The roles of plasticity versus dominance in maintaining polymorphism in mating strategies.

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Supplementary Results: Extinction probability and strategy extinction time in two phenotype populations

Simulations with populations initially composed of individuals presenting only two of the three alleles leads to the fixation of the strongest strategy in the RPS game context (i.e. P wins against M, M wins against S and S wins against P) (Figure S1).

Under the genetic dominance hypothesis, the loss of $m$ alleles is higher compared to other alleles and the $m$ allele persists roughly three times longer than the $s$ and $p$ alleles do (Table S1). This difference between the $m$ allele and the others alleles can be explained by the fact that in a polygynous/monogamous population, heterozygotes carry the $m$ allele but express the winning P phenotype whereas in the other heterozygous cases, individuals express the losing strategy (i.e. $ps$ and $ms$ individuals express respectively losing phenotypes P and S) increasing allele extinction speed.

Under the plasticity hypothesis, the trend is reversed and the $m$ allele disappears faster than the $p$ and $s$ alleles (Table S1). Loss times for $p$ and $s$ alleles were similar to $m$ under the genetic dominance assumption due to the ability of heterozygotes to express the winning strategy. As expected, extinction time of the $m$ allele decreased under the plasticity hypothesis because $pm$ individuals can adopt a strategy of low selective value. In addition, the losing M strategy can be sometime chosen whilst genetic dominance leads to the P strategy winning in all cases. However, this decrease may also be explained by the asymmetry of mating systems between polygynous and monogamous strategists. Such asymmetry may accelerate the extinction speed of $m$ allele compared to others.

Under the genetic dominance hypothesis, the heterozygote cost does not significantly change the probability or time before extinction of alleles (Table S1). Under the plasticity mechanism, the heterozygote cost only influences the extinction speed of the $p$ allele when P plays against S (Table S1). Under this hypothesis, $p$ and $m$ alleles have similar extinction patterns explained by the matting system asymmetry. Indeed, in these cases, $ps$ individuals have reduced harem size compared to $pp$ and $ss$ individuals.

Figure legends:

Figure S1: Under the RPS game assumptions, populations composed of only two phenotypes leads to the fixation of a single phenotype according to the RPS game rules. In this case, P wins against M, M wins against S and S wins against P. The graphs represents the number of time steps leading to the extinction of the losing strategy assuming allelic dominance $p>s>m$ (upper panels) and that heterozygotes express the best strategy (lower panels). From left to right, eviction time of $s$ allele when playing against M strategists, loss
time of \( m \) allele in a P/M population and eviction time of \( p \) allele when the P strategy is sneaked by S strategists.

**Figure S2:** Construction by multi-resolution analysis of the three strategy frequencies in the RPS game context at time scales for which we detected cyclical structures (4 time step to 32 time step scale). Paper strategy corresponds to the red lines, rock corresponds to the blue lines and scissors corresponds to the black lines. The pattern exhibited by strategy frequencies between 16 and 32 time steps scale is consistent with the pattern expected for an RPS game \(^2^4\). Structures exhibited at the 4 time step scale corresponding to density-dependence of population dynamics and the structures of the 8 time step time scale is a mixture of density-dependence and the RPS game.
Table and table legend:

**Table S1:** Under the RPS game assumptions, populations composed of only two phenotypes leads to the fixation of a single phenotype according to the RPS game rules. In this case, P wins against M, M wins against S and S wins against P. The Table reports the number of time steps before extinction of the disappearing strategy in a population with two phenotypes (i.e. extinction of \( p \) allele in a population of P and S strategists). Alleles are assumed to be carried by a single locus and \( p > s > m \).

| model hypothesis | genetic dominance | plasticity |
|------------------|-------------------|------------|
|                  | \( p \) | \( m \) | \( s \) | \( p \) | \( m \) | \( s \) |
| mean extinction  | 27   | 130.4 | 34.9 | 157.7 | 69.7 | 154.5 |
| SE extinction time | 1.8 | 11.6  | 2.5 | 10.8  | 5.2  | 12.1  |
| heterozygosity cost | mean extinction | 27.3 | 127.2 | 32.5 | 79.9 | 70.3 | 152.3 |
|                  | SE extinction time | 1.9 | 11.4  | 2.3 | 5.2  | 5.5  | 12.5  |
Figure S1: Extinction time of allele $s$, Extinction time of allele $m$, Extinction time of allele $p$. Allelic Dominance ($p > m > s$) and Phenotypic plasticity.
Figure S2:
Supplementary Method: Elements of time series analysis using continuous wavelet

The goal of this supplement is to explain the major concepts underlying wavelet and multi-resolution analysis rather than all the mathematics and statistics which are well established see 5-10. In essence, we provide a mini-primer on these analyses which are less familiar to evolutionary ecologists.

Wavelet and single signal multi-resolution analyses

Here we examine wavelet analysis and multi-resolution signature of a simple sinusoidal function. We built three simple sinusoidal functions (f1, f2 and f3) made of 10400 points. Function f1 (equation S1) presents an abrupt change in oscillation frequency, f2 (equation S2) is composed of two sinusoidal functions of different amplitude and period and f3 (equation S3) presents a slow-down in its oscillations (Figure S3):

\[
\begin{align*}
    f_1(t) &= A_1 \sin \left( \frac{2\pi t}{p_1} \right) & \text{if } t < t_t \\
    f_1(t) &= A_1 \sin \left( \frac{2\pi t}{p_2} \right) & \text{if } t \geq t_t
\end{align*}
\]  

(equation S1)

\[
f_2(t) = A_1 \sin \left( \frac{2\pi t}{p_1} \right) + A_2 \sin \left( \frac{2\pi t}{p_2} \right)
\]

(equation S2)

\[
\begin{align*}
    f_3(t) &= A_1 \sin \left( \frac{2\pi t}{p_1} \right) & \text{if } t < t_t \\
    f_3(t) &= A_1 \sin \left( \frac{2\pi t}{p(t)} \right) & \text{if } t \geq t_t
\end{align*}
\]  

(equation S3)

Where \( A_1=2, A_2=1, p_1=\pi/60, p_2=\pi/12, t_t=5000 \) and \( p(t) = p_1 + (p_2 - p_1) \left( \frac{t-t_{\text{min}}}{b_t} \right) \) with \( a=0.9 \) and \( b=0.2 \).

We then perform a wavelet analysis using the "Morlet" wavelet 11 and a multi-resolution analysis on the modeled signals (Figure S3). The wavelet analysis determines the temporal localization of information carried by the signal. This analysis detects when information 12 is present and how this information "travels" across temporal scales 5-11. Multi-resolution analyses then assumes that the global signal is the result of the addition of the signal carried by the different temporal scales and separates the global signal into its different components 6,7.

Figure A1 shows the wavelet and the multi-resolution signatures of the three functions:
The wavelet power spectrum shows that a high power spectrum (in dark red) is moving-down from low frequency oscillations (period ≈ 20 temporal unit or t.u.) to medium frequency oscillations (period ≈ 8 t.u.). The multi-resolution analysis shows that the signal is composed of a single signal at period = 16 t.u. until t = 5000 t.u. where it switches to another single signal at period = 8 t.u.

The wavelet power spectrum shows that high power of spectrum is carried by two different temporal scales (period ≈ 20 t.u. and period ≈ 8 t.u.) all along the signal. The multi-resolution analysis shows that the signal is composed of a mixture of two signals with at period = 16 t.u. and period = 8 t.u.

The wavelet power spectrum shows that a high power spectrum is located around the 8 t.u. time scale until the signal shows an amplified oscillation. Then the high power spectra moves-up to lower frequencies of oscillations. The multi-resolution analysis shows that the signal is initially composed of a single signals at period = 8 t.u.. Then, the global signal becomes a combination of signals from period = 4 and sliding to 16.
Multiple signal analyses

In this section, the main idea is to determine if a signal \( S_1 \) influences another signal \( S_2 \) and if so, to determine the temporal scale of this influence. The cross-correlation function between \( S_1 \) and \( S_2 \) allows us to determine if a causal relation exists between \( S_1 \) and \( S_2 \) see [6] for details. If no causal relation exists, the cross-correlation function is symmetrical whereas it is asymmetrical if a causal relationship exists. When the function is asymmetrical, if both the signals are in phase, the function is centered on 0, otherwise the function is centered on the phase difference. The direction of the deviation from 0 reflects the direction of the relationship. If \( S_1 \) is positive and induces a positive response of \( S_2 \), the deviation will be also positive. Finally, the cross-correlation function presents at the same time the effect of \( S_1 \) on \( S_2 \) (x>0) and the feed-back effects of \( S_2 \) on \( S_1 \) (x<0) [6].

With complex signals, it can be interesting to identify the time scale at which one signal, \( S_1 \) or its components influences \( S_2 \) (Figure S4). We have seen before that multi-resolution tools can split the signal into its different components and we are able to perform correlations between \( S_1 \) or its components and \( S_2 \)'s components to detect the time scale of interactions between \( S_1 \) (or its components) and \( S_2 \) (or its components). The intensity of these correlations corresponds to the intensity of the transfer of information from \( S_1 \) to \( S_2 \) [6].

Figure A3, shows the combined used of the previously described statistical technics on our simulation results.

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Figure legends:

**Figure S3:** Wavelet analyses and multi-resolution analyses of three simple sinusoidal functions (left panels) with an abrupt change in oscillation period ($f_1$), a function ($f_2$) composed of two sinusoidal functions and a function ($f_3$) beginning regularly and at mid-time accelerating and then slowing-down. Central panels are the wavelet power spectra of the different signals and represent the specific signature (see text). The multi-resolution (right panels) presents the specific signatures of the different functions in a discrete environment. Signals are split into time scale specific sub-signals. For readability, only temporal windows between 4000 t.u. and 6000 t.u., temporal components of oscillations between 4 t.u. and 32 t.u. are represented and the multi-resolution analysis have been normalized.

**Figure S4:** Correlation between a signal $S_1$ and the components of a signal $S_2$. $S_1$ is the frequency of the M strategy and $S_2$ is the frequency of P strategy under the genetic dominance mechanism without cost of heterozygosity and both the sexes exhibiting alternative reproductive strategy. The maximum of information transfer from $S_1$ to $S_2$ occurs at the 32 time steps scale and corresponds to the maximum correlation between $S_1$ and each components of $S_2$.

**Figure S5:** Wavelet ("Morlet" wavelet) and multi-resolution analyses of strategy frequencies dynamics. From top to bottom, results are provided for focal time series of respectively Paper, Rock and Scissors strategy frequency dynamics. The time series are outputs from a simulation with allelic dominance and where heterozygosity is not costly. Left panels correspond to the correlation between the non focal time series of strategy frequencies and the multi-resolution decomposition of the focal time series. Dark blue, black and red lines represent the effect of each of the two non-focal time series on the component of the focal time series listed on the left of the graph and grey, orange and light blue lines are the effects of the focal time series on each of the non-focal time series. Non-focal time series are red, blue or black for Paper, Rock and Scissors strategy frequency dynamics respectively and are orange, light blue and grey respectively when considering the effect of focal time series on non-focal time series. Central panels are the power spectra analysis of the strategy frequencies. The colors code for power values from relative low values (dark blue) to relative high values (dark red). The nature (period, stationarity) of the cycles detected
in the time series are determined using their specific signatures of alternation between red and blue regions. Right panels are the multi-resolution decomposition of the strategy frequencies which correspond to the time series decomposition at each time scale. The analyzed time series is the sum of the multi-resolution decomposition.

Figures:

**Figure S3**
Time serie

Scalogramm of the power spectra

Multi-resolution decomposition
Figure S4:

Figure S5:
Correlations between pairs of strategy frequency time series

Scalogramm of the power spectra of the focal strategy frequency time series

Multi-resolution decomposition of the focal strategy frequency time series

Polygynous

Monogamous

Sneaker
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