Minisymposium: Bifurcation theory and applications in biological systems

Smoking eradication via tipping points in an eco-epidemiological model

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Worldwide smoking is perceived as a major epidemic. This century the mortality from smoking is estimated to be one billion people, while health care costs associated with smoking are estimated at around 6-15% of the total health care costs. Models used to study the effects of smoking in relation to societal costs are typically Markov models that ignore population dynamics. However, it seems prudent to study the epidemiological dynamics of smoking in relation to human ecological dynamics for two reasons:

1. The effects of smoking occur on a timescale of decades;

2. The human population has grown, and continues to grow, on this same timescale.

We therefore propose an eco-epidemiological model, which includes both ecological and epidemiological processes [1]. The human population is divided into three classes: non-smokers, smokers, and ex-smokers. Human population growth is explicitly modelled via resource dynamics, and the model includes a time-dependent term for mass closure. The parameters that describe epidemiological processes, like the "infection" rate of non-smokers by smokers, the abstinence rate of smokers, and the relapse rate of ex-smokers, are time-dependently scaled.

The model has been parameterized for the Dutch population between 1900 and 2010, for which there is data freely available [2]. Bifurcation analysis has been used to evaluate model behaviour. The rate of infection of non-smokers and the relapse rate of ex-smokers can be influenced by policy and health care. A bifurcation plot of these two parameters reveals three parameter regions, separated by bifurcation curves:

1. A region in which the only stable steady state includes smokers, suggesting that attempts to eradicate smoking under these conditions are futile;

2. A region in which the only stable state is smoker-free. Smoking eradication will eventually happen, but efforts to reduce parameters to such values may be unattainable;

3. An intermediate region with both the smoker-endemic and the smoker-free steady states, i.e., bi-stability. A significant effort to reduce smoking may result here in the crossing of a 'tipping point', leading to smoking eradiction.

References

[1] Van Voorn, G.A.K., B.W. Kooi (2013). Smoking epidemic eradication in a eco-epidemiological model. *Ecological Complexity* 14:180-189.

[2] StatLine, the electronic database of the CBS (Central Bureau for Statistics in the Netherlands), Den Haag/Heerlen. http://www.cbs.nl/en-GB, retrieved May 16, 2012.