Too Hot to Handle? Climate Change & Conserving California's Coastal Ecosystems

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California relies on its coastal ecosystems

1,100 miles of coastline

68% of the population live in coastal counties

NOAA Office for Coastal Management
California relies on its coastal ecosystems

- 1,100 miles of coastline
- 68% of the population live in coastal counties
- Almost $45 billion annually

Source: NOAA Office for Coastal Management, 2015a
California coastal marine systems are diverse

- kelp forests
- estuaries
- intertidal zone
- wetlands
Humans add more CO$_2$ (a greenhouse gas)

Sources
- Land use change
- Burning fossil fuels

Goes to
- Atmosphere
- Terrestrial
- Ocean
Oceans' rising acidity a threat to shellfish— and humans

New satellite images show Northern California's kelp forest almost gone. Here's the reason

California's Pacific Coast Highway is falling into the ocean. Is this the end of the road for one of America's most scenic drives?

Scientists Are Breeding Sea Stars in a Lab to Rehabilitate Warming Oceans

California coastal waters rising in acidity at alarming rate, study finds
A Billion Seashore Animals Cooked Alive During Pacific Northwest Heat Wave

By Aila Slisco on 7/5/21 at 11:42 PM EDT

More than 1 billion sea creatures along the Vancouver coast were cooked to death during a record-breaking heat wave in the Pacific Northwest.

It’s so hot that Canada’s sea creatures are cooking to their death in the... Extreme heat caused the death of what one marine biologist estimates to be roughly one billion animals in the Salish Sea.

🔗 thestar.com
The “Blob”

Source: NOAA
We know the climate is changing, but we don’t know:

- How much (and how fast) will climate change in the future?
- What are the impacts on species & ecosystems?
- What should we do about it?

*Stakeholders: policy makers, managers, the public*
We know the climate is changing, but we don’t know:

**How much (and how fast) will climate change in the future?**

**What are the impacts on species & ecosystems?**

**What should we do about it?**

*Stakeholders: policy makers, managers, the public*
Global change consequences & coping:

What conditions are “too hot to handle”?

How can we mitigate global climate change locally?

What happens when new species arrive on the scene?
Global change consequences & coping:

What conditions are “too hot to handle”?

How can we mitigate global climate change locally?

What happens when new species arrive on the scene?
Foundation species are plants and animals that play a strong role in structuring the community.

- Oysters
- Mussels
Foundation species are plants and animals that play a strong role in structuring the community.

- Rockweed
- Seagrass
- Bull kelp
- Giant kelp
As climate changes, mussels are declining.

Mussel cover

1970s

2002

Diversity (# species in mussel bed)

40%

60%

Smith, Fong, & Ambrose 2006
A Billion Seashore Animals Cooked Alive During Pacific Northwest Heat Wave

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How do we know when hot is TOO hot?

Vulnerability = Sensitivity + Exposure

Can they survive?
What do they experience?

Physiology
Field Measurements
Vulnerability $= \text{Sensitivity} + \text{Exposure}$

- How do we know when hot is TOO hot?

Field studies: record temperature across different habitats

Ability to survive temperatures across life stages
Robotic Mussels Track Rising Temperatures for Climate Research
Sometimes mussels experience temperatures they can’t handle

Vulnerability = Sensitivity + Exposure

Mussels die off at

- 30°C
- 35°C
- 44°C

But temperatures can reach up to

- 44°C
Older mussels don’t die as easily in heat

Dr. Lauren Pandori
Combing sensitivity & exposure measurements is a useful tool to predict survival.

\[
\text{Vulnerability} = \text{Sensitivity} + \text{Exposure}
\]

- Single
- Bunched together
- Around algae/plants
- In a tidepool

Pandori & Sorte 2021, Ecosphere
Combing sensitivity & exposure measurements is useful tool to predict survival

Vulnerability = Sensitivity + Exposure

Single
Combing sensitivity & exposure measurements is useful tool to predict survival

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Combing sensitivity & exposure measurements is a useful tool to predict survival.

Vulnerability = Sensitivity 🌡 + Exposure ☀️

Around algae/plants
Combing sensitivity & exposure measurements is a useful tool to predict survival.

\[ \text{Vulnerability} = \text{Sensitivity} \leftarrow + \text{Exposure} \rightarrow \]

In a tidepool.
Combing sensitivity & exposure measurements is a useful tool to predict survival.

Vulnerability = Sensitivity 🔥 + Exposure ☀

- Single
- Bunched together
  - Around algae/plants
  - In a tidepool

Pandori & Sorte 2021, Ecosphere
Mussels in solitary habitats were more at risk

Exposure > Sensitivity

Pandori & Sorte 2021, Ecosphere
Trampling (human use) impacts mussel populations

Smith, Fong, & Ambrose 2008

~20%
The Blob devastated California kelp forests

90% loss of bull kelp canopy
The Blob devastated California kelp forests

- 90% loss of bull kelp canopy

- Crash of fishery worth $44 M

- Crash of fishery worth $3 M

Rogers-Bennett & Catton, 2019
Effects on important foundation species scale up to community and ecosystem impacts
Survival of species depends on their tolerances

Research Needs (OPC Objective 1.3)
• Physiological tolerances
• Restoration best practices
• Potential mechanisms of adaptation

Policy and Management Implementation
• Monitoring and protecting vulnerable populations
• Restoration efforts & funding (e.g., KELP Act, OPC Obj. 3.1 & 3.2)
• Marine Protected Areas (MPA) design planning
Global change consequences & coping:

Survival of a species depends on their tolerances

How can we mitigate global climate change locally?

What happens when new species arrive on the scene?
Vulnerability = Sensitivity + Exposure

Exposure occurs at local scales

Global climate change → Local climate change → Impact on ecosystem
Vulnerability = Sensitivity + Exposure

Exposure at local scales can be influenced by vegetation
Vulnerability = Sensitivity + Exposure

Can marine vegetation influence local CO$_2$ levels and acidity?
Yes! Marine vegetation can influence local CO$_2$ levels and acidity

Tide pool with robust population of vegetation becomes less acidic over time as CO$_2$ is taken up by photosynthesis

\[
\text{CO}_2 = \downarrow \quad \text{pH} = \uparrow \quad \text{acidity}
\]
Yes! Marine vegetation can influence local CO$_2$ levels and acidity

- 60 tide pools at 4 locations spanning SoCal to OR
- Tide pools with more robust populations of vegetation were less acidic

$\text{CO}_2 = \uparrow \text{pH} = \uparrow \text{acidity}$

Silbiger & Sorte 2018 *Scientific Reports*
Can marine vegetation mitigate climate change locally? Yes!

- Experimentally added CO₂ to 10 pools
- Tide pools with less vegetation became more acidic
- Tide pools with more vegetation mitigated this CO₂ addition and were less acidic

Effect of CO₂ addition on pH (total scale hr⁻¹)

CO₂ = pH = acidity

Bracken, Silbiger, Bernatchez & Sorte 2018 Peer J
• Marine vegetation influences local CO$_2$ levels and acidity
• Robust populations can mitigate climate change locally

Report conclusions:

“Investing in protection and restoration of [marine vegetation] is a “no-regrets” coastal management strategy for maintaining functional, resilient ecosystems in the face of” climate change.

Photos: T. Mai, NOAA NMS
• Marine vegetation influences local CO$_2$ levels and acidity
• Robust populations can mitigate climate change locally

Legislation that would promote these aims:

AB 63:

In CA marine managed areas:

“This bill would authorize the designating entity or managing agency to also permit restoration and monitoring activities”

Photos: T. Mai, NOAA NMS
Global change consequences & coping:

Survival of a species depends on their tolerances

How can we mitigate global climate change locally?

What happens when new species arrive on the scene?
As the climate changes, many species are declining, including foundation species of shellfish & vegetation.
As the climate changes, not all species are declining... some are increasing, including invasive species

- Marine invasions cost global economy $billions in 2020 (Cuthbert et al. 2021 Science Total Environment)
- SF Bay CA: >$34 million to date spent on control of single species, cordgrass (Cart 2021 calmatters.org)
Climate change is also causing native species to move into new locations.
Impacts of “climate invaders” can be as strong or stronger than non-native invasive species

Sorte et al. 2010 *Global Ecology & Biogeography*
How do we anticipate impacts of “climate invaders”? Can we use risk assessments developed for invasive species?

**EICAT** (Environmental Impact Classification of Alien Taxa):

IUCN standard for classifying impact of alien species on the environment

Risk assessments not previously used for native “climate invasions”
“Climate invasions” have costs & benefits

• Risk assessments developed for invasive species can be modified as a tool for anticipating impacts of “climate invasions”

• Ideally combined with vulnerability assessments for impacted species

• Inform the evaluation and prioritization of policies and management actions
Global change consequences & coping:

Survival of species depends on their tolerances

**Need:** research into tolerance limits & adaptation ability

Marine vegetation can mitigate climate change locally

**Need:** measures to conserve & restore native vegetation

“Climate invasions” have costs and benefits

**Need:** “watch” lists & risk assessments of species likely to arrive
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