

Appendix 1: Facultative paedomorphosis as a mechanism promoting intraspecific niche differentiation

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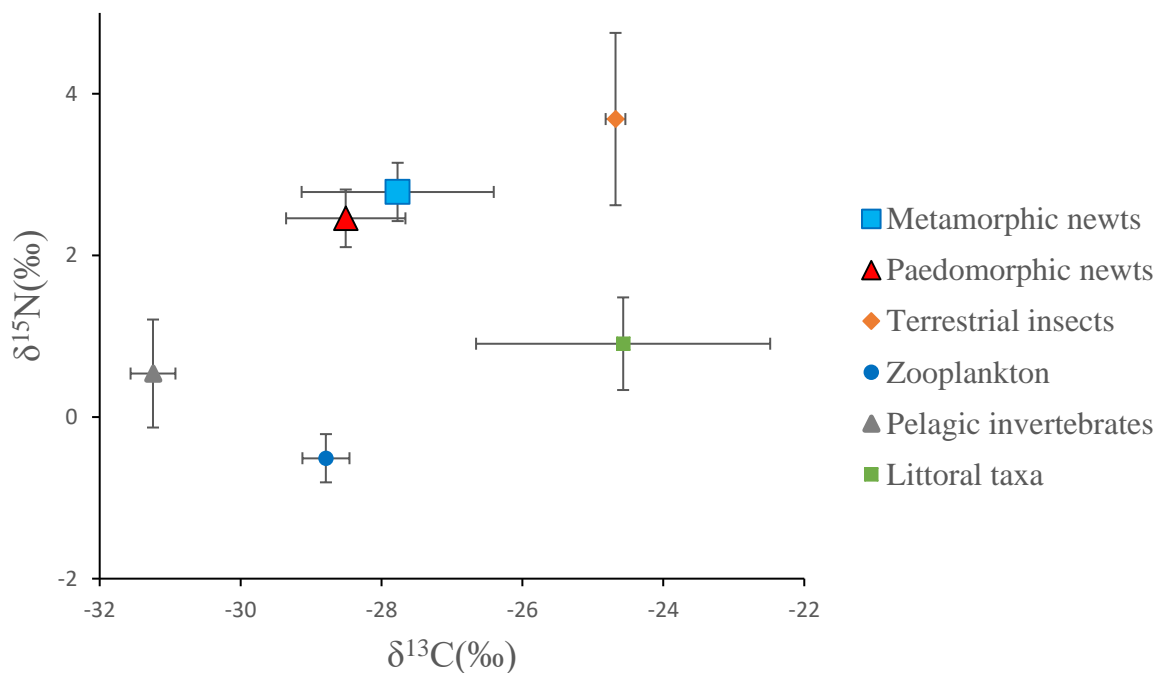


Fig. A1. Position of consumers and prey in the isospace of Carbon and Nitrogen stable isotopes. Isotopic compositions of each group is presented as mean and standard deviation. Metamorphic newts = light blue square, paedomorphic newts = red triangle, terrestrial insects = orange diamond, zooplankton = dark blue circle, pelagic invertebrates = grey triangle, littoral taxa = green square. “Pelagic invertebrates” includes Chaoboridae pupae and fairy shrimps, “Littoral taxa” includes “Littoral taxa” includes aquatic adults and larvae Coleoptera; “Terrestrial insects” are prey that had fallen on water surface. Mean \pm SD of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ composition of sources before and after pooling are available in Supplementary Material Appendix 1 Table A2.

Table A1. PERMANOVA (Euclidean distances, 9999 permutations) on the SVL of newts (snout-vent length): effects of phenotype (paedomorph vs metamorph), sex and their interaction.

	D.f.	SS	MS	Pseudo-F	P
Phenotype	1	15.32	15.32	0.91724	0.3343
Sex	1	233.54	233.54	13.983	0.0005
Interaction	1	0.086027	0.086027	0.0051506	0.9415
Residuals	74	1236	16.702		

D.f. = degrees of freedom, SS = sum of squares, MS = mean sum of squares, Pseudo-F = F value by permutation. Bold face indicates statistical significance ($P < 0.05$).

Table A2. Mean \pm SD of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ composition of food sources before and after pooling.

Prey types (n = 6)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
Zooplankton	-28.79 ± 0.33	-0.51 ± 0.3
Fairy shrimp	-31.26 ± 0.24	0.31 ± 0.94
Chaoboridae	-31.23 ± 0.42	0.77 ± 0.14
Aquatic Coleoptera larvae	-22.65 ± 1.48	1.51 ± 0.36
Aquatic adult Coleoptera	-25.60 ± 0.72	0.76 ± 0.29
Terrestrial insects	-24.68 ± 0.14	3.69 ± 1.07
Mixed food sources for SIAR (n = 12)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
Pelagic invertebrates	-31.24 ± 0.32	0.54 ± 0.67
Littoral taxa	-24.57 ± 2.09	0.91 ± 0.57

‘Pelagic invertebrates’ = Chaoboridae pupae and fairy shrimps, ‘Littoral taxa’ = aquatic Coleoptera larvae and adults.

Table A3. PERMANOVA (Euclidean distances, 9999 permutations) on individual Shannon index (H') of alpine newts, calculated from abundances of prey in stomach contents, including newts’ size (Ln-transformed snout-vent length) as a covariate: effects of the covariate, phenotype (paedomorph vs metamorph), sex and their interaction.

	D.f.	SS	MS	Pseudo-F	P
Covariate: Size	1	0.33481	0.33481	2.6359	0.1019
Phenotype	1	2.255	2.255	17.753	0.0002
Sex	1	0.016239	0.016239	0.12785	0.7239
Phenotype x Sex	1	0.11849	0.11849	0.93285	0.3387
Residuals	73	9.2725	0.12702		

D.f. = degrees of freedom, SS = sum of squares, MS = mean sum of squares, Pseudo-F = F value by permutation. Bold face indicates statistical significance ($P < 0.05$).

Table A4. Proportion of trophic niche overlap (Schoener Index), calculated based on abundances of prey in stomach contents between each pair of alpine newt categories.

Group 1	Group 2	Schoener Index
Paedomorphs	Metamorphs	0.58
Males	Females	0.98
Paedomorphic female	Paedomorphic male	0.94
Paedomorphic female	Metamorphic female	0.69
Paedomorphic female	Metamorphic male	0.83
Paedomorphic male	Metamorphic female	0.75
Paedomorphic male	Metamorphic male	0.88
Metamorphic female	Metamorphic male	0.86

Table A5. PERMANOVA (Bray-Curtis distances, 9999 permutations) on square-root transformed proportions of prey abundances from stomach contents of alpine newts, including newts' size (ln-transformed snout-vent length) as a covariate: effects of SVL, phenotype (paedomorph vs metamorph), sex and their interaction.

	D.f.	SS	MS	Pseudo-F	P
Covariate : Size	1	4145.8	4145.8	2.7072	0.061
Phenotype	1	8096	8096	5.2867	0.0043
Sex	1	528.83	528.83	0.34533	0.7723
Phenotype x Sex	1	1318.4	1318.4	0.86094	0.4592
Residuals	73	111790	1531.4		

D.f. = degrees of freedom, SS = sum of squares, MS = mean sum of squares, Pseudo-F = F value by permutation. Bold face indicates statistical significance ($P < 0.05$).

Table A6. PERMANOVA (Euclidean distances, 9999 permutations) on the biomass intake of newts (Dry Weight of the total stomach content) corrected by snout-vent length (SVL): effects of phenotype (paedomorph vs metamorph), sex and their interaction.

	D.f.	SS	MS	Pseudo-F	P
Phenotype	1	0.11761	0.11761	2.0922	0.151
Sex	1	0.0088325	0.0088325	0.15712	0.7033
Interaction	1	0.012097	0.012097	0.21519	0.6663
Residuals	74	4.1598	0.056214		

D.f. = degrees of freedom, SS = sum of squares, MS = mean sum of squares, Pseudo-F = F value by permutation. Bold face indicates statistical significance ($P < 0.05$).

Table A7. PERMANOVA (Euclidean distances, 9999 permutations) on the residuals of body condition of newts: effects of phenotype (paedomorph vs metamorph), sex and their interaction. Residuals of body condition were calculated by computing the residuals of the regression of ln-transformed body mass on ln-transformed snout-vent length.

	D.f.	SS	MS	Pseudo-F	P
Phenotype	1	8.652e-06	8.652e-06	0.0004389	0.9819
Sex	1	0.07313	0.07313	3.7096	0.0588
Interaction	1	0.033101	0.033101	1.6791	0.1975
Residuals	74	1.4588	0.019714		

D.f. = degrees of freedom, SS = sum of squares, MS = mean sum of squares, Pseudo-F = F value by permutation. Bold face indicates statistical significance ($P < 0.05$).

Table A8. Different estimates and metrics of the isotopic niche of alpine newts.

	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	SEA	SEA _C	SEA _B (CI ₉₅)	TA
P♀	-28.4 ± 0.8	2.3 ± 0.3	0.719	0.770	0.701 (0.401–1.164)	1.754
P♂	-28.7 ± 1.0	2.7 ± 0.2	0.715	0.786	0.658 (0.381–1.247)	1.896
M♀	-27.9 ± 1.3	2.8 ± 0.3	1.306	1.361	1.247 (0.860–1.890)	3.861
M♂	-27.6 ± 1.5	2.8 ± 0.4	1.560	1.631	1.504 (1.024–2.357)	4.299

$\delta^{13}\text{C}$ (‰) and $\delta^{15}\text{N}$ (‰) are given as Mean ± SD, SEA = Standard Ellipse Area, SEA_C = SEA corrected for sample size, SEA_B = Bayesian estimates of SEA with 95% Credible Intervals (CI₉₅) and based on 10⁵ draws, TA = Total area of the convex Hull. P♀ = Paedomorphic females, P♂ = Paedomorphic males, M♀ = Metamorphic females, M♂ = Metamorphic males.

Table A9. Isotopic niche overlap between each pair of alpine newt categories, based on SEA_C (Standard Ellipse Area corrected for sample size).

Ellipse 1	Ellipse 2	SEA _C 1	SEA _C 2	Overlap	Overlap ellipse 1 on 2	Overlap ellipse 2 on 1
P♀	P♂	0.770	0.786	0.117	15.2%	14.9%
P♀	M♀	0.770	1.361	0.129	16.7%	9.5%
P♀	M♂	0.770	1.631	0.049	6.4%	3.0%
P♂	M♀	0.786	1.361	0.582	74.1%	42.8%
P♂	M♂	0.786	1.631	0.391	49.7%	24%
M♀	M♂	1.361	1.631	1.126	82.8%	69.0%

SEA_C = Standard ellipse area corrected for sample size. P♀ = Paedomorphic females, P♂ = Paedomorphic males, M♀ = Metamorphic females, M♂ = Metamorphic males.

Table A10: PERMANOVA (Euclidean distances, 9999 permutations) on the isotopic composition of both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of newts, including newts' size (ln-transformed snout-vent length) as a covariate: effects of the covariate, phenotype (paedomorph vs metamorph), sex and their interaction. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ were ln-transformed prior to the analysis to reduce heteroscedasticity. Note that since all values of $\delta^{13}\text{C}$ were negative, the transformation was done on their absolute value.

	D.f.	SS	MS	Pseudo-F	P
Covariate: Size	1	0.08341	0.08341	4.1935	0.0354
Phenotype	1	0.27227	0.27227	13.688	0.0003
Sex	1	0.044098	0.044098	2.2171	0.1308
Phenotype x Sex	1	0.14189	0.14189	7.1334	0.0065
Residuals	73	1.452	0.01989		

D.f. = degrees of freedom, SS = sum of squares, MS = mean sum of squares, Pseudo-F = F value by permutation. Bold face indicates statistical significance ($P < 0.05$).

Table A11. Relative contribution of 4 food sources to the diet of the 4 alpine newt categories, presented as “mode (CI₉₅)”, from SIAR mixing model.

Food sources	P♀	P♂	M♀	M♂
Zooplankton	0.62 (0.43–0.82)	0.39 (0.20–0.60)	0.36 (0.21–0.58)	0.34 (0.17–0.61)
Pelagic invertebrates	0.19 (0.05–0.33)	0.35 (0.20–0.50)	0.28 (0.12–0.40)	0.26 (0.07–0.40)
Littoral taxa	0.16 (0.02–0.25)	0.18 (0.01–0.32)	0.28 (0.11–0.42)	0.33 (0.17–0.61)
Terrestrial insects	0.01 (0.00–0.10)	0.06 (0.00–0.15)	0.07 (0.00–0.16)	0.07 (0.00–0.17)

“Pelagic invertebrates” includes Chaoboridae pupae and fairy shrimps, “Littoral taxa” includes aquatic adults and larval Coleoptera; “Terrestrial insects” are prey that had fallen on water surface. P♀ = Paedomorphic females, P♂ = Paedomorphic males, M♀ = Metamorphic females, M♂ = Metamorphic males.

Table A12. Pairwise comparison of the contribution of 4 food sources to the isotopic composition of each pair of alpine newt categories, expressed as posterior probability values, calculated from the output data of SIAR mixing model (10^5 draws).

Test	Zooplankton	Pelagic invertebrates	Littoral taxa	Terrestrial insects
$P_{\text{♀}} > M_{\text{♀}}$	0.95557	0.23756	0.11646	0.19357
$P_{\text{♀}} > M_{\text{♂}}$	0.94942	0.33379	0.07971	0.21897
$P_{\text{♀}} > P_{\text{♂}}$	0.9435	0.06962	0.38959	0.24479
$P_{\text{♂}} > M_{\text{♀}}$	0.54529	0.79518	0.20882	0.44862
$P_{\text{♂}} > M_{\text{♂}}$	0.57576	0.83645	0.14912	0.47287
$M_{\text{♀}} > M_{\text{♂}}$	0.53063	0.58568	0.37477	0.52329

“Pelagic invertebrates” includes Chaoboridae pupae and fairy shrimps, “Littoral taxa” includes aquatic adults and larvae Coleoptera; “Terrestrial insects” are prey that had fallen on water surface. $P_{\text{♀}}$ = Paedomorphic females, $P_{\text{♂}}$ = Paedomorphic males, $M_{\text{♀}}$ = Metamorphic females, $M_{\text{♂}}$ = Metamorphic males.