Can rapid evolutionary adaptation to clear-cut habitats occur in ground beetles?

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CONTEXT:

Clear-cuts increase sun exposure and soil temperatures but decrease soil moisture. For remnant biodiversity surviving in clearcuts, recovery following clear-cutting will depend on a population's reproductive capacity and survivorship, both of which may be linked to current habitat conditions as well and evolutionary adaptations passed from parents to offspring.

Research Questions:

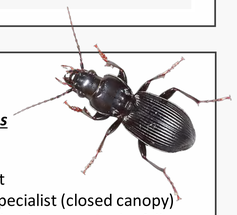
To investigate if remnant populations can rapidly adapt to clear-cut habitats, we addressed two main research questions:

- How does clear-cutting impact fecundity in two ground beetle species, *Pterostichus pensylvanicus* and *Pterostichus coracinus*?
- Does parental lineage and/or rearing habitat impact survivorship and overall fitness in the offspring's generations?

STUDY ORGANISMS:

Pterostichus pensylvanicus

- Abundant
- Habitat generalist
- Spring breeder: lays eggs in spring, larvae complete developmental cycle before fall, overwintering as adults.



Pterostichus coracinus

- Abundant
- Habitat specialist (closed canopy)
- Fall breeder: lays eggs in the fall, overwinters as larvae, and does not mature into adults until spring

METHODS:

We sampled in the Lake Duparquet Research and Teaching forest. We selected three unharvested stands to use as controls, and three stands which were clear-cut 5-6 years prior to the study. In each plot we placed 25 dry pitfall traps for a total of 75 traps per treatment.

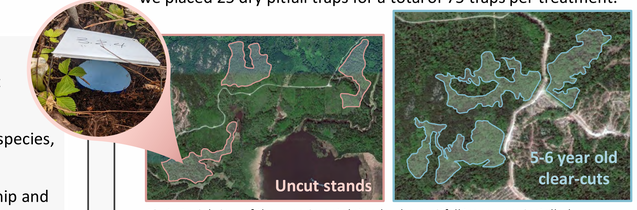


Fig 1. Aerial view of the experimental stands where pitfall traps were installed.

We collected mature adults from pitfall traps every 48 hours. Adults were then placed in male/female pairs in clear-cut x clear-cut crosses and uncut x uncut crosses. Eggs from each pair were counted weekly and then placed in incubation chamber to hatch.

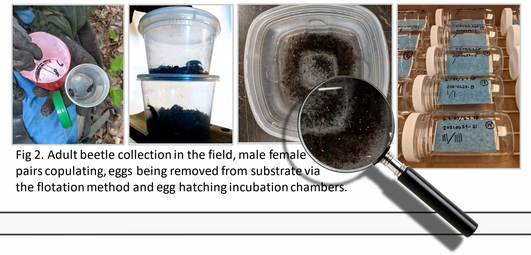


Fig 2. Adult beetle collection in the field, male female pairs copulating, eggs being removed from substrate via the flotation method and egg hatching incubation chambers.

First instar larvae were reared in the lab in a controlled environment as part of a common garden experiment or placed back out into the field in arenas in a reciprocal transplant experiment.

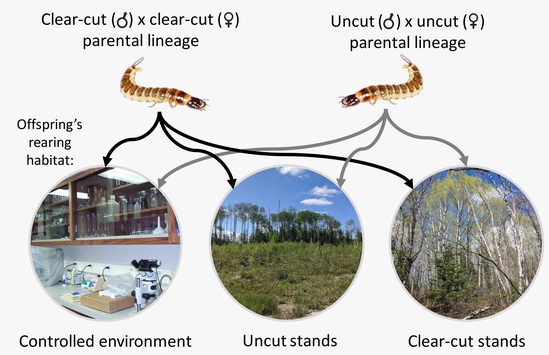


Fig 3. Schematic depiction of the distribution of first instar larvae into rearing habitats.

ANALYSES:

Table 1. Response and explanatory variables used in each regression analysis to determine the impacts of clear-cutting on fecundity and survivorship.

		Response variables	Explanatory variables
Parents	Fecundity	o Body size o Total eggs laid per female o Incubation period o Proportion of eggs hatched	o Habitat (clear-cut vs. uncut stands) o Maternal body size*
Offspring	Survivorship (Common garden)	o Developmental period o Lifespan	o Parental lineage o Maternal body size
Offspring	Survivorship (Reciprocal transplant)	o Probability of survival	o Rearing habitat (clear-cut vs. uncut stands) o Parental lineage o Maternal body size

* We included maternal body size, in addition to habitat/lineage, as an explanatory variable as body size can impact the quantity & size of eggs a female can stored at one time, which is also thought to impact offspring fitness.

RESULTS & DISCUSSION:

Fecundity:

***P. pensylvanicus*:** Body size, total number of eggs laid per female, and the average incubation period for those eggs did not differ by habitat or maternal body size. However, a larger proportion of eggs hatched from clear-cut females and their eggs took less time to hatch.

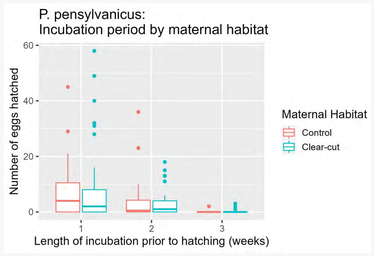


Fig 4. Incubation time by maternal habitat for *P. pensylvanicus* eggs.

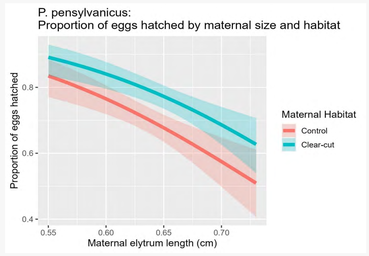


Fig 5. Proportion of eggs hatched by habitat and maternal size for *P. pensylvanicus*.

Changes in fecundity in clear-cut females suggests that remnant populations are beginning to adapt to their new environmental conditions

***P. coracinus*:** Body size did not differ by habitat. However, eggs laid by females from the clear-cuts hatched faster than those laid by females from the uncut stands. There was also a significant interaction between parental habitat and maternal body size on the total number of eggs laid per female and the proportion of eggs hatched.

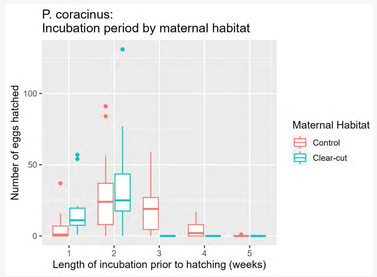


Fig 6. Incubation time by maternal habitat for *P. coracinus* eggs.

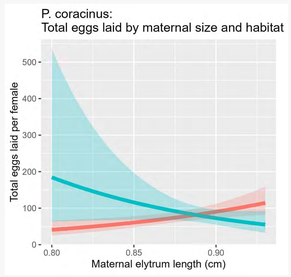


Fig 7. Proportion of eggs laid by habitat and maternal size for *P. coracinus*.

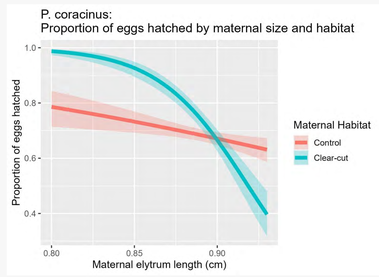


Fig 8. Proportion of eggs hatched by habitat and maternal size for *P. coracinus*.

Faster maturation times may decrease the chance of mortality via desiccation in hot/dry soils

Common Garden:

P. pensylvanicus: Offspring from clear-cut lineages reached maturity more quickly than those from uncut lineages.

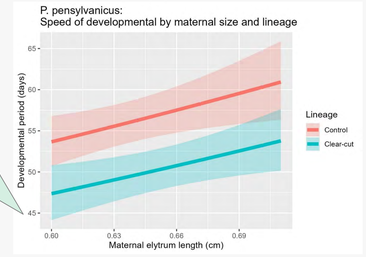


Fig 9. Time to maturity by habitat and maternal size for *P. pensylvanicus*.

***P. coracinus*:** Offspring from clear-cut lineages had a shorter lifespan than those from uncut lineages.

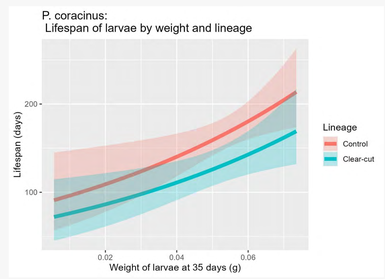


Fig 10. Time to maturity by habitat and maternal size for *P. coracinus*.

Increased impacts of clear-cutting on *P. coracinus* is likely due lower tolerances for increased heat in fall breeding species. Thus, *P. coracinus* may not have the necessary genetic variation in their gene pool to adapt to these changes.

Reciprocal Transplant:

P. pensylvanicus: Probability of offspring's survival was not affected by parental lineage or maternal body size. However, probability of survival was lower when larvae were reared in the clear-cut stands.

Table 2. Predicted probability of survival from regression analysis for *P. pensylvanicus* larvae of clear-cut and uncut lineages reared in clear-cut and uncut stands.

Parental Lineage	Rearing Habitat (F1)	Fit	SE Fit	Upper Limit	Lower Limit	Predicted Probability of Survival
Clear-cut	Clear-cut	-0.723	0.26	0.447	0.226	32%
Uncut	Clear-cut	-0.435	0.296	0.536	0.266	39%
Clear-cut	Uncut	-0.131	0.256	0.591	0.347	46%
Uncut	Uncut	0.157	0.306	0.681	0.391	53%

P. coracinus: Probably of offspring's survival was affected by both the rearing habitat and the parental lineage

Table 3. Predicted probability of survival from regression analysis for *P. coracinus* larvae of clear-cut and uncut lineages reared in clear-cut and uncut stands.

Parental Lineage	Rearing Habitat (F1)	Fit	SE Fit	Upper Limit	Lower Limit	Predicted Probability of Survival
Clear-cut	Clear-cut	-3.045	1.023	0.261	0.006	4%
Uncut	Uncut	-1.609	0.49	0.343	0.071	16%
Uncut	Clear-cut	-0.693	0.387	0.516	0.19	33%
Clear-cut	Uncut	-0.56	0.443	0.577	0.193	36%

Fig 11. Design of reciprocal transplant arenas.

IMPLICATIONS:

Maintaining nearby **refuge habitats** may lessen impacts of clear-cutting on fall breeding species like *P. coracinus*.

→ Refuge habitats allow individuals emigrating from neighboring uncut stands to relieve genetic bottlenecks or declining abundance, and may prevent local extinction until the canopy returns.

Additionally, as probability of survival increased significantly when *P. coracinus* larvae were reared in novel environments, maintaining nearby refuge habitats could **increase survival** in both populations by permitting adults to disperse to neighboring habitats to deposit their eggs.