Evolutionary rescue and dispersal: the effect of habitat choice on successful adaptation

Pete Czuppon

in collaboration with
Florence Débarre (Sorbonne Université),
François Blanquart (Collège de France),
Hildegard Uecker (Max Planck Institute for Evolutionary Biology)

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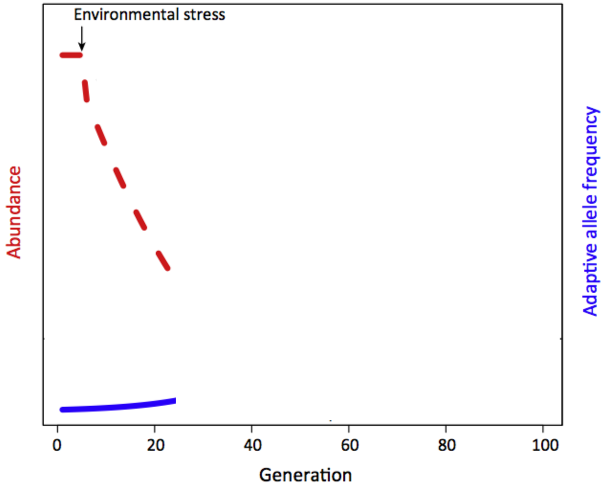
Evolutionary rescue?



Carlson et al., 2014, *TRENDS in Ecology & Evolution*

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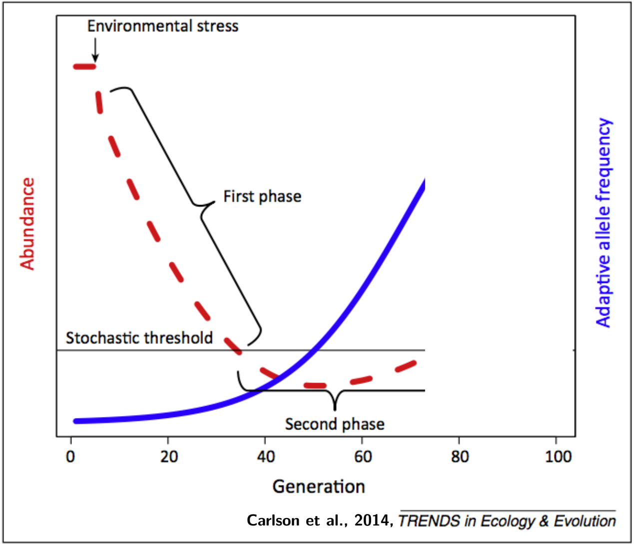

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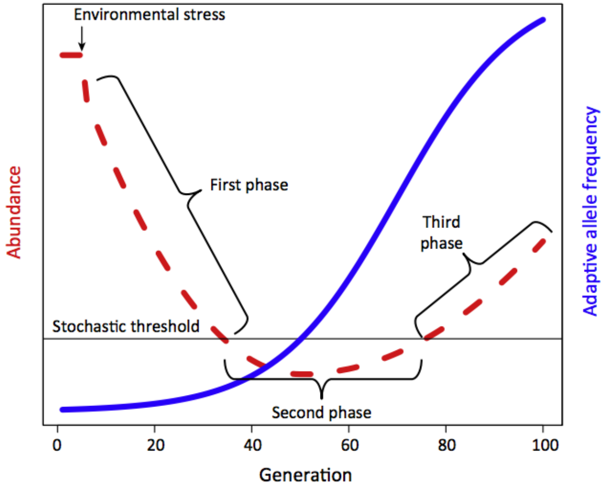

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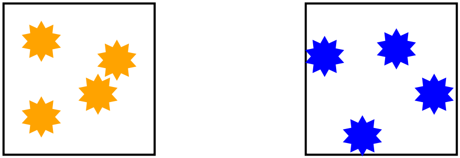
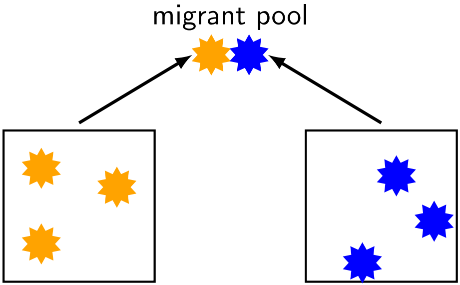
Applications: conservation biology, epidemiology

Dispersal?



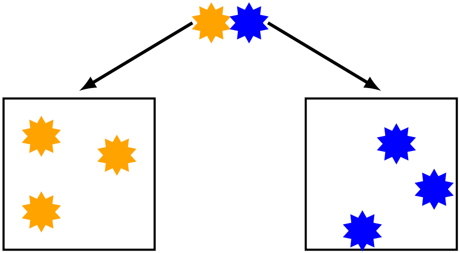
Dispersal?

Emigration



Dispersal?

Immigration



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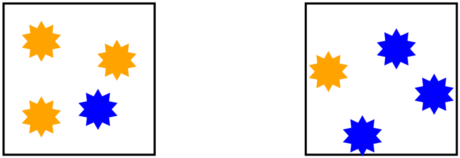

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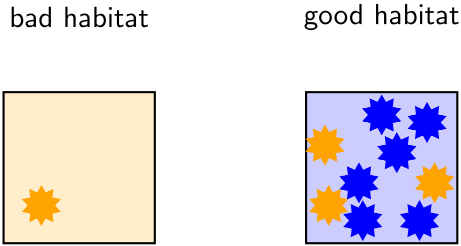
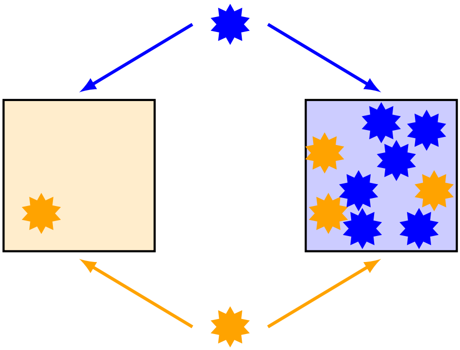


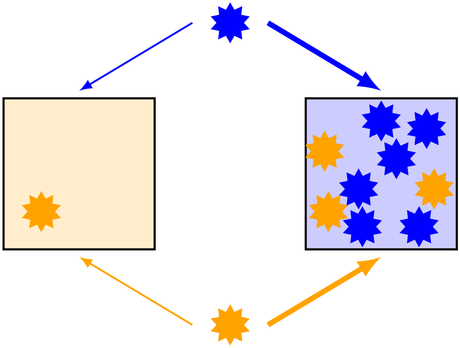
Dispersal?

Random dispersal (RD) - no habitat bias



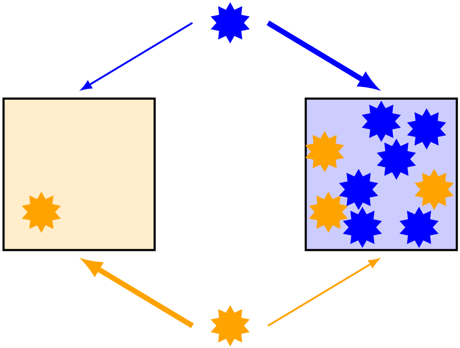
Dispersal?

Absolute habitat matching (AHM) - all prefer the good habitat
e.g. reptiles, birds, ...



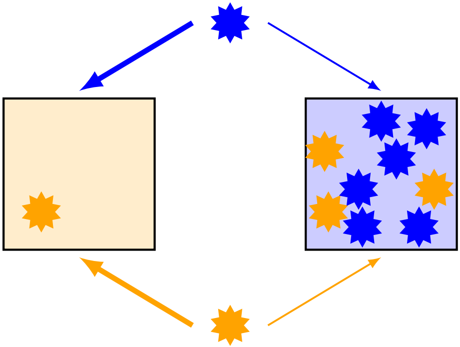
Dispersal?

Relative habitat matching (RHM) - all prefer the habitat where they are relatively more fit
e.g. ciliates (specialist vs generalist dispersal)

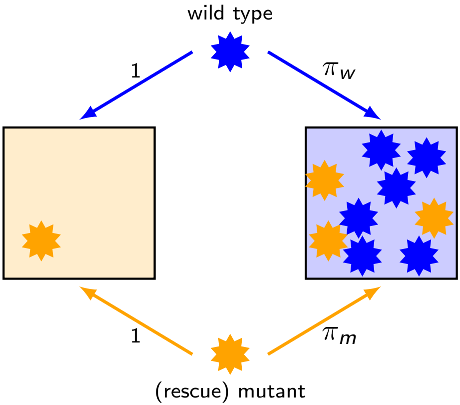


Dispersal?

Negative density-dependent dispersal (NDD) - all prefer the less crowded habitat
e.g. fish, birds, ...



Dispersal?



How does dispersal (and different dispersal schemes) affect the probability of evolutionary rescue?

Model

Life cycle: Dispersal - Reproduction - Regulation

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Good habitat dynamics:

- Assumption: carrying capacity is always reached
  $\Rightarrow$ Wright-Fisher sampling
- wild type better adapted than the mutant
- mean number of offspring of one mutant: $1 + s_{\text{good}}$
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Bad habitat dynamics:

- Assumption: wild type population declines
  $\Rightarrow$ carrying capacity is not reached (offspring number $\sim$ Poisson)
- mean number of offspring of one wild-type individual: $1 - r$ with $r \in (0, 1]$
- mean number of offspring of one mutant: $1 + s_{\text{bad}}$ with $s_{\text{bad}} > 0$

Establishment probability in a heterogeneous environment

Technique: Multi-type branching process theory (weak selection, weak dispersal approximation)

$$\varphi_{\text{good}} \approx s_{\text{good}} \left(1 + \frac{(1 - f_{\text{good}} + \pi_m f_{\text{good}})}{\sqrt{C}} (s_{\text{good}} - s_{\text{bad}})\right)$$

$$+ m \left(\frac{s_{\text{bad}}(1 - f_{\text{good}})}{\sqrt{C}} + \frac{s_{\text{good}} \pi_m f_{\text{good}}}{\sqrt{C}} - \frac{(s_{\text{good}} - s_{\text{bad}})(1 - f_{\text{good}})}{\sqrt{C}}\right)$$

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$$\varphi_{\text{bad}} \approx s_{\text{bad}}\left(1 + \frac{(1 - f_{\text{good}} + \pi_m f_{\text{good}})}{\sqrt{C}}(s_{\text{bad}} - s_{\text{good}})\right) + m\left(\frac{s_{\text{bad}}(1 - f_{\text{good}})}{\sqrt{C}} + \frac{s_{\text{good}}\pi_m f_{\text{good}}}{\sqrt{C}} - \frac{(s_{\text{bad}} - s_{\text{good}})\pi_m f_{\text{good}}}{\sqrt{C}}\right)$$

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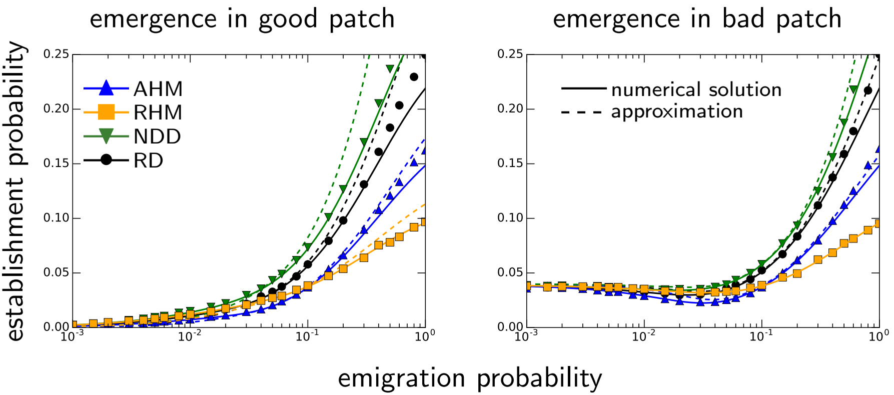
(constant patch configuration – 50% good patches)

Weak selection in the good habitat ($s_{\text{good}} \sim -0.01$)



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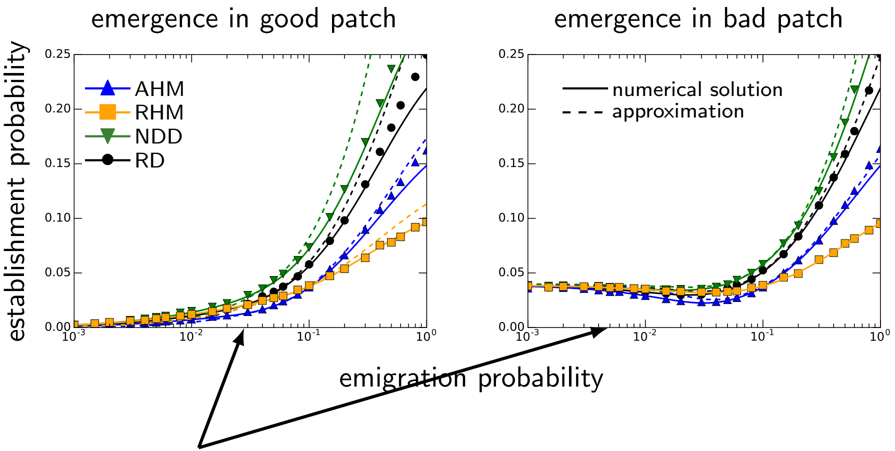

Increasing migration rates ⇒ influx to / outflux from bad habitat

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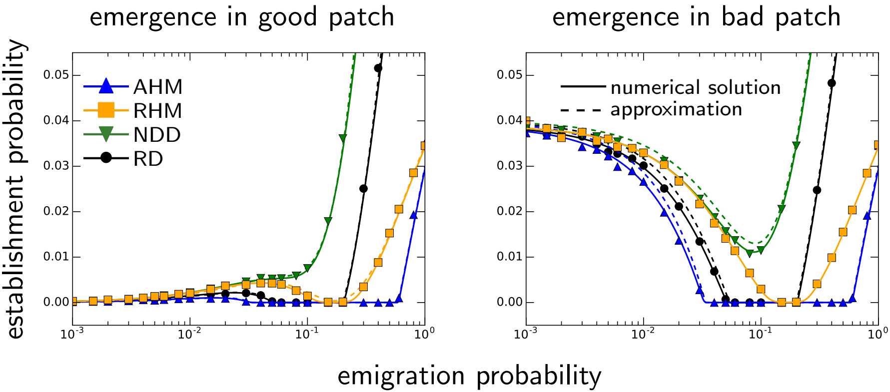

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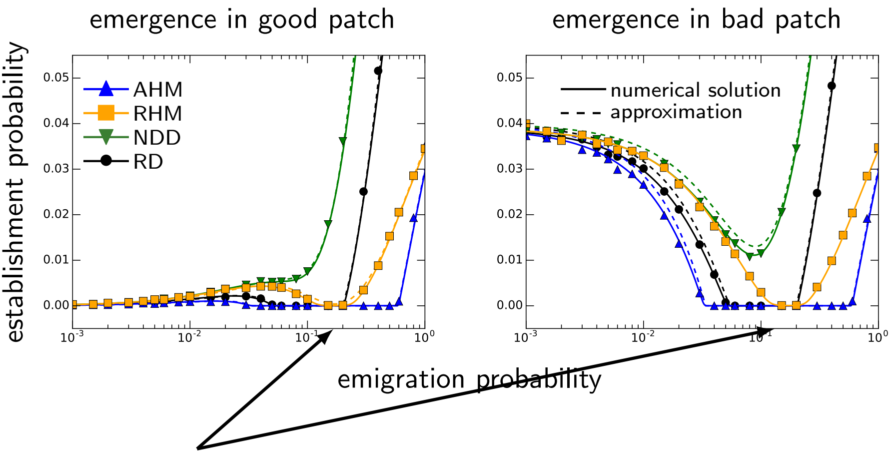
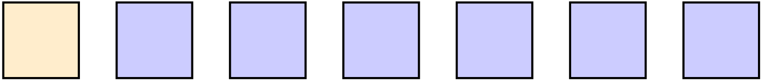


High migration rates ⇒ relaxed competition in good patches

Probability of evolutionary rescue

$t = 0$



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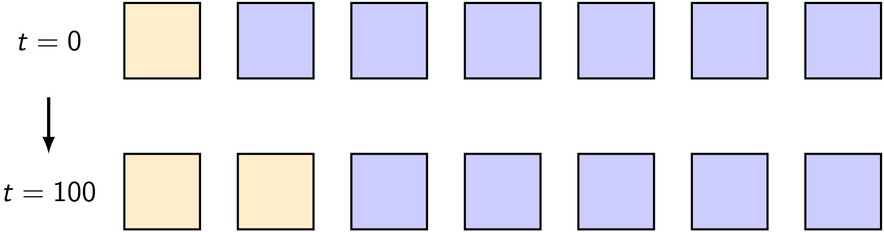

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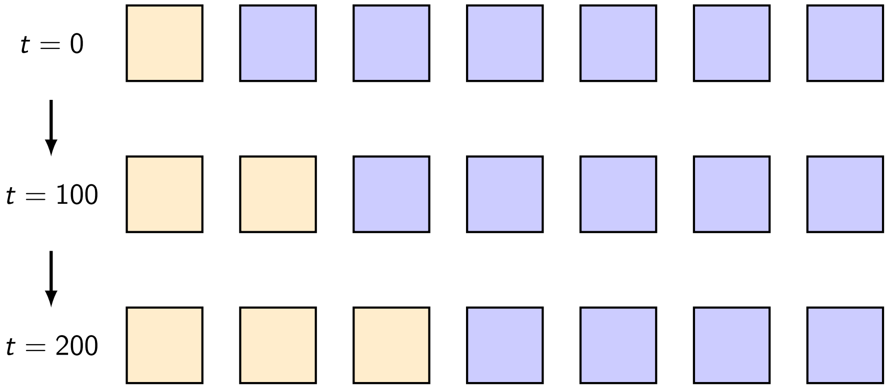

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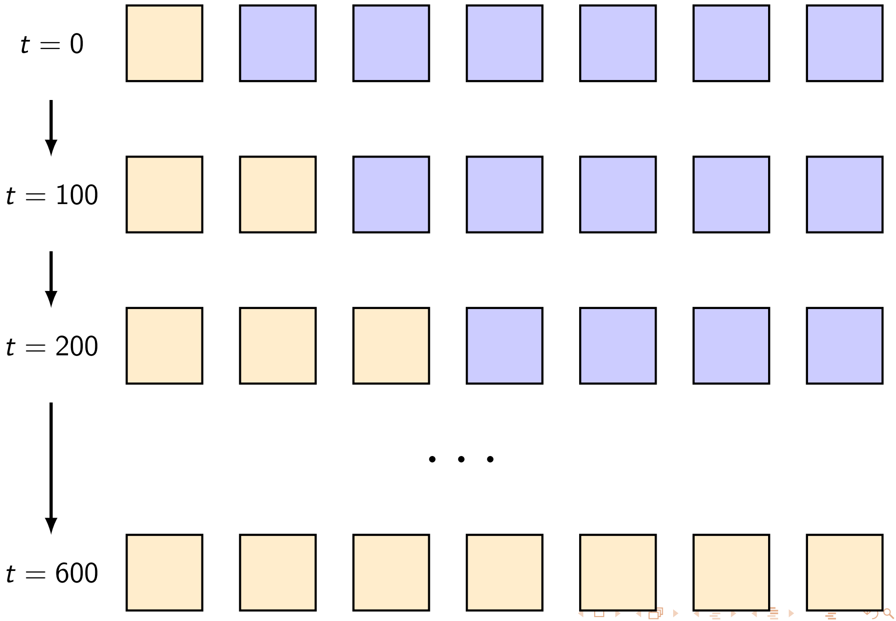
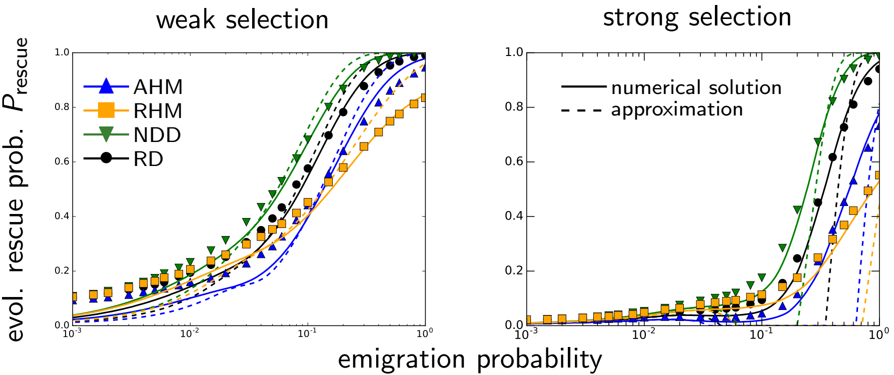


Probability of evolutionary rescue

(deterioration of patches one after the other over time)

10 patches in total, 100 generations between deterioration events



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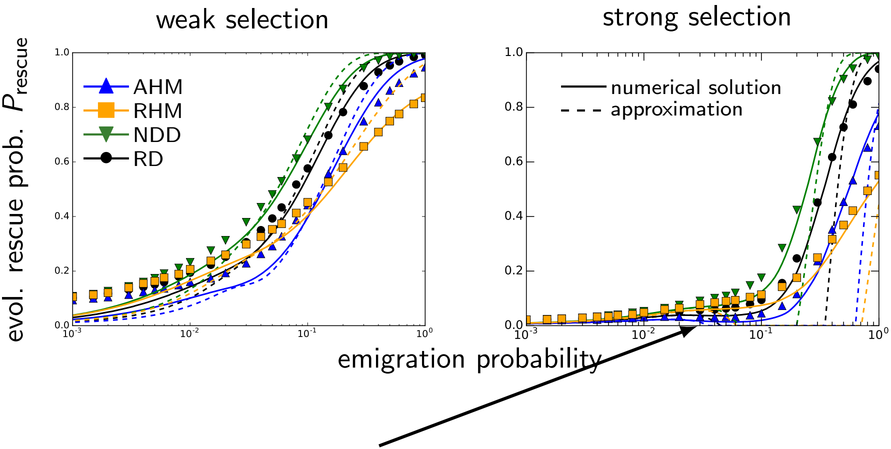

Stronger selection ⇒ non-monotone probability

Conclusions

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- Habitat choice hinders adaptation and evolutionary rescue under weak selection
- Relative habitat choice promotes adaptation and evolutionary rescue for strong selection (at least for low to intermediate dispersal rates)

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@FrancoisJB

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Probability of evolutionary rescue

$$P_{\text{rescue}} \approx 1 - \exp\left(-\tau u \sum_{i=0}^{M-1} \left(\underbrace{\varphi_{\text{good}}\left(f_{\text{good}}(i)\right) N_w^{\text{good}}(i)}_{\text{old habitat contribution}} + \underbrace{\varphi_{\text{bad}}(f_{\text{good}}(i)) i N_w^{\text{bad}}(i) \left(f_{\text{good}}(i)\right)}_{\text{new habitat contribution}} \right) \underbrace{- u\varphi_{\text{bad}}(0) \sum_{i=\tau(M-1)}^{\infty} N_w^{\text{bad}}(i)}_{\text{contribution after the last patch has deteriorated}} \right)$$