Applied Evolutionary Ecology Part 2: Evolutionary Traps

Michael Noonan

Biol 417: Evolutionary Ecology

Table of contents

Review

Review

Last lecture we saw how organisms will have a preferences for habitats where $R_0 \geq 0$, and will avoid those where $R_0 < 0$. Over evolutionary timescales, they have developed the capacity to use environmental cues to guide habitat selection.

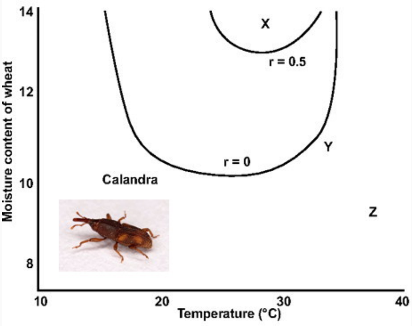
...but when a recent anthropogenic change in the environment breaks the normal cue-habitat quality correlation, organisms can find themselves at risk of experiencing an ecological trap.

We also saw how an ecological trap can be straightforward to correct if we know the mechanisms underlying the disconnect.

Today we will build on the concept of ecological traps to explore the concept of evolutionary traps.

Evolutionary Traps

Organisms will have a preferences for habitats where $R_0 \geq 0$, and will avoid those where $R_0 < 0$.

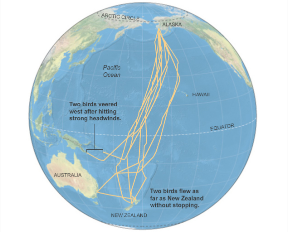


Birch (1953)

The term ‘ecological trap’ was coined in the context of negative outcomes of inappropriate habitat selection

...but organisms also rely on environmental cues to make a range of behavioural and life-history ‘decisions’ other than habitat selection.

When to migrate.



Whom to mate with.

How many young to bear.

What to eat.

Evolutionary traps

Organisms use cues in their environment to guide their choices.

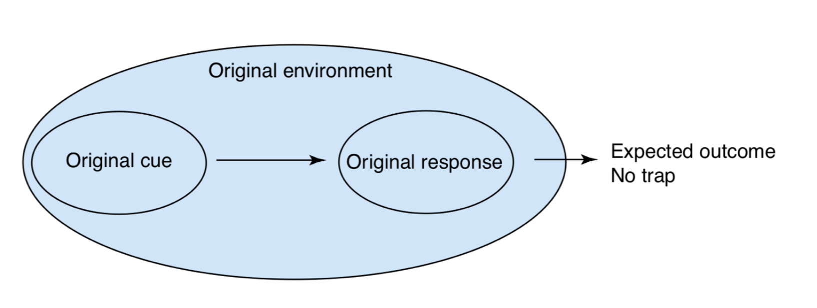
An **'Ecological Trap'** describe the situation in which an organism's choice of habitat results in $R_0 < 0$ because of a recent anthropogenic change in the environment that broke the normal cue-habitat quality correlation.

An **'Evolutionary Trap'** describe the broader phenomenon whereby any decision becomes maladaptive because of a sudden anthropogenic disruption.

The mechanism underlying an evolutionary trap is identical to that of an ecological trap (i.e., an organism is constrained by its evolutionary past to make a mistake), but the scope is expanded.

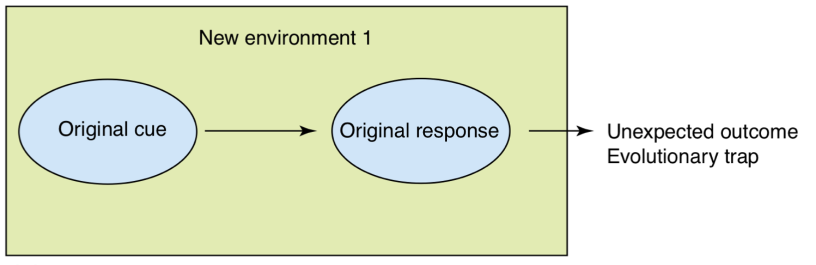
Evolutionary traps cont.

Normally, a cue in the original environment of an organism elicits a corresponding behavioral response that is associated predictably with an adaptive outcome.



Schlaepfer *et al.* (2002)

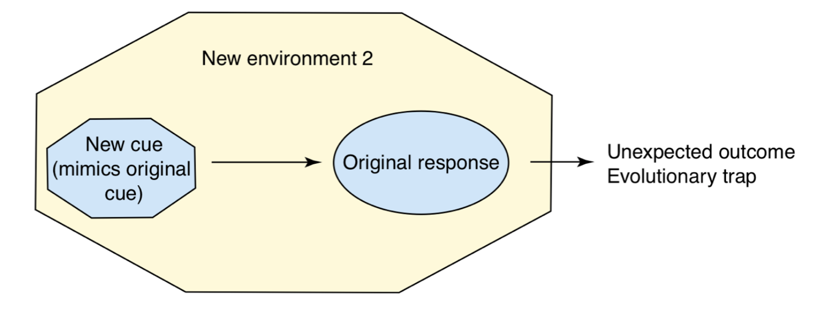
In a human modified environment, although the original cue still occurs and elicits its normal behavioral response, there no longer is a match between the behavior and the environment.



Schlaepfer *et al.* (2002)

Evolutionary traps cont.

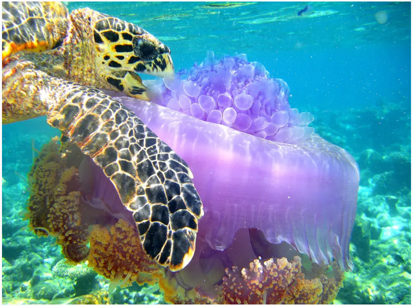
It is also possible for the altered environment to contain a novel element that mimics the original cue closely enough to elicit the original behavior, but in an inappropriate context



Schlaepfer *et al.* (2002)

Food choice by sea turtle spp.

Sea turtles ingest floating transparent prey (jellyfish)



Source: Boris Barath

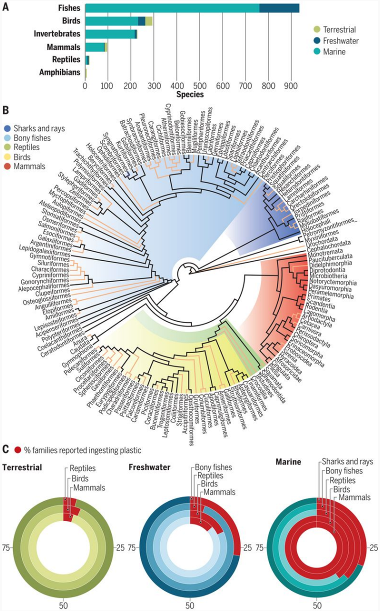
Transparent plastics discarded in ocean have similar structural cues as natural prey.

Source: WWF

This leads to impaction of digestive tract and possible death (Bjorndal *et al.*, 1994).

Plastic Ingestion as an Evol. Trap

THE UNIVERSITY OF BRITISH COLUMBIA
Okanagan Campus



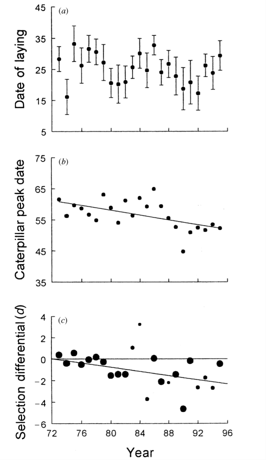
(Santos *et al.*, 2021)

Great tit breeding

Great tits (*Parus major*) time the hatching of young to coincide with prey emergence based on day length.

Source: YouTube

... but birds and insects respond differentially to global warming, causing a temporal mismatch.



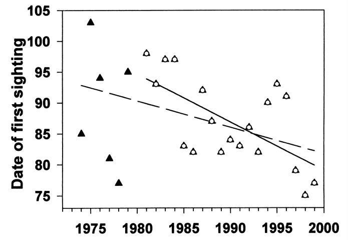
(Visser *et al.*, 1998)

... leading to reduced prey availability for feeding hatchlings.

American robins (*Turdus migratorius*) use air temperature to time their annual migration.

Source: Wikipedia

Inouye *et al.* (2000) found that robins are arriving at their summer grounds earlier, but the growing season hasn't changed.



(Inouye *et al.*, 2000)

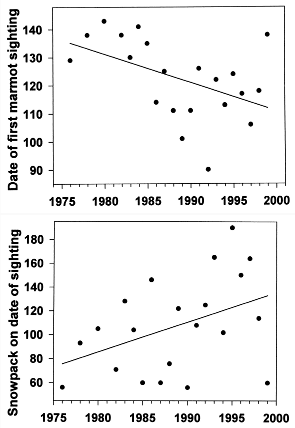
… leading to the interval between arrival date and the first date of bare ground having grown by 18 days.

Dormancy timing

Yellow-bellied marmots (*Marmota flaviventris*) use air temperature to time their emergence from hibernation.

Source: Wikipedia

Dissociation between air temperature and date of snow melt at high altitude locations leaves them out of sync with environmental conditions.



(Inouye *et al.*, 2000)

Mate selection

Beetles (*Julodimorpha Bakewelli*) mate recognition is based on morphological appearance.

Source: Wikipedia

Beer bottles resemble a beetle carapace, leading to males attempting to mate with beer bottles (Gwynne & Rentz, 1983).

Source: Jiri Lochman

Mate selection cont.

Male southern toads (*Bufo Terrestris*) attempt to mate with females based on cues normally associated with a receptive female (e.g. immobile).

Source: Wikipedia

High densities of road-killed females don't move and attract males in search of mates

Source: tillsonburg, Getty Images

... leading to no reproductive output, greater exposure to traffic (Meshaka Jr, 1996).

Evolutionary responses to evolutionary traps

Escaping evolutionary traps

In the short term, organisms are 'trapped' in their evolved response to cues that now occur in a novel context.

However, these traps are not necessarily evolutionary dead ends and populations can avoid extinction/extirpation if:

1. The negative effects of the trap on reproduction and survival are not too severe.

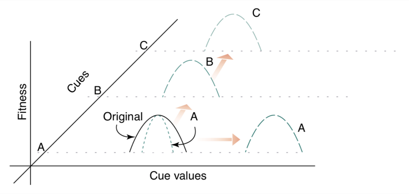
2. There is some genetic variation or behavioral plasticity in the response to the novel environment within the population.

3. The population is large enough and can persist long enough for adaptation to occur.

Escaping evolutionary traps cont.

Behavioural plasticity can serve as an effective mechanisms to escape ecological and evolutionary traps (especially for long-lived species)... but there is a limit to how flexible this can be.

Selection on existing underlying genetic variation is longer-term solution (assuming the environmental change is permanent).



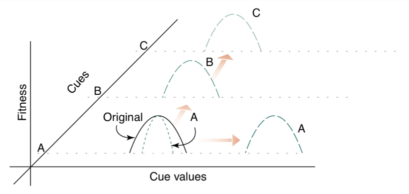
Schlaepfer *et al.* (2002)

If a cue still carries relevant information in the novel environment, the range of cue values under which the behavior is elicited can evolve (A).

Escaping evolutionary traps cont.

Behavioural plasticity can serve as an effective mechanisms to escape ecological and evolutionary traps (especially for long-lived species)... but there is a limit to how flexible this can be.

Selection on existing underlying genetic variation is longer-term solution (assuming the environmental change is permanent).



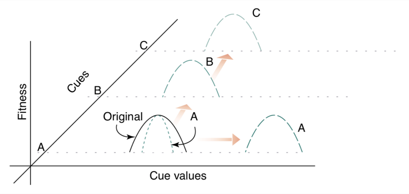
Schlaepfer *et al.* (2002)

Example: As temperature and productivity become dissociated, marmots might time their emergence from hibernation based on higher temperatures.

Escaping evolutionary traps cont.

Behavioural plasticity can serve as an effective mechanisms to escape ecological and evolutionary traps (especially for long-lived species)... but there is a limit to how flexible this can be.

Selection on existing underlying genetic variation is longer-term solution (assuming the environmental change is permanent).



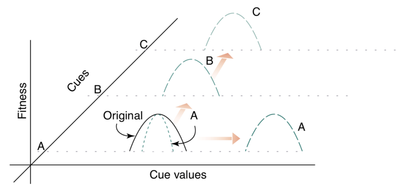
Schlaepfer *et al.* (2002)

Alternatively, a new set of cues (e.g. B or C) might be necessary to identify the most adaptive situation in a new environment.

Escaping evolutionary traps cont.

Behavioural plasticity can serve as an effective mechanisms to escape ecological and evolutionary traps (especially for long-lived species)... but there is a limit to how flexible this can be.

Selection on existing underlying genetic variation is longer-term solution (assuming the environmental change is permanent).



Schlaepfer *et al.* (2002)

Example: As circadian rhythms and mean annual temp. become dissociated, birds might rely more on different phenological cues to time their migrations.

Traps vs. disturbance

From a pure evolutionary perspective, an ecological or evolutionary trap does not differ fundamentally from any natural 'disturbance' and its associated natural selection.

What makes traps unique, however, is that they are induced by humans and generally occur in a shorter time span than natural environmental changes.

If the magnitude of the change exceeds the range of values normally encountered, some populations might not have the ability to survive the novel circumstances.

Trap Take Homes

Natural selection has provided species with a set of ‘Darwinian Algorithms’ that they use to respond to environmental cues.

These algorithms are fine-tuned to be only as complex as is necessary to yield adaptive outcomes under normal circumstances, and not so complex as to cover all possible contingencies (risk responding to noise and not the signal).

When a recent anthropogenic change in the environment breaks the normal cue-response correlation, organisms can find themselves at risk of ecological and evolutionary traps.

Trap Take Homes cont.

Understanding the mechanisms underlying the disconnect is critical for designing effective conservation/management strategies.

Next lecture we will cover an important generator of traps: Roads.

References

Birch, L. (1953). Experimental background to the study of the distribution and abundance of insects: Ii. the relation between innate capacity for increase in numbers and the abundance of three grain beetles in experimental populations. *Ecology*, 34, 712–726.

Bjorndal, K.A., Bolten, A.B. & Lagueux, C.J. (1994). Ingestion of marine debris by juvenile sea turtles in coastal florida habitats. *Marine pollution bulletin*, 28, 154–158.

Gwynne, D.T. & Rentz, D.C. (1983). Beetles on the bottle: male buprestids mistake stubbies for females (coleoptera). *Australian Journal of Entomology*, 22, 79–80.

Inouye, D.W., Barr, B., Armitage, K.B. & Inouye, B.D. (2000). Climate change is affecting altitudinal migrants and hibernating species. *Proceedings of the National Academy of Sciences*, 97, 1630–1633.

Meshaka Jr, W.E. (1996). Anuran davian behavior: a darwinian dilemma. *Florida Scientist*, 59, 74–75.

Santos, R.G., Machovsky-Capuska, G.E. & Andrades, R. (2021). Plastic ingestion as an evolutionary trap: Toward a holistic understanding. *Science*, 373, 56–60.

Schlaepfer, M.A., Runge, M.C. & Sherman, P.W. (2002). Ecological and evolutionary traps. *Trends in Ecology Evolution*, 17, 474–480.

Visser, M.E., Noordwijk, A.v., Tinbergen, J. & Lessells, C. (1998). Warmer springs lead to mistimed reproduction in great tits (parus major). *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 265, 1867–1870.