Heroin Model Summary

Original

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\begin{aligned}
\frac{dS}{dt} &= \beta E - \alpha S - \underbrace{S(\sigma + \xi(I+H))}_{\text{to resistant}} - \underbrace{S(\delta_1 E + \delta_2 I)}_{\text{to opioid addiction}} - \underbrace{S(\mu_1 + \mu_2 H)}_{\text{to heroin addiction}} \\
&\quad + d_I I + d_H H + d_r R + d_e E \\
\frac{dE}{dt} &= -\beta E + \alpha S - \underbrace{E(\sigma + \xi(I+H))}_{\text{to resistant}} - \underbrace{E(\mu_1 + \mu_2 H)}_{\text{to heroin addiction}} - \underbrace{\epsilon E}_{\text{to I}} - d_e E \\
\frac{dI}{dt} &= \underbrace{\epsilon E}_{\text{from E}} + \underbrace{S(\delta_1 E + \delta_2 I)}_{\text{from S}} - \underbrace{\gamma(H) I}_{\text{to H}} - \underbrace{iI}_{\text{to R}} - d_I I \\
\frac{dH}{dt} &= \underbrace{\gamma(H) I}_{\text{from I}} + \underbrace{(S+E)(\mu_1 + \mu_2 H)}_{\text{from S and E}} - \underbrace{hH}_{\text{to R}} - d_H H \\
\frac{dR}{dt} &= \underbrace{(S+E)(\sigma + \xi(I+H))}_{\text{from S and E}} + \underbrace{iI}_{\text{from I}} + \underbrace{hH}_{\text{from H}} - d_r R \\
\gamma(H) &= \gamma_0(\mu_1 + \mu_2 H)
\end{aligned}
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We assume that $0 \leq \delta_1 \leq \delta_2 \leq 1$, $\mu_1 < \mu_2$, and d_r includes both natural death and backsliding from drug resistant to susceptible.

I and H feeds S

$$
\begin{aligned}
\frac{dS}{dt} &= \beta E - \alpha S - \underbrace{S(\sigma + \xi(I+H))}_{\text{to resistant}} - \underbrace{S(\delta_1 E + \delta_2 I)}_{\text{to opioid addiction}} - \underbrace{S(\mu_1 + \mu_2 H)}_{\text{to heroin addiction}} \\
&\quad + \underbrace{iI}_{\text{from I}} + \underbrace{hH}_{\text{from H}} + d_I I + d_H H + d_r R + d_e E \\
\frac{dE}{dt} &= -\beta E + \alpha S - \underbrace{E(\sigma + \xi(I+H))}_{\text{to resistant}} - \underbrace{E(\mu_1 + \mu_2 H)}_{\text{to heroin addiction}} - \underbrace{\epsilon E}_{\text{to I}} - d_e E \\
\frac{dI}{dt} &= \underbrace{\epsilon E}_{\text{from E}} + \underbrace{S(\delta_1 E + \delta_2 I)}_{\text{from S}} - \underbrace{\gamma(H) I}_{\text{to H}} - \underbrace{(i + d_I) I}_{\text{to S, rec. \& death}} \\
\frac{dH}{dt} &= \underbrace{\gamma(H) I}_{\text{from I}} + \underbrace{(S+E)(\mu_1 + \mu_2 H)}_{\text{from S and E}} - \underbrace{(h + d_H) H}_{\text{to S, rec. \& death}} \\
\frac{dR}{dt} &= \underbrace{(S+E)(\sigma + \xi(I+H))}_{\text{from S and E}} - d_r R \\
\gamma(H) &= \gamma_0(\mu_1 + \mu_2 H)
\end{aligned}
$$

No R

$$
\begin{aligned}
\frac{dS}{dt} &= \beta E - \alpha S - \underbrace{S(\delta_1 E + \delta_2 I)}_{\text{to opioid addiction}} - \underbrace{S(\mu_1 + \mu_2 H)}_{\text{to heroin addiction}} + \underbrace{iI}_{\text{from I}} + \underbrace{hH}_{\text{from H}} + d_I I + d_H H + d_e E \\
\frac{dE}{dt} &= -\beta E + \alpha S - \underbrace{E(\mu_1 + \mu_2 H)}_{\text{to heroin addiction}} - \underbrace{\epsilon E}_{\text{to I}} - d_e E \\
\frac{dI}{dt} &= \underbrace{\epsilon E}_{\text{from E}} + \underbrace{S(\delta_1 E + \delta_2 I)}_{\text{from S}} - \underbrace{\gamma(H) I}_{\text{to H}} - \underbrace{(i + d_I) I}_{\text{to S, rec. \& death}} \\
\frac{dH}{dt} &= \underbrace{\gamma(H) I}_{\text{from I}} + \underbrace{(S+E)(\mu_1 + \mu_2 H)}_{\text{from S and E}} - \underbrace{(h + d_H) H}_{\text{to S, rec. \& death}} \\
\gamma(H) &= \gamma_0(\mu_1 + \mu_2 H)
\end{aligned}
$$