Methods for the simulations of coral cover

We used simulations to illustrate our method of using scaled coral cover (i.e., the z-score) and the temporal variability in coral cover to designate different types of oases. Based on our understanding of reef trajectories over the past half-century, we identified four relevant scenarios – stable cover, phase shift, linear trends and non-linear oscillation.

For a reef exhibiting stable coral cover at a given time (y):

with an intercept (*b*) and random variation (*w*). In a phase shift, we selected a new intercept (*bpost*) and variation (*wpost*) at a year selected randomly between year 10 and year 30 to simulate a new coral cover (*ypre*):

For a reef exhibiting a linear trend in coral cover, we selected randomly the slope (*m*):

Finally, we used a cosine curve to simulate oscillations over time:

with an amplitude (*a*) and phase shift (*c*). Pseudocode is provided in the Appendix, and the R scripts are archived in a digital repository (<https://github.com/jrguest/Powell_Reef_Oasis/blob/master/scripts/elahi/coral_sims/0_sim_functions.R>). We simulated 100 time-series for each scenario. We then calculated the median z-scores of coral cover for each simulation (i.e., site), as well as its temporal variability (coefficient of variation).

Pseudocode

**Stable**

1. Select starting coral cover (cc), using a coin flip to decide between one of the two following options:
   1. Sample from a normal distribution, with a mean of 40 and a standard deviation of 5
   2. Sample from a uniform distribution between 40 and 5
2. Select the standard deviation of the coral cover (cc\_sd)
   1. Sample from a normal distribution, with a mean of 0.1\*cc and standard deviation of 0.5
   2. If the resulting standard deviation is below 0.1, set it at 0.1
3. Get the time series
   1. Sample each time point from a normal distribution, with a mean of cc and standard deviation of cc\_sd

**Phase shift**

1. Same as above
2. Same as above
3. Select when the phase shift begins
   1. Sample from a uniform distribution between year 10 and year 30
   2. Round down to the nearest integer
4. Select the new starting coral cover (cc\_new),
   1. Sample from a uniform distribution between 0.5\*cc and 1
5. Select the standard deviation of the coral cover (cc\_sd\_new)
   1. Sample from a normal distribution, with a mean of cc\_sd and standard deviation of 0.1
   2. If the resulting standard deviation is below 0.1, set it at 0.1
6. Get the new time series after the phase shift
   1. Sample each time point from a normal distribution, with a mean of cc\_new and standard deviation of cc\_sd\_new

**Linear trend**

1. Same as above (starting coral cover is used as the intercept in a linear model)
2. Same as above
3. Get the linear trend
   1. Sample from a normal distribution with mean of -0.5 and a standard deviation of 0.25
4. Get random variation (w) around the trend for each time point
   1. Sample from a normal distribution with a mean of 0 and a standard deviation of cc\_sd
5. Get the time series
   1. Cover ~ slope \* year + intercept + w

**Oscillations**

1. Same as above, but using an initial starting value of 30 for coral cover
2. Same as above
3. No linear trend
4. Get random variation (w) for each time point
   1. Sample from a normal distribution with a mean of 0 and a standard deviation of cc\_sd
5. Get the phase shift (phase\_shift)
   1. Sample the offset from a normal distribution of with a mean of 0 and a standard deviation of 0.25; multiply this value by pi (if phase shift is 0 then the cosine curve starts at the chosen amplitude)
6. Get the amplitude (amp)
   1. Sample from a normal distribution with a mean of 15 and a standard deviation of 7.5
7. Get the period
   1. Sample from a normal distribution with a mean of 40 and a standard deviation of 5 (a period of 30 for a 30 year time series results in a half-cycle, i.e., a ‘U’)
8. Get the time series
   1. Cover ~ amplitude \* cos(period\*year + phase\_shift)
   2. In code:
      1. cs = amp \* cos(2 \* pi \* 1/year/period + phase\_shift)

