Evolutionary factors and synthetic biology

NAS Joint Session on Climate Change and Ecology

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Synthetic Biology & Conservation

*Available online*

- Call for Synthetic Biologists and Conservationists to work together
- Guiding Principles
Outline

1. Our priority target – Coral reef resilience
   - Assisted evolution
   - Synthetic biology

2. Challenges and Opportunities
Local and global stress is driving worldwide declines in coral reef health

Environmental change is outpacing innate capacity of corals to adapt
Assisted Evolution

(Courtesy of Madeleine van Oppen)

(van Oppen et al., PNAS 112, 2015)
G x E association analysis of Single Nucleotide Polymorphism (SNP) allele frequencies with 4 temperature and 12 water quality parameters

Two loci show significant correlation to both temperature and water quality: Candidate QTLs (Quantitative Trait Loci)

Jin et al. 2016 Science Advances
Coral thermal tolerance is dependent on the type of *Symbiodinium* that they host

*Symbiodinium* DNA phylogenies:
9 phylogenetic clades and many types or subclade (≈ species) within each clade.

Jones et al. 2008 PRSLB
Symbiont and stress responses

Endosymbionts can provide their hosts with resistance to a number of different stresses through unknown mechanisms.

From Eleftherianos et al. 2013
Synthetic Biology: Engineering Reef Resilience

1. Integrative –omics and biological modelling of coral symbionts under heat stress
2. Coral symbiont engineering technologies
   Biobricks designed using identified resilience genes/pathways
3. Engineering thermal tolerance coral symbionts
   Resilience assessments of coral with engineered symbionts
4. Ecological Impact Modelling
   Risk Assessment Framework
   Community Buy-in

CSIRO Synthetic Biology Future Science Platform
Evolution: Identifying the underlying mechanisms

- Accurately defining the species boundaries
- Detecting variation in resilience traits
- QTL, GWAS, differential expression analysis to determine the genetic basis
Between species variation: Heat tolerance in climate generalist and specialist Drosophila species

- Heat resistance in *Drosophila melanogaster* is controlled by a few genes of major effect that regulate the expression of downstream genes.
- Their orthologues largely explain differences in the transcriptional responses to heat stress of other resistant vs sensitive Drosophila species.

(Courtesy of John Oakeshott & Ary Hoffmann)
Challenges

- We can only reasonably target one keystone species using synthetic biology, possibly a few.
- Do we know enough about the ecology and genetics of target systems?
- How do we get buy-in for synthetic biology approaches from all stakeholders, especially the general public?
Technological challenges

- CRISPR-Cas9 genome/gene editing

- Not trivial to achieve workability in all potential target species – especially symbionts!

- Not yet achieved in *Symbiodinium* (but progress is being made)

(Cyranoski & Reardon *Nature* 2015).
Future target?

Climate-driven regime shift of a temperate marine ecosystem

(Science 353, 2016)
What about de-extinction?

Woolly mammoth & Asian elephant Whole genome sequences

Woolly mammoth AA changes

Tuning of thermoTRP sensors

10°C 20°C 30°C 40°C 50°C 60°C

TRPA1
TRPM4
TRPM8
TRPV4
TRPV3
Thank you

Owain Edwards

John Oakeshott

Madeleine van Oppen

Ary Hoffmann

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