INTRODUCTION

In this concept poster we investigate the dynamics that determine the sustainability of social-ecological systems. We ask: Under what conditions do human societies evolve to appropriate more productivity from ecosystems, and why might such an evolutionary trajectory make socialecological systems (SES) vulnerable to crossing critical thresholds and sudden reorganization?

HYPOTHESIS & PREDICTIONS

1. The substantial declines in radiocarbon dates that we observe in all of our case studies take place during a period of increased variability in the climate.

2. SES lose diversity in the realm of food production while populations grow and appropriate more ecosystem productivity between 2000 and 800 BP in N. America and 2000 and 600 BP in S. America.

RESULTS

• The major decline in radiocarbon date frequencies occurs during the transition between the Medieval Warm Period and the Little Ice Age. In N. America, the drop begins around 1000 Cal. BP and accelerates after 800 BP. In the S. America, the drop in radiocarbon date frequencies occurs between 650 and 500 Cal. BP.

• In general, we observe a decline in subsistence diversity coincident with increasing energy consumption prior to the sharp decline in radiocarbon date frequencies.

Policies 2K

• A key challenge to designing sustainable SES is to understand the conditions under which human societies evolve to appropriate more productivity from ecosystems and how and why such an evolutionary trajectory might make SES vulnerable to crossing critical thresholds.

• We propose the creation of PEOPLE 2K, a research network to study trade-offs inherent to the climate-human population-institutional adaptation dynamics, and to describe threshold changes in social-ecological systems (SES) over the last 2000 years.

Figure 1: One way to observe the appropriation of energy by humans and sudden reorganization is by examining the frequencies of radiocarbon dates in large samples of dated trash (summed probability distributions). We explore why dates decline (signaling SES reorganization) between 800 and 600 Cal. BP. In each case there is an exponential increase in radiocarbon date frequencies associated with human activity between 2000 and 800 Cal. BP. In each case, there is a collapse in the SPD time-series. In N. America the collapse occurs about 800-700 Cal. BP, in the S. American cases it occurs about 600-500 Cal. BP. Why do all of these cases experience near simultaneous declines?

Figure 2: Bifurcation plot from a sustainable harvestor model [1]. As population density increases, individuals appropriate more biomass (high productivity branch). This makes the system vulnerable to a flip into a ‘poverty trap’. Individuals specialize to make their diet robust to population, but the whole system becomes vulnerable to increases in climate variation.

Hypothesis: Increases in the energy consumption of an economy, along with a strong shift in climate variability, make systems vulnerable to sudden reorganization. We predict:

Figure 3: Time-series of temperature anomalies from [2; Figure 1]. Note that between 1250 and 1400 (850-600 Cal. BP) there is an increase in variation in the climate signals. This increase in variation is particularly noticeable in the El Niño signal. This is consistent with the proposition that increased variation in the climate may have played a role in the reorganization seen in our case studies.

Figure 4: CW Argentina case study. Volatility Index (rolling standard deviation) for a time-series of human bone isotopes in CW Argentina; (a) volatility in 13C collagen over time and (b) volatility in 15N collagen over time. The red line marks the collapse in the CW Argentina SPD curve. In each graph, the standard deviation in 13C and 15N isotope values decline from 1000 to 1400 CE (1000-600 Cal. BP)

Figure 5: SW Wyoming case study. The rolling mean (a) and volatility index (b) of artiodactyl/lagomorphs declines after 2000 because there is a more specialized use of lagomorphs, and then increases during the time period that radiocarbon dates decline.

Figure 6: E. Utah case study. Agricultural component index (magenta curve) and summed probability distribution of radiocarbon dates (black curve & blue best-fit line) on the y-axis, and calibrated radiocarbon years BP on the x-axis. The Agricultural index is the summed probability of dates on agg. components (the summed probability of all dates + summed probability of dates on agg components). Agricultural component index of 0, people are specialized in hunting and gathering; at about 0.7 people are specialized in agriculture. In general, as the SPD increases, people in E. Utah became more specialized in agriculture at the expense of hunting and gathering. Specialization decreases between 1200 and 800 BP, but there is still more specialization than at 2000 BP.

These results are suggestive, but we need more work to synthesize data on changes in ecosystem diversity, social diversity and local paleoclimate.