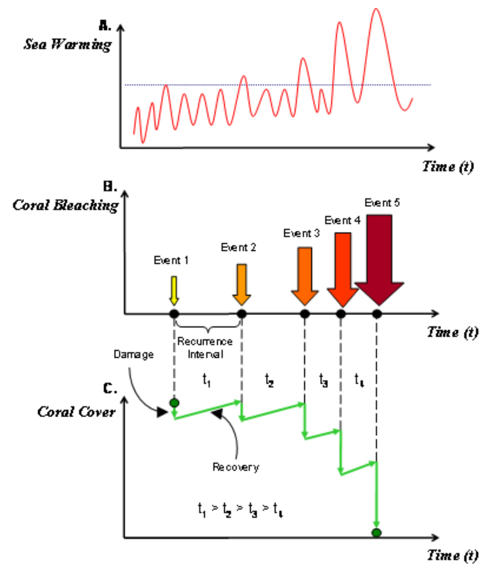
1) Corals are adapted to relatively constant temperature, salinity, nutrient, and oxygenation regimes. They are very sensitive to warming events and are known to eject their symbiotic zooxanthellae when temperatures are too high, leading to a phenomenon known as coral bleaching. If temperatures cool again, the corals can recover, the zooxanthellae will re-enter the corals and the ecosystem will recuperate. However, as the graph on the right shows, when these warming events become too frequent, there is not time for the community to recovery between disturbances and the community will continue to decline and eventually die. To understand how populations of corals will fare in the future, under a warmer climate, Riegl & Purkis conducted a study in the Arabian/Persian Gulf where warming is already frequent and severe. They conducted phototransect surveys of several coral communities both before and after a major disturbance event. From their images they classified the corals into 4 size classes SC1 = <5cm, SC2 = 5 – 10 cm, SC3 = 10 – 20 cm, SC4 = >20 cm. From this data they constructed a transition matrix (similar to the population matrices we've discussed before), although it is important to keep in mind that unlike most of the organisms we've discussed, corals can both grow and shrink. They found that before disturbance, one of the species (*Dipsastrea pallida*) had the following statistics:



- SC1 colonies had an 86% chance of remaining SC1 and a 13% chance of becoming SC2.
- SC2 colonies had a 44% chance of shrinking to SC1, a 42% chance of remaining SC2, and a 14% chance of becoming SC3.
- SC3 colonies had a 44% chance of shrinking to SC1, a 31% chance of shrinking to SC2, a 14% chance of remaining SC3 and an 11% chance of growing to SC4.
- All SC4 colonies shrank to SC1.

After the disturbance:

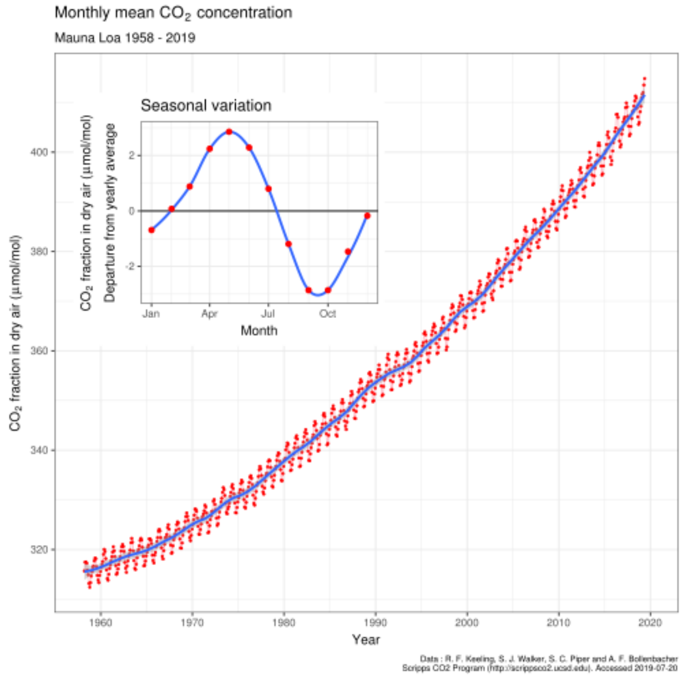
- SC1 colonies had a 95% chance of remaining SC1 and a 4% chance of becoming SC2
- SC2 colonies had a 49% chance of shrinking to SC1, a 44% chance of remaining SC2, and a 6% chance of growing to SC1.
- All SC3 colonies shrank to SC1
- All SC4 colonies shrank to SC1

A) Please construct the transition matrices (population matrices) for this species before and after the disturbance.

B) Please determine the steady-state size distributions and long-term population growth rates before and after the disturbance

C) What does this tell you about the long-term viability of the ecosystem?

2) The Keeling Curve shown on the right plots measured changes in carbon dioxide in the atmosphere.



a)If we want to discover the sources and sinks for carbon dioxide, one of the first steps is to figure out how rapidly it is changing at different times of the year, so please compute the rate of change of CO_2 in the atmosphere (you will need to start by writing a function for CO_2 like in the last problem set).

b) If we know the mass of the atmosphere (which is ~5.1×10^{18} kg) and the molecular weight of CO2 relative to the other common gases in the atmosphere (O2 and N2), we can calculate how much actual the total mass of CO_2 in the atmosphere is increasing. The following function shows the approximate total mass of CO_2 in the earth's atmosphere (in metric tons) as a function of its atmospheric concentration (in ppm):

$$M(C) = 2.1 \times 10^9 \times C$$

Using this equation, please compute the rate of change of the total amount of CO_2 in earth's atmosphere.

c) The following graph shows global emissions of carbon dioxide. If you compare this graph to your estimate of how rapidly carbon dioxide is increasing in the atmosphere, what can you conclude about how much of the carbon dioxide we are emitting is remaining in the atmosphere?