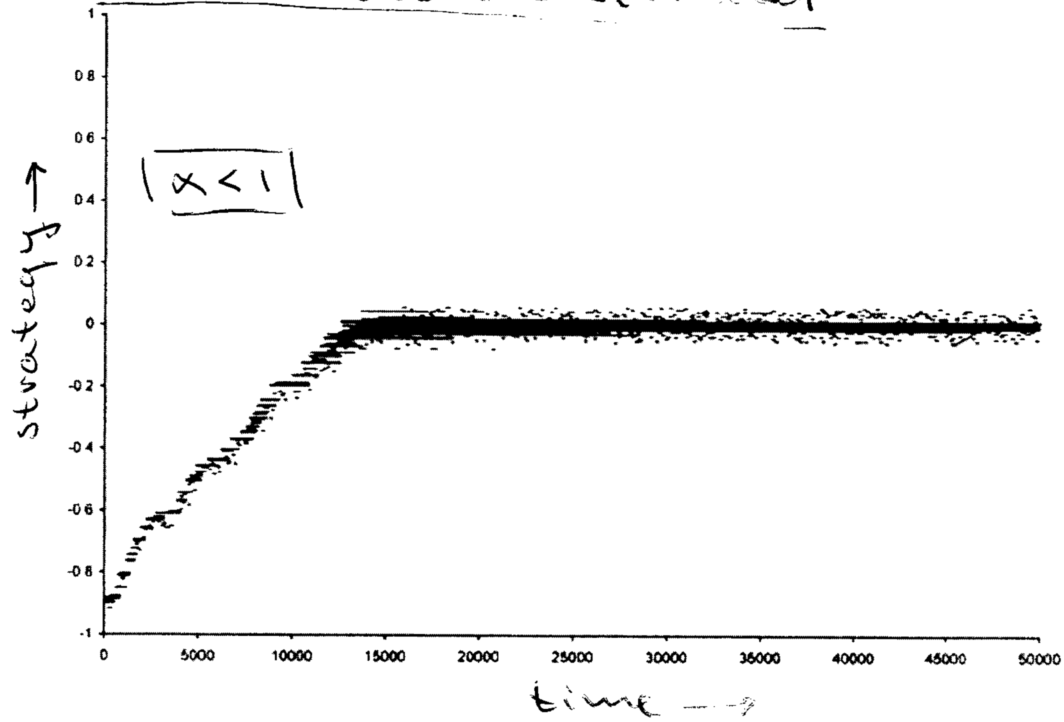
The new strategy is created by a small mutation of one of the strategies already present.

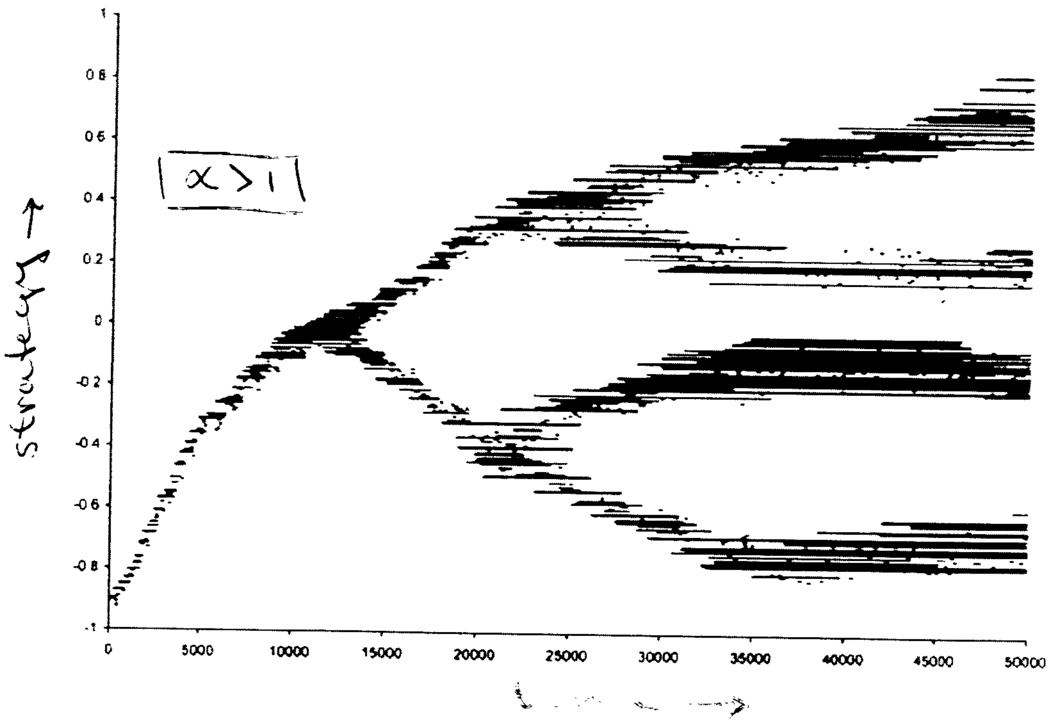
Further choices

(2)
$$\begin{cases} r(x) = 1 & (\text{"intrinsic rate of increase"}) \\ K(x) = e^{-x^2} & (\text{"carrying capacity"}) \\ a(x,y) = e^{-\alpha(x-y)^2} & (\text{"competition kernel"}) \end{cases}$$

(Interpret ?)

Simulation outcomes





How can we understand these simulation results?

Note: the simulation is not adaptive dynamics, but they motivate the following basic assumptions of adaptive dynamics.

Basic assumptions of adaptive dynamics

(a) Almost faithfull replication of strategies (i.e., faithfull safe of the rare occurrence of a mutation)

(b) Fast selection, slow mutation.

(c) Low initial mutant population density in a large resident population.

(d) Small mutation steps.

Remarks.

ad (a) In most applications this means clonal reproduction of individuals. This simplifies the complexity on the genetic side, which enables us to consider more complex ecological scenarios.

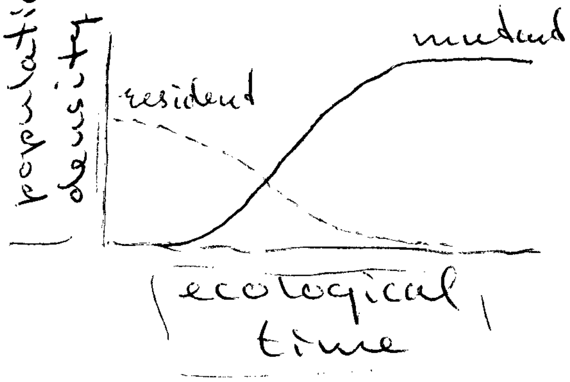
ad (b) Selection = population dynamics.

A population is assumed to have reached a population attractor before the next mutant comes along.

This leads to separate time scales for the population dynamics and the strategy dynamics, which in turn enables us to study more complex ecological systems.

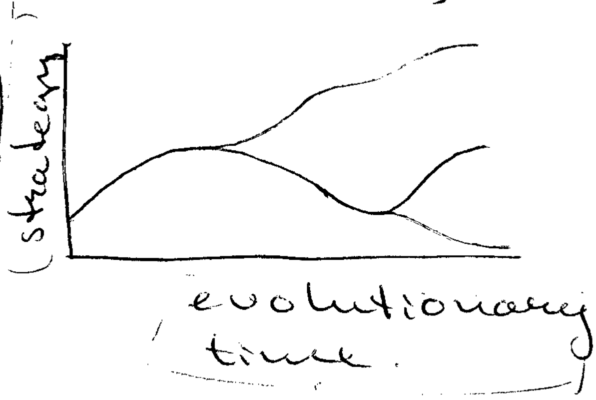
Fast

Pop. dyn. (selection)



Slow

Strat. dyn. (mutation)



| ad (c) | Enables us to define the notions of <u>invasion</u> and <u>invasion fitness</u>.

(Later more explanation).

| ad (d) | Small mutations enable us to derive model-independent results

(Later more explanation).

Discussion points:

- Discuss the four assumptions of adaptive dynamics in relation to the simulation outcomes on page 3
- Discuss the assumptions in relation to ① population genetics and ② quantitative genetics and ③ game theory.

Separation of ecological and evolutionary time scales lead to two kind of questions.

Ecology (fast)	Evolution (slow)
(pop. dyn.)	(strategy dyn.)
• Who can ivade whom? • Outcome of an invasion event? (coexistence or substitution)	• Long-term effects of many invasion events.
(Dynamics in pop. state space),	(Dynamics in strategy space),