Effects of Overfishing on Coral Reef Ecosystems

Coral Reefsearchers

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1. Background
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   - General Question
   - Definitions

Background

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- They play a crucial role in the marine ecosystem's biodiversity along with other functions, such as coastal defense from storms and economic benefits from tourism or local fisheries[7].
- According to the 2008 State of the Coral Reef Ecosystems of Guam report, Guam's coral reef resources are both economically and culturally important, providing numerous goods and services for the residents of Guam, including cultural/traditional use, tourism, recreation, fisheries, and shoreline/infrastructure protection [6].

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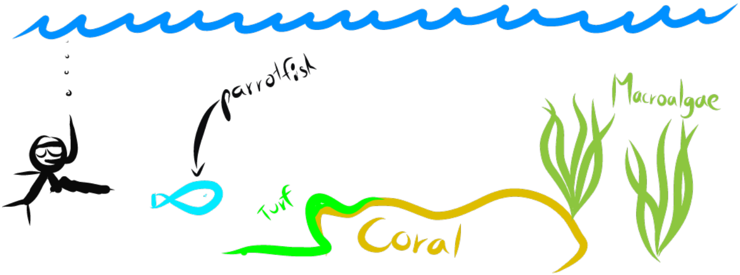
- Factors that affect coral reefs include climate change, coral reef resilience[10], and exploitative fishing practices[9].

Our Question

- General Question: How will Guam's reef ecosystem change over the coming decades?

$$\Downarrow$$

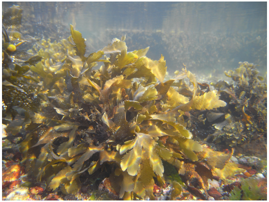
- Specific Question: How will overfishing affect Guam's coral reef ecosystem in the upcoming decades?



Definitions

(a) Corals[1]

(b) Algal Turfs[2]



(c) Macroalgae[3]

Figure 1: Images of Ecosystem

Definitions (Cont.)

Figure 2: Parrot Fish[4]

- Parrot fish are common reef fish found in many tropical reefs[5] and are known to feed on algal turfs and macroalgae.
- Their bites on corals have been shown to improve and promote coral growth.
- Parrot fish are one of the most overfished reef fish in the Caribbean, and potentially on Guam as well[5].

2 Mathematical Model

- Assumptions
- Compartments
- Parameters
- Compartment Model
- Equations
- Plots

Assumptions

- Ecosystem is closed (i.e. no migration of parrot fish).
- Macroalgae is the only predator for coral.
- Rates are measured in year(s).
- Coral recruit to and overgrow algal turfs[7].
- Corals are overgrown by macroalgae[7].
- Macroalgae colonize dead coral by spreading vegetative over algal turfs[7].
- Coral natural death rate is nonexistent (i.e. not from macroalgae overgrowth).
- Algal Turf and Macroalgae do not have a death rate.

Coral Reef Ecosystem Model Compartments

Compartments

The Ecosystem Model consists of 4 compartments:

- C: Corals
- T: Algal Turfs
- M: Macroalgae
- P: Parrotfish

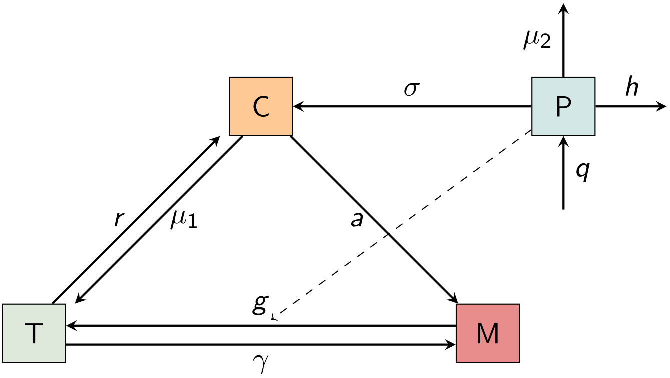
$$\text{where } C + T + M = 1.$$

Coral Reef Ecosystem Model Parameters

Parameter	Description	Value
μ_1	natural death rate of coral reefs	0.15[12]
μ_2	natural death rate of parrotfish	0.22[8]
a	rate that coral is overgrown by macroalgae	0.1[13]
r	rate that coral recruit to overgrow algal turfs	10 [12]
g	grazing rate that parrotfish graze macroalgae without distinction from algae turfs	10 [12]
γ	rate that macroalgae spread vegetative over algal turfs	0.8[13]
q	intrinsic growth rate for parrotfish	0.47[8]
β	carrying capacity of parrotfish	21*
h	harvesting rate for parrotfish	0.14 [8]
α	maximum grazing intensity	1*
σ	rate that parrot fish bite coral	0.01*

$* = \textit{estimated value}$

Coral Reef Ecosystem Model[7]



Differential Equations

System of differential equations derived from compartment model:

$$
\begin{aligned}
\frac{dC}{dt} &= rTC + \sigma PC - (aM + \mu_1)C \\
\frac{dP}{dt} &= qP\left(1 - \frac{P}{\beta C}\right) - P\left(h + \mu_2\right) \\
\frac{dT}{dt} &= \mu_1 C + \frac{g(P)M}{M + T} - T(rC + \gamma M) \\
\frac{dM}{dt} &= (aC + \gamma T)M - \frac{g(P)M}{M + T}
\end{aligned}
\tag{1}
$$

Coral Ecosystem Model Dynamics

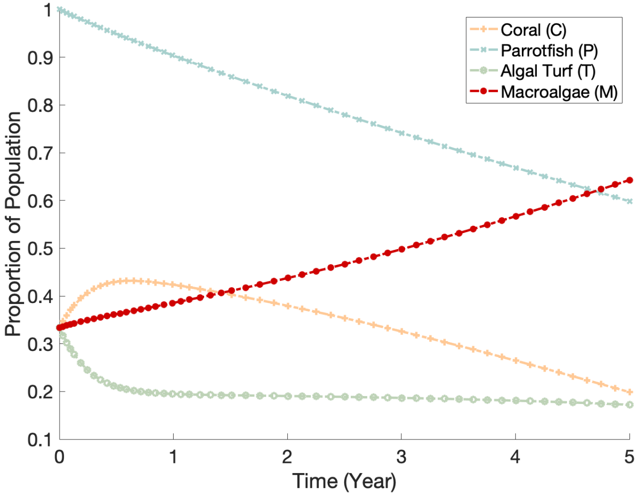


Figure 3: Initial Conditions: $C = T = M = \frac{1}{3}$, and $P = 1$

Coral Ecosystem Model Dynamics (Cont.)

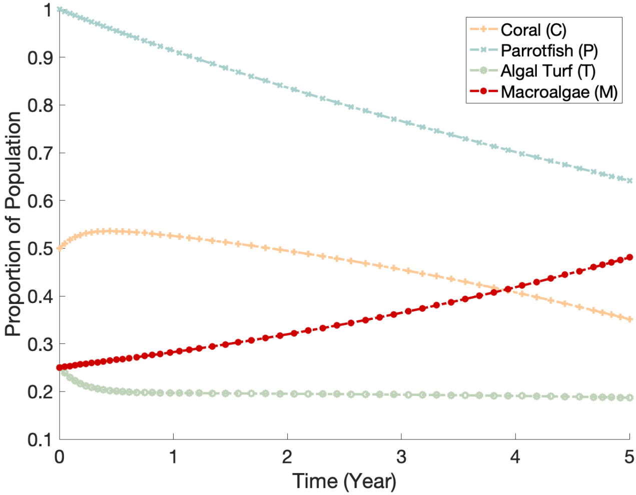


Figure 4: Initial Conditions: $C = \frac{1}{2}$, $T = M = \frac{1}{4}$, and $P = 1$

Coral Ecosystem Model Dynamics (Cont.)

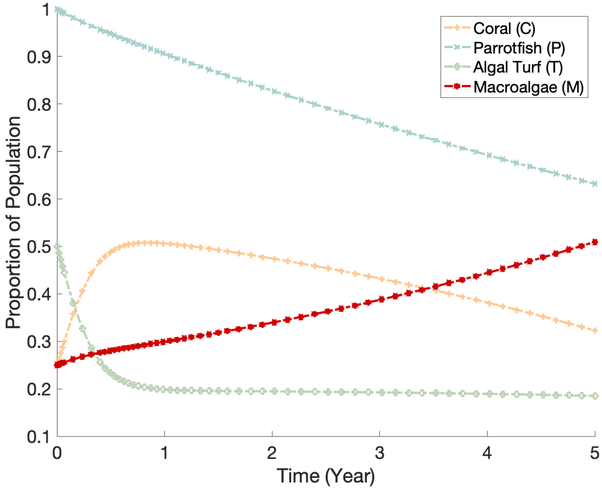


Figure 5: Initial Conditions: $T = \frac{1}{2}$, $C = M = \frac{1}{4}$, and $P = 1$

Coral Ecosystem Model Dynamics (Cont.)

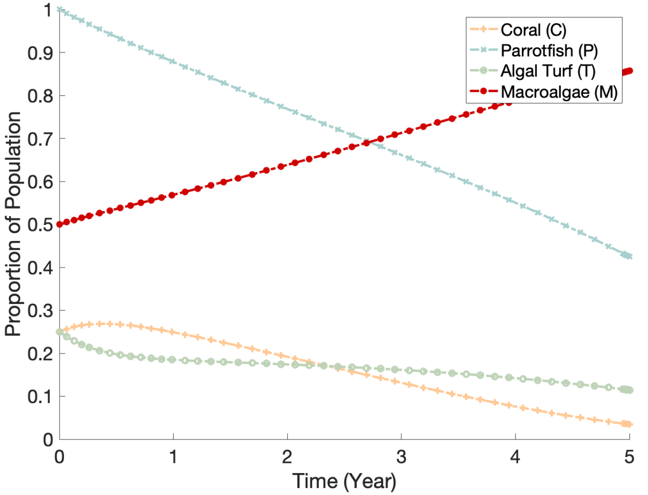


Figure 6: Initial Conditions: $M = \frac{1}{2}$, $C = T = \frac{1}{4}$, and $P = 1$

3 Plans

Future Plans

- Establish our methodology and finalize our mathematical model and assumptions
- Find missing parameter values
- Refine and improve differential equations to improve dynamics
- Application of Education Game Theory on the harvest rate parameter (h) to quantify human behavior and the best strategy to protect coral reef sustainability

Questions?

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Thank you!