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Abstract The text of your abstract. 150 – 250 words.

Keywords key · dictionary · word ·

Mathematics Subject Classification (2000) MSC code 1 · MSC code 2 ·

1 Introduction

Your text comes here. Separate text sections with [1].

2 Background

In this section we first review two well-established techniques commonly used in sustainable fishery management. These are the maximum sustainable yield (MSY) and the constant escapement (CE) approaches. After this, deep reinforcement learning is briefly reviewed

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2.1 Fishery management

2.2 Deep reinforcement learning

3 Dynamical models used

In this section we present three models of increasing complexity which plausibly describe the population dynamics of a marine ecosystem. These models will form the test beds for the comparison between classical fishery management strategies and DRL.

3.1 A one-dimensional tipping point model.

Consider a population V whose dynamics is given by

$$\frac{\mathrm{d}V}{\mathrm{d}t} = rV\left(1 - V/K\right) - \frac{\beta H V^2}{V_0^2 + V^2}. \tag{1}$$

This model has been used in [2] to describe a grazing ecosystem, where a species V of vegetation is harvested by a constant herbivore population H.

In (1), a population V grows logistically with rate r up to carrying capacity K. This is expressed by the first term in the equation,

$$L(V \mid r,\ K) := rV\left(1 - V/K\right).$$

Moreover, V is predated on by a (constant) population H, as can be seen from the negative term

$$F(V,\ H \mid \beta,\ V_0) := \frac{\beta H V^2}{V_0^2 + V^2}$$

which saturates to βH as $V \to \infty$, and whose half maximum is V_0, i.e. $F(V = V_0,\ H; \beta,\ V_0) = \beta H/2$.

Ref. [2] studies the fixed points of (1) in order to show that in certain parameter regimes, its dynamics can undergo a *catastrophe*. A catastrophe is a sudden change in the state of the system from one stable state to another—often, the final state is ecologically detrimental, possibly associated with extinction or near-extinction events.

Fig. **??** shows the stable V populations for differing values of H. Here one sees that as $H \to T_2$, the top stable state is annihilated with the unstable fixed point. A possible situation of concern here is the following: The system begins in the high stable point for some $H < T_2$. Slowly, H slowly drifts upward, bringing the system up to $H = T_2$. At this point, the system suddenly finds itself in the lower stable point's "basin"—this leads to a quick collapse of V down to the stable point. Along a similar vein, if the system's evolution is noisy, then this catastrophe may happen for lower H values: for H close enough to T_2, there is a large probability that the V crosses the unstable state and collapses towards the lower stable state. **[FMM: Maybe this can be explained in the figure better?]**

This way, if, e.g. the system is at the high stable state for low H, and H were to slowly drift until $H = T_2$, the system would collapse to the low stable state, leading to a near extinction of V.

System (1) *as a simple fishery model.* We reinterpret the model (1) as a simplified model for a fishery. There is some precedent for this already in [2], however our approach here is not in 1-to-1 correspondence to the approach used in that reference. **[FMM: Refers to the fact that in the reference $F(\,\cdot\,)$ is our harvest quota, using constant effort. But here, it is a predation term, we compete with the predator in this case.]**

We use this

4 Results

5 Discussion

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$$a^2 + b^2 = c^2 \tag{2}$$

References

1. R. Mislevy, in *Educational Assessment*, ed. by R.L. Brennan (American Council on Education and Praeger Publishers, 2006), chap. 8
2. R.M. May, Thresholds and breakpoints in ecosystems with a multiplicity of stable states, Nature **269**(5628), 471 (1977)