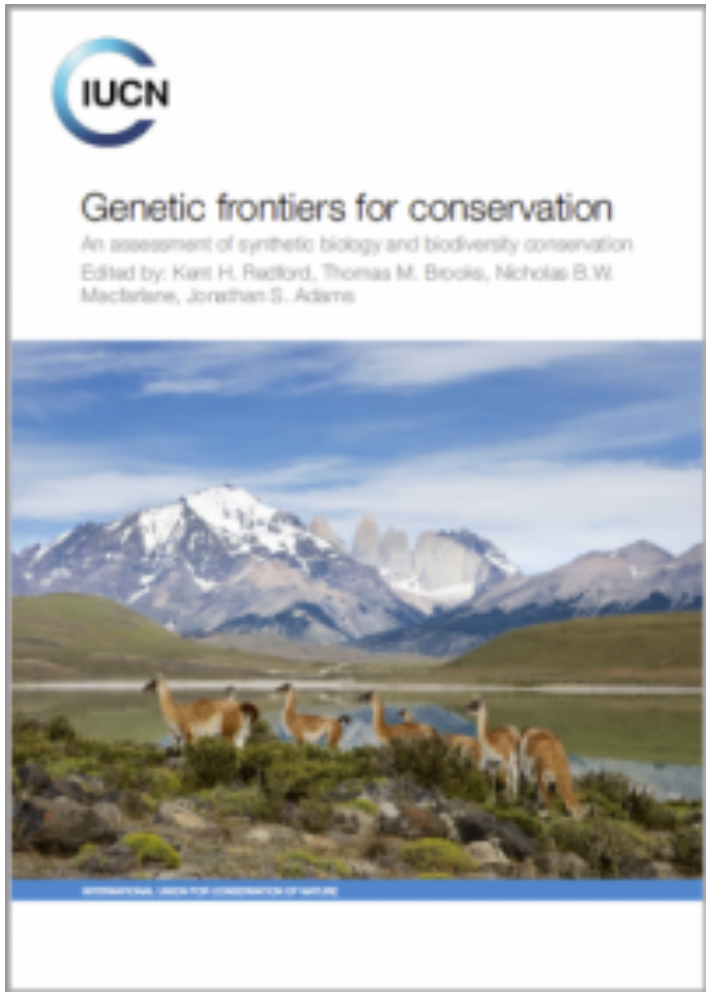
Case Studies:

Rate these real proposals, currently reviewed in an IUCN (International Union for the Conservation of Nature) report



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Research Coordination Network in Undergraduate Biology Education: Build a Genome Network

Proposal 1: Eliminating Mosquitoes in Hawaii

- Hawaii's endemic bird species are some of the most endangered in the world
- 31 species have already gone extinct in historic times, including 24 species of honeycreeper
- Such rapid declines are largely due to an introduced species of mosquito (*Culex quinquefasciatus*)
  - Transmit avian pox and avian malaria
  - Expected to invade higher elevation habitats (the current refuge for most remaining native species) with on-going climate change

Current Methods of Control

- Release of sterile adults: requires release of a lot of adults
- Insecticides: also harmful to native arthropods
- **Proposal : Use gene drives to eliminate mosquitos (i.e., by skewing sex ratios or causing infertility)**

Your Current Recommendation (choose one answer)

- YES
- YES, but with precautions:

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- NO

Other Social/Ecological Considerations

- There is considerable local support for conservation of native plants & animals
    - In Hawaii, ecotourism is also an important industry
- In other parts of the world, mosquitos are also an important food source for animals (including endangered ones, such as bats and fish) and important as pollinators
- Do you think gene drives would be viewed positively or negatively by local Hawaiian communities? Why?

Precautions and Other Risks

- If this project proposal becomes a reality, what reasonable precautions do you think could be put in place? (Think about export of agricultural products, tourism, etc.)
- What might a negative consequence be to gene drives not working as well as proposed?

Department of Land and Natural Resources
State of Hawaii

Your Final Recommendation
(choose one answer)

- YES
- YES, but with precautions:

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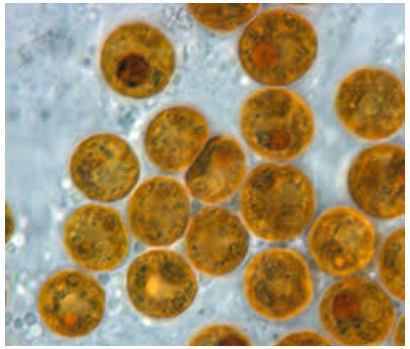
- NO

Proposal 2: Engineering Coral to Withstand Changing Temperatures

- Heat waves of 2014-2017 caused the drastic decline of corals across many parts of the world
- 2016/2017: 3rd global mass bleaching event (death of corals) and caused 50% loss of Australia's Great Barrier Reef
- Threats are associated with climate change: increased disease/loss of symbiotic algae/symbiotic microbes turning parasitic
- Coral reefs provide habitat for a huge diversity of sea life and have been compared to the biodiversity of tropical forests
- Important to coastal communities: fisheries and tourism

Strategies to Stabilize Coral Reefs

- Increase thermal resistance in coral & their symbiotic algae (species of Symbiodiniaceae)
    - Selective breeding, assisted gene flow within species, species hybridization, application of probiotic microbes
- **Proposal: Use genetic engineering to insert antioxidant compounds and enzymes that are known to reduce heat stress**
    - Research continues to identify other genes that may be important to improving resilience against heat stress
- Genetic engineering has not yet discussed gene drives in these cases - but you will still evaluate the possibility of the the use of this additional technology!



Your Current Recommendation for Genetic Engineering (choose one answer)

- YES
- YES, but with precautions:

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- NO

Your Current Recommendation for Genetic Engineering with Gene Drives (choose one answer)

- YES
- YES, but with precautions:

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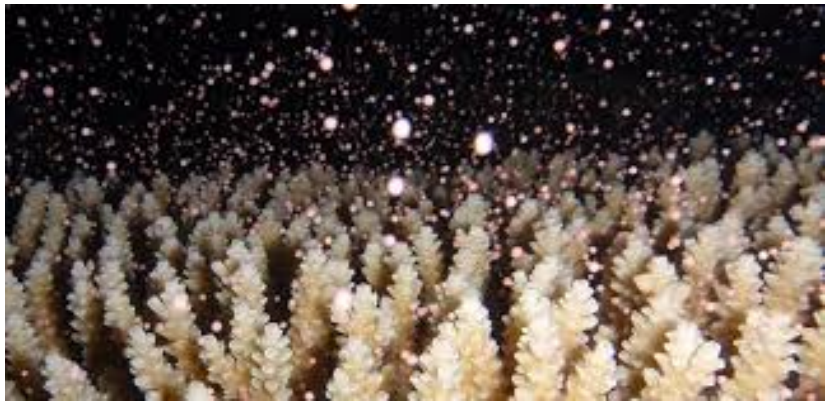
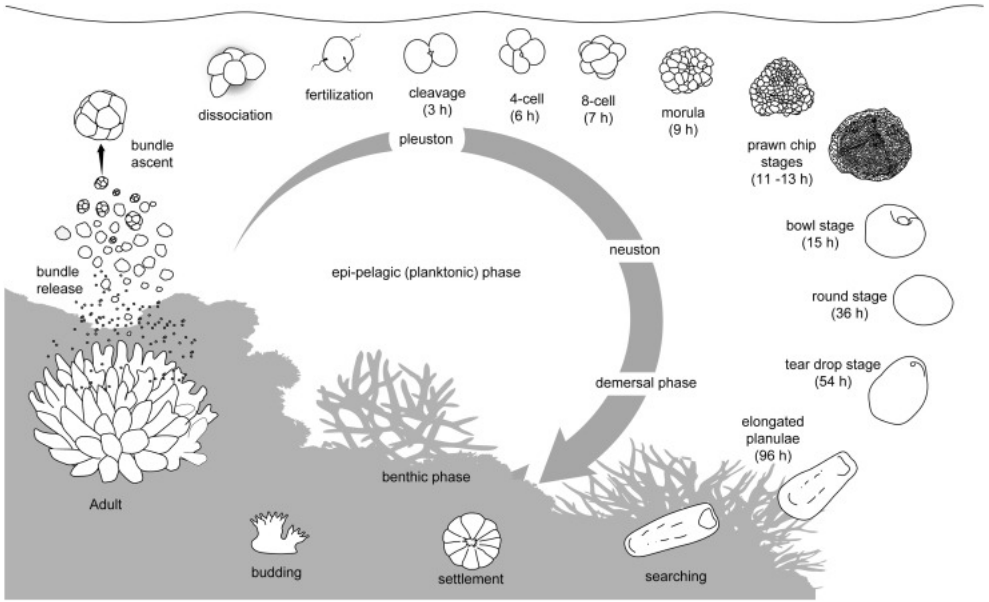
- NO

Spawning, Currents, Hybridization

- Species with sexual reproduction release gametes into the water, which are fertilized externally
    - Dispersal distances unknown for many species, based on timing of the spawn and strength of ocean currents
- Hybridization between species can be common, but has not been adequately quantified
- How might the release of an engineered organism be problematic in these conditions?





Lifespan and Asexual Reproduction

- Coral are made out many polyps that grow on the calcium deposit of old polyps (corals are colonial animals)
    - Corals can be very long-lived
    - Corals can also release free-swimming asexual clones
- Will genetic changes persist for a longer time in such animals?
- What about gene-drives: are they truly self-limiting in a long-lived animal with many reproductive episodes (both sexual and asexual)?
- What will happen to genetically-modified animals if ocean temperatures start to cool again?

Your Final Recommendation: Genetic Engineering (choose one answer)

- YES
- YES, but with precautions:

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- NO

Your Final Recommendation: Genetic Engineering with Gene Drives (choose one answer)

- YES
- YES, but with precautions:

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- NO

Proposal 3: Bringing Back the American Chestnut

- The American chestnut (*Castenea dentata*) was once one a large, long-lived and ecologically important tree in eastern US forests
  - Nut crops were consumed by both humans and wildlife
  - The many ways ecosystems changed with its reduction/loss is unknown
- It has been almost entirely lost by an invasive blight fungus that was accidentally brought to the US in the late 1800s
- Nonreproductive seedlings and stump sprouts still exist, but without ever reaching reproductive maturity (functionally extinct)

Efforts to Bring Back the Chestnut

- Asian species of chestnut can resist blight infections
- Experiments to hybridize the species have been successful, but these also include many traits of the Asian species that may not be desirable in the US
  - Traditional breeding can remove some of these traits, but is slow and unpredictable
  - We know that resistance in the Asian chestnut is controlled by multiple genes
- Would you consider such a hybrid tree to belong to the same species as American chestnut seedlings?

Genetic Engineering

- **Proposal: Use genetic engineering to insert a gene (found in other plants, such as wheat) into the American chestnut and release into the wild**
- Has been successfully done in controlled environments
- Gene product breaks down oxalic acid (toxin) which is produced by the blight and kills tissues of the chestnut
  - It appears to make American chestnuts tolerant of blight infections: they may have blight infections, but infections do not cause much damage
  - Would you consider a genetically modified American chestnut as being the same species as an unmodified chestnut?

Your Current Recommendation (choose one answer)

- YES
- YES, but with precautions:

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- NO

Genetically Modified Organisms (GMOs)

- The US currently regulates GMO crops through the US Department of Agriculture and the Environmental Protection Agency
- Should we release a GMO tree into natural habitats?
- Do we have an obligation to reverse its human-caused extinction?
- Are we tampering with nature even more by releasing this tree back into natural areas?

Your Final Recommendation
(choose one answer)

- YES
- YES, but with precautions:

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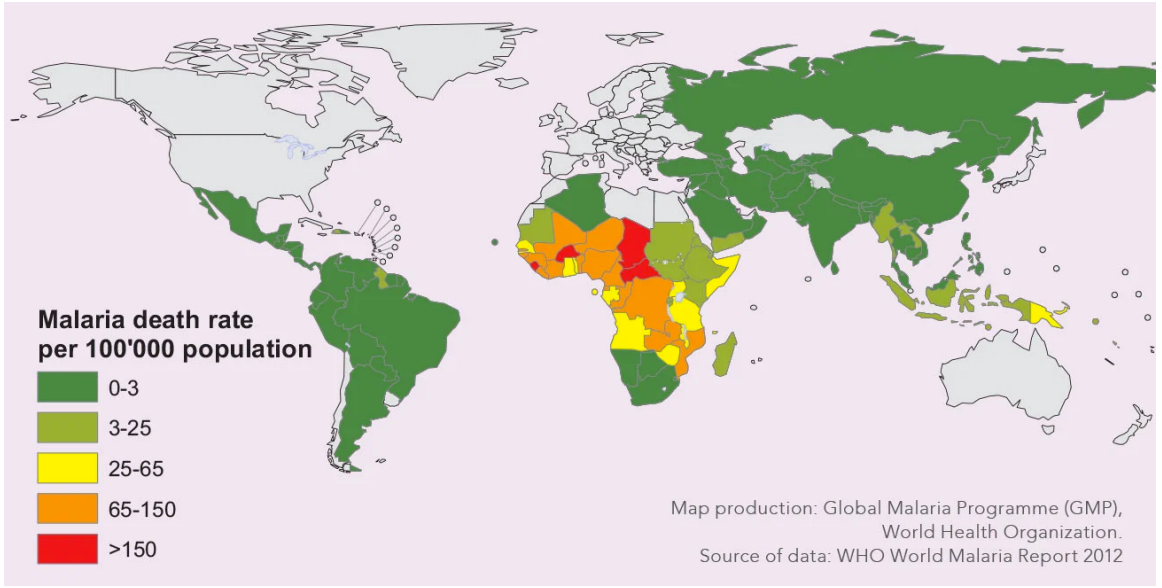
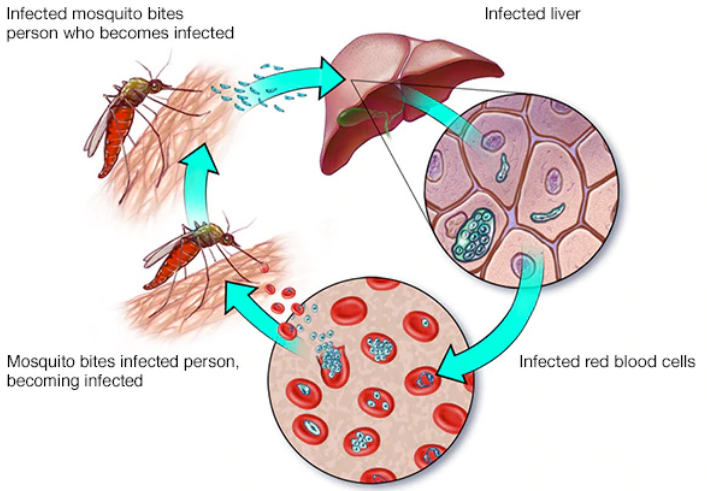
- NO

Proposal 4: Reduce Populations of Mosquitos that are Vectors for Malaria

- Malaria cases are in excess of 200 million per year
- The World Health organization estimates that $9 million is needed to cover 90% of the effected population, only $2.4 million is available
- Primarily caused by *Plasmodium falciparum*, transmitted by female *Anopheles* mosquitoes
  - 90% of cases occur in Africa, where *A. gambiae* is the predominant vector





Vector Control

- Vector control primarily focuses on insecticides and insecticide-treated netting
- Insecticides effect many species of arthropods
- DDT was re-approved as an insecticide in 2006, despite toxicity and environmental impacts (such as loss of raptors)
- **Proposal: Use gene drives to reduce local mosquito populations (not total extinction)**
  - Produce all males
  - Reduce female fertility

Your Current Recommendation (choose one answer)

- YES
- YES, but with precautions:

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- NO

Ecological Consequences

- Should humans exterminate/reduce a native species in its native range?
    - All other examples that we are discussing involve reversing ecological damage caused by humans
- Current research suggests that *A. gambiae* does not hold a unique ecological role, and that other species of mosquitoes will still provide food to other animals/pollination/etc.
    - However, studies on ecological roles of the different species are very limited
- Hybridization among species of mosquitos exists but its extent is largely unknown

Failure of Gene Drives

- Some studies suggest gene drives may not work as well as they are intended to work
    - Success assumes a lot of gene flow within the mosquito population
- What are the health consequences of relying on this technology and it failing to reduce mosquito populations in some places?
- What are the consequences to public opinion if this technology fails in some places?
- Given the limited funding for the many cases of malaria, what might be some other concerns that may emerge in local communities?

Your Final Recommendation
(choose one answer)

- YES
- YES, but with precautions:

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- NO