Derivation of condition (3)

The generalized predator-dependent predator-prey system of equations including prey harvesting is described by equation (2). For the coexistence equilibrium we need to solve for $\frac{\mathrm{d}x}{\mathrm{d}t} = 0$ and $\frac{\mathrm{d}y}{\mathrm{d}t} = 0$ (i.e., find the values of x and y for which the populations do not increase or decrease).
Setting:

$$\begin{aligned}
&\frac{\mathrm{d}y}{\mathrm{d}t} = 0 \\
&\frac{c\alpha xy}{y^m + \alpha hx} - dy = 0
\end{aligned}$$

We are looking for the coexistence equilibrium, therefore we know that $y \neq 0$ and $x \neq 0$.

$$\begin{aligned}
&c\alpha x - d(y^m + \alpha hx) = 0 \\
&c\alpha x - dy^m + d\alpha hx = 0 \\
&\alpha x(c - dh) - dy^m = 0
\end{aligned}$$

$$x^* = \frac{dy^m}{\alpha(c - dh)} \tag{1}$$

Equation 1 describes the predator zero-isocline and it is positive if and only if

$$c > dh$$

This is a necessary condition for the co-existence equilibrium to exist.

Derivation of prey isocline

Setting:

$$\begin{aligned}
&\frac{\mathrm{d}x}{\mathrm{d}t} = 0 \\
&bx\left(1 - \frac{x}{K}\right) - \frac{\alpha xy}{y^m + \alpha hx} - zx = 0 \\
&b\left(1 - \frac{x}{K}\right)(y^m + \alpha hx) - \alpha y - z(y^m + \alpha hx) = 0 \\
&\left[b\left(1 - \frac{x}{K}\right) - z\right](y^m + \alpha hx) - \alpha y = 0 \\
&y^m(b - z) - \frac{y^m bx}{K} + \alpha hx(b - z) - \frac{\alpha hbx^2}{K} - \alpha y = 0 \\
&-\frac{\alpha hbx^2}{K} + x\left(\alpha h(b - z) - \frac{y^m b}{K}\right) + y^m(b - z) - \alpha y = 0
\end{aligned}$$

Solving for x^* using the quadratic formula:

$$
\begin{aligned}
x^* &= \frac{\frac{y^m b}{K} - \alpha h(b-z) \pm \sqrt{\left(\alpha h(b-z) - \frac{y^m b}{K}\right)^2 + 4\frac{\alpha h b}{K}(y^m(b-z) - \alpha y)}}{-2\frac{\alpha h b}{K}} \\
&= \frac{K(b-z)}{2b} - \frac{y^m}{2\alpha h} \pm \\
&\pm \frac{K}{2\alpha h b}\sqrt{\alpha^2 h^2 (b-z)^2 - 2\alpha h(b-z)\frac{y^m b}{K} + \left(\frac{y^m b}{K}\right)^2 + \frac{4\alpha h b y^m (b-z)}{K} - \frac{4\alpha^2 h b y}{K}} \\
&= \frac{K(b-z)}{2b} - \frac{y^m}{2\alpha h} \pm \frac{K}{2\alpha h b}\sqrt{\alpha^2 h^2 (b-z)^2 + \frac{2\alpha h(b-z) y^m b}{K} + \left(\frac{y^m b}{K}\right)^2 - \frac{4\alpha^2 h b y}{K}} \\
&= \frac{K(b-z)}{2b} - \frac{y^m}{2\alpha h} \pm \frac{K}{2\alpha h b}\sqrt{\left(\alpha h(b-z) + \frac{y^m b}{K}\right)^2 - \frac{4\alpha^2 h b y}{K}}
\end{aligned}
$$

This follows the same form as the prey isocline equation for an unharvested system, as derived by [23], with the only difference of factor b in the first fraction and under the square root being $b - z$ in this case. Based on this, we propose that at any given time t the stability inequality takes the form:

$$\alpha(hK)^{1-m} < (b-z)^m$$

This implies that if this condition holds for an unharvested system making the system stable, harvest z at time t can push the system to instability. It is also worth noting that no trivial criterion can determine whether the expression at the square root becomes negative [23].

Figure S1

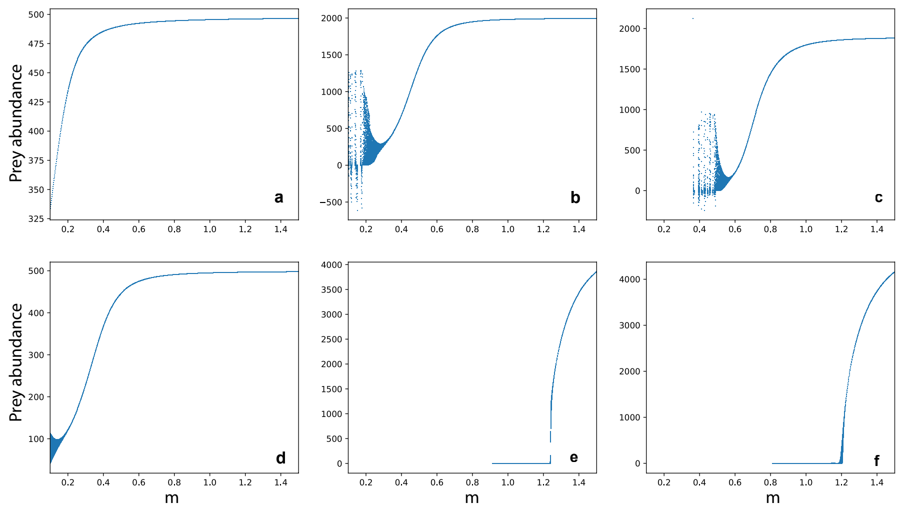

Figure 1: **Bifurcation diagrams for systems presented in Fig. 1., with regards to predator interference parameter m.** (a) Prey-dependent system with a global attractor stable equilibrium ($\alpha = 0.005, b = 0.5, c = 0.5, d = 0.5, h = 0.1, K = 500, m = 0$), with initial conditions prey=600 and predator=200; (b) Predator-dependent system with a global attractor stable equilibrium ($\alpha = 0.005$, $b = 0.5$, $c = 0.5$, $d = 0.1$, $h = 0.1$, $K = 2000$, $m = 0.7$), with initial conditions prey=3000 and predator=200; (c) Predator-dependent system with unstable equilibrium and limit cycles as the global attractor ($\alpha = 0.047$, $b = 0.877$, $c = 0.666$, $d = 0.094$, $h = 0.306$, $K = 1893.72$, $m = 0.465$), with initial conditions prey=600 and predator=600; (d) Prey-dependent system with unstable equilibrium and limit cycles as the global attractor ($\alpha = 0.005$, $b = 0.5$, $c = 0.5$, $d = 0.1$, $h = 0.1$, $K = 2000$, $m = 0$), with initial conditions prey=500 and predator=200; (e) Predator-dependent system with unstable equilibrium and deterministic extinction ($\alpha = 1.775$, $b = 0.389$, $c = 0.441$, $d = 0.083$, $h = 0.941$, $K = 4465.07$, $m = 0.107$), with initial conditions prey=500 and predator=500; (f) Predator-dependent system with two equilibria and no global attractor ($\alpha = 0.796$, $b = 0.215$, $c = 0.565$, $d = 0.137$, $h = 0.472$, $K = 4858.48$, $m = 1.21$), with initial conditions prey=2000 and predator=1000. All diagrams show 100 iterations of system dynamics, after skipping the first 100 iterations. All systems assume no process noise. Periodic behavior can be seen

Figure S2

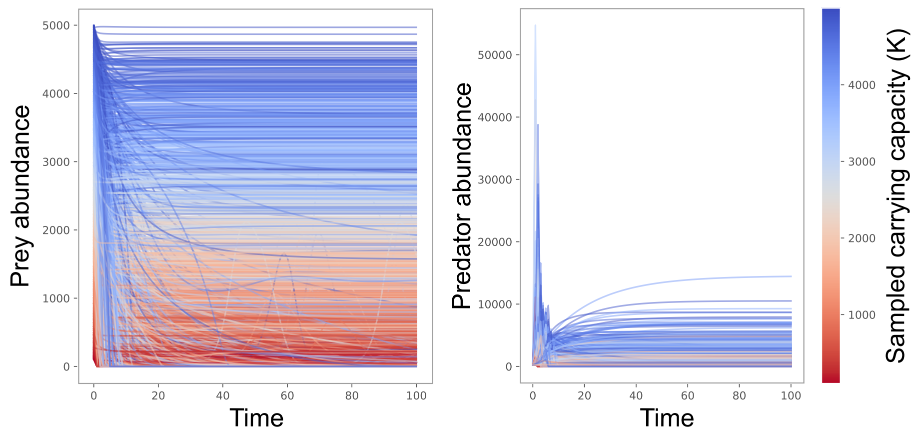

Figure 2: **Population trajectories for prey and predator populations under all sampled SOWs.** The color of each trajectory corresponds to the sampled value of carrying capacity (K) for that SOW. All trajectories assume no harvest in order to illustrate dynamics without human action.

Figure S3

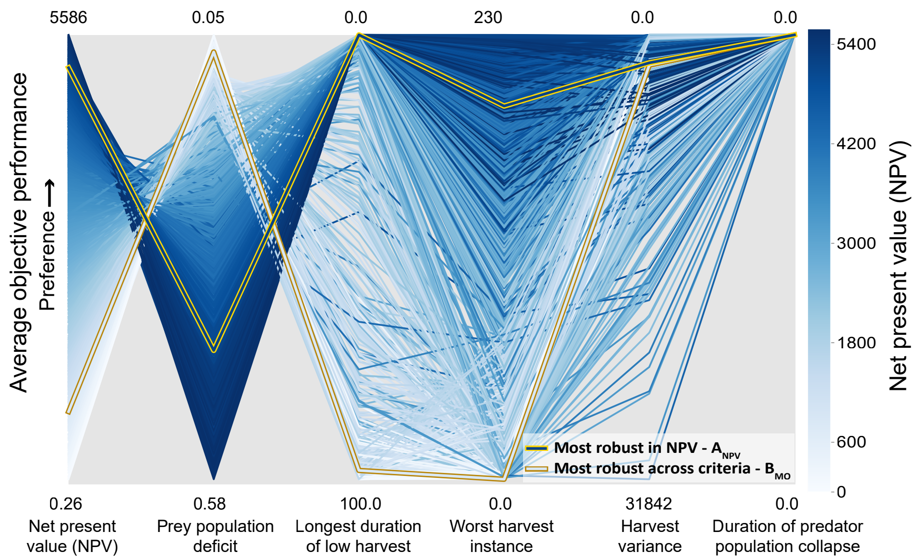

Figure 3: **Parallel axis plot of the objective values achieved by each optimized solution in the assumed SOW** Replicate of Fig. 2, with two highlighted solutions. The two highlighted solutions, A_{NPV} and B_{MO}, were identified using two robustness definitions, meeting criterion 1 and meeting all criteria, respectively.