Scientific & Technical Subcommittee Highlights

Co-Chairs: Susie Arnold, Stephen Dickson, Ivan Fernandez

GOVERNOR'S OFFICE OF
Policy Innovation and the Future

MAINE DEPARTMENT OF
Environmental Protection

March 14, 2024

Introduction

Ivan J. Fernandez
School of Forest Resources
Climate Change Institute
University of Maine

Scientific & Technical Subcommittee Highlights

March 14, 2024

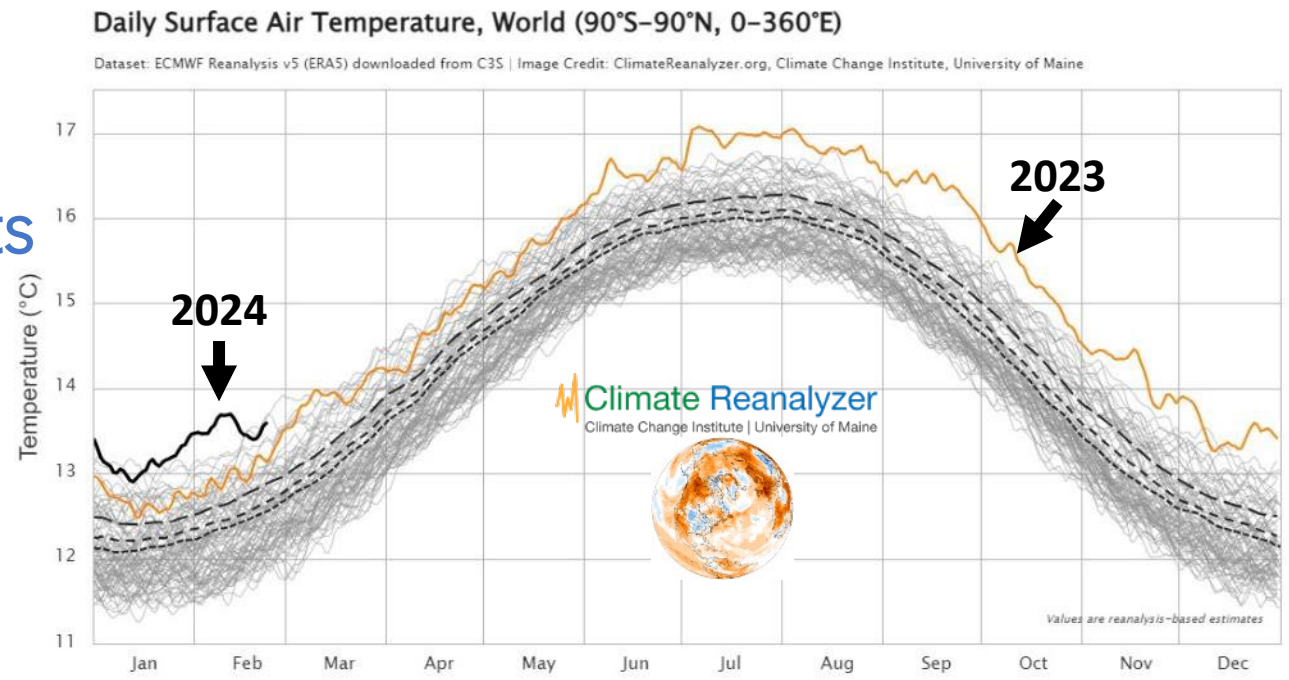
The Maine Climate Council Scientific and Technical Subcommittee **What do we do?**

In 2019, Public Law Chapter 476 established the Maine Climate Council and the Scientific and Technical Subcommittee (STS) within the Council **"to identify, monitor, study and report out to the council and to the working groups…findings and recommendations related to climate change in the State and its effects on the State's climate, species, marine and coastal environments and natural landscape and on the oceans and other bodies of water."**

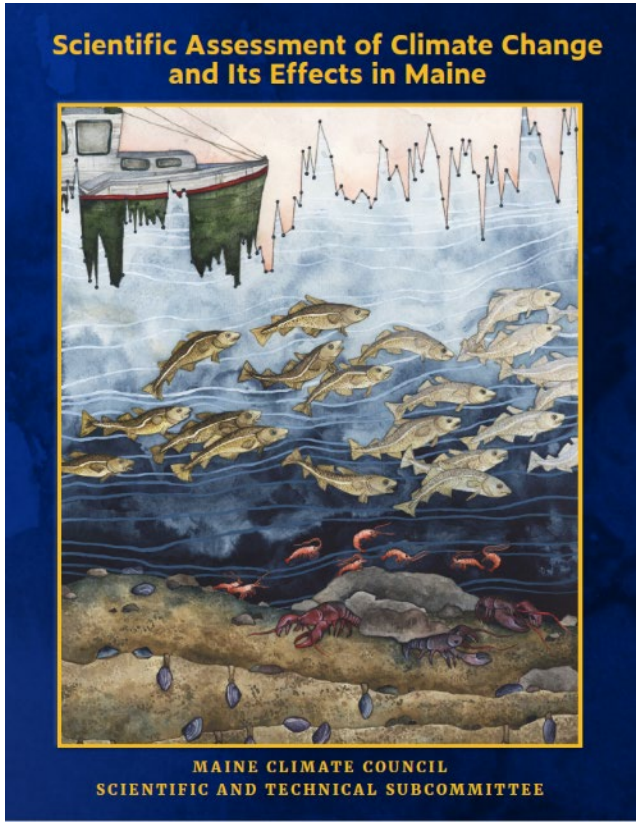
Global and National Science

Global and National Science

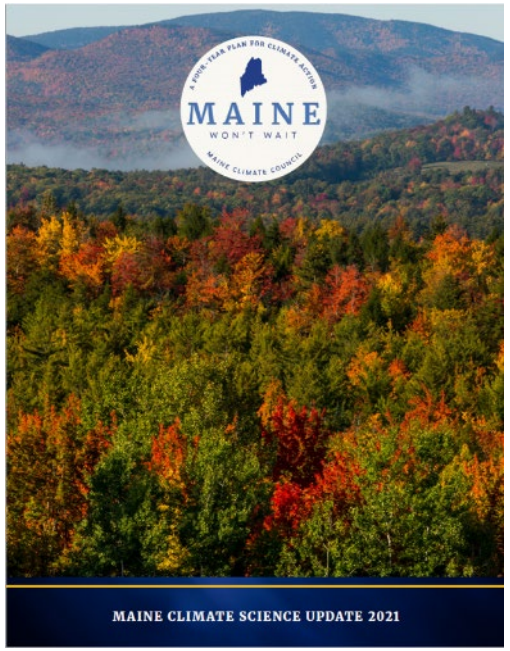
- ✓Accelerating indicators of change
- ✓Tipping points
- ✓Accelerating costs – extreme events
- ✓Every 0.1°C matters
- ✓Progress - but not enough
- ✓Solutions are accelerating!



Maine Climate Science Assessment



2020



2021

Scientific Assessment of Climate Change and Its Effects in Maine

2024

Agenda

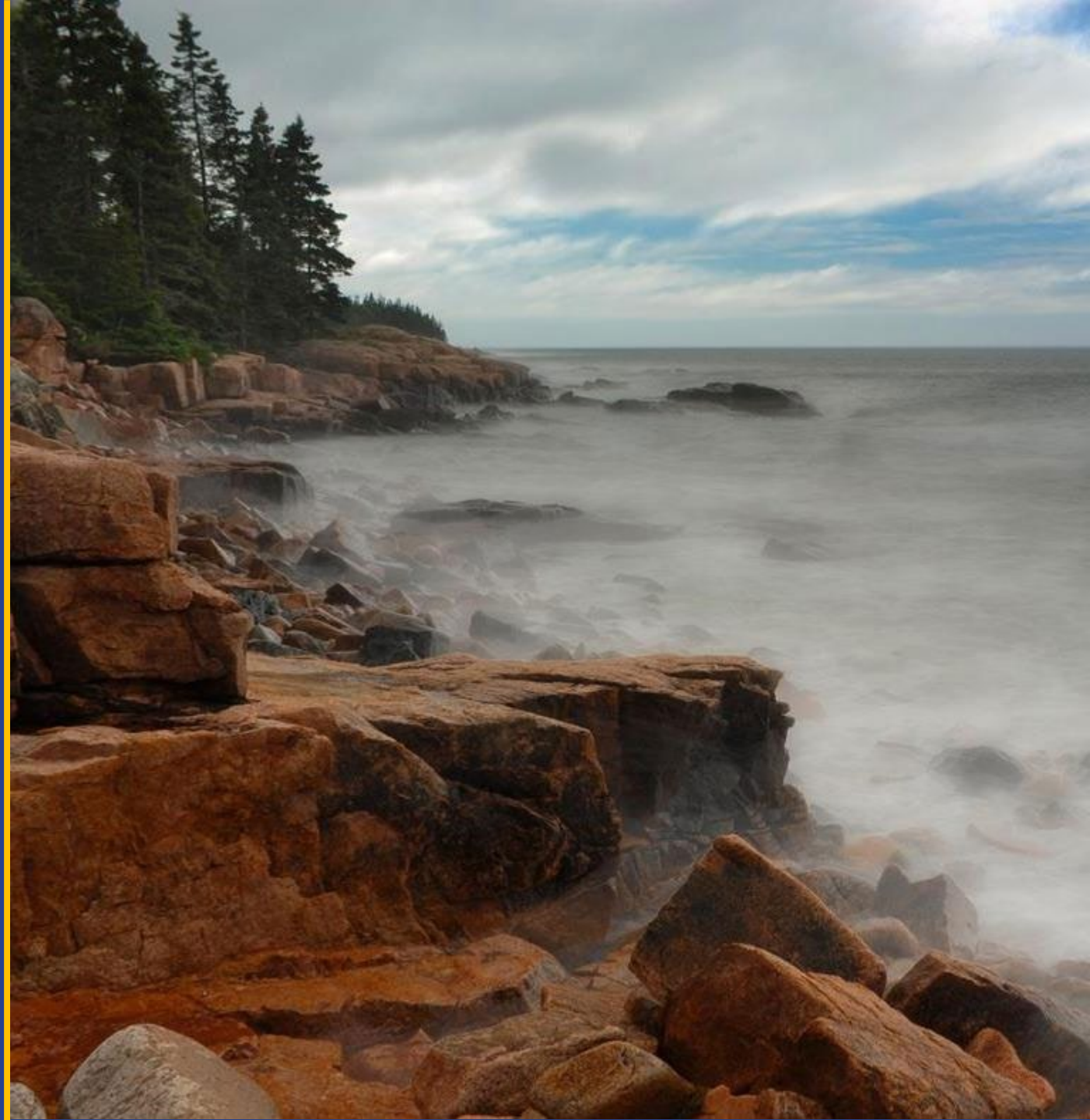
1. Introduction
2. Climate
3. Human Dimensions
4. Human Health
5. Sea Level Rise & Storm Surge
6. Marine
7. Agriculture & Food
8. Forests & Biodiversity
9. Information Needs
10. The Science of Hope
11. Reflections

Climate

Sean Birkel
Climate Change Institute
Cooperative Extension
University of Maine

**Scientific &
Technical Subcommittee Highlights**

March 14, 2024



Maine's climate continues to get warmer and wetter with more extremes

Temperature

- Annual increase of about 3.5 °F since 1895
- Overnight lows have risen more than daytime highs
- All 10 warmest have occurred years since 1998
- Projected 2–10 °F warming depending on emissions scenario

Precipitation

- Annual increase of about 6" since 1895
- Heavy precipitation > 2" per day becoming more common
- Projected 5-14% annual rainfall increase by 2100 and more frequent extremes

Scientific & Technical Subcommittee Highlights

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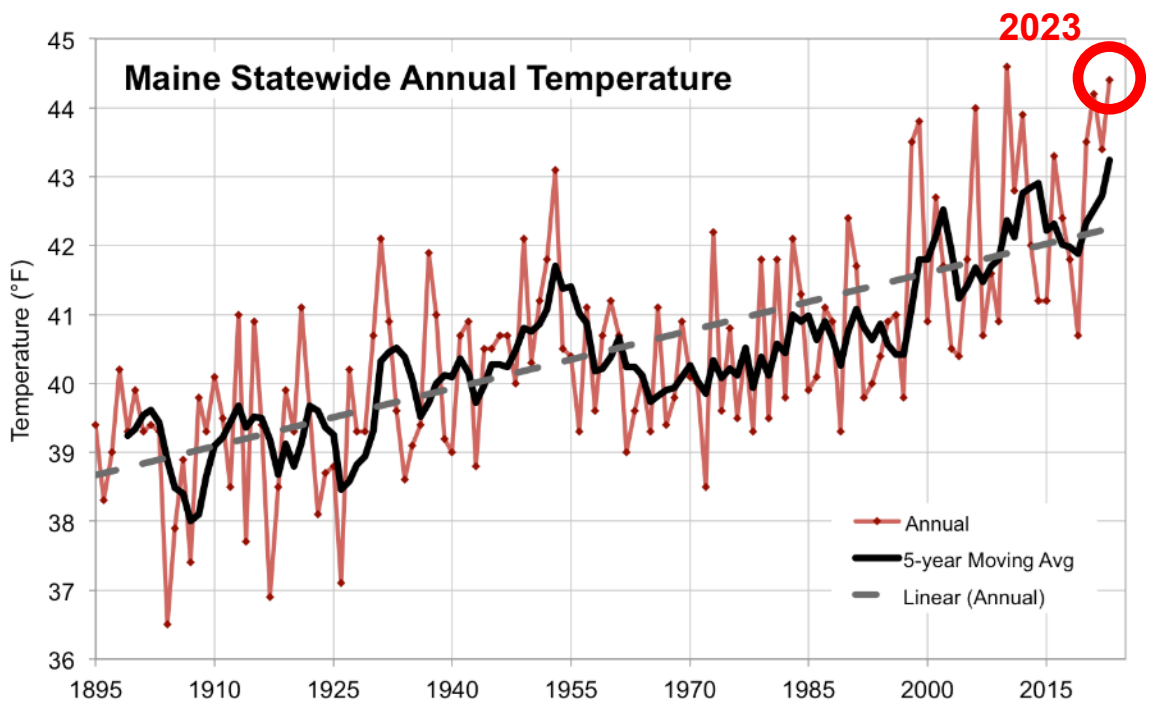
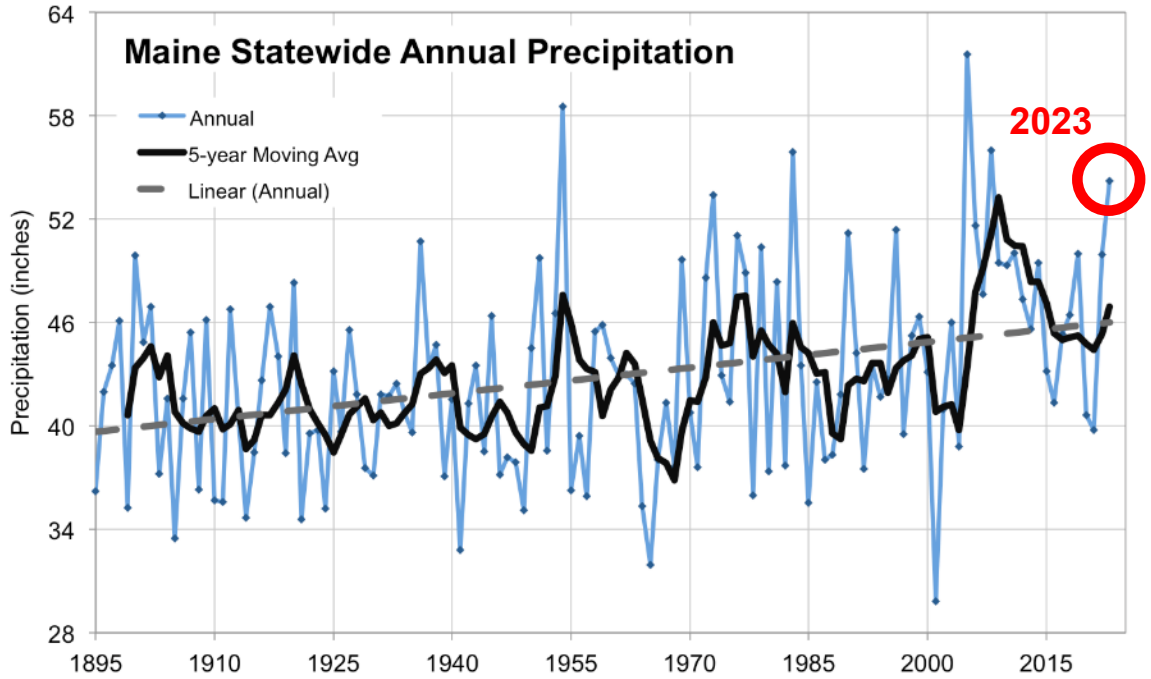
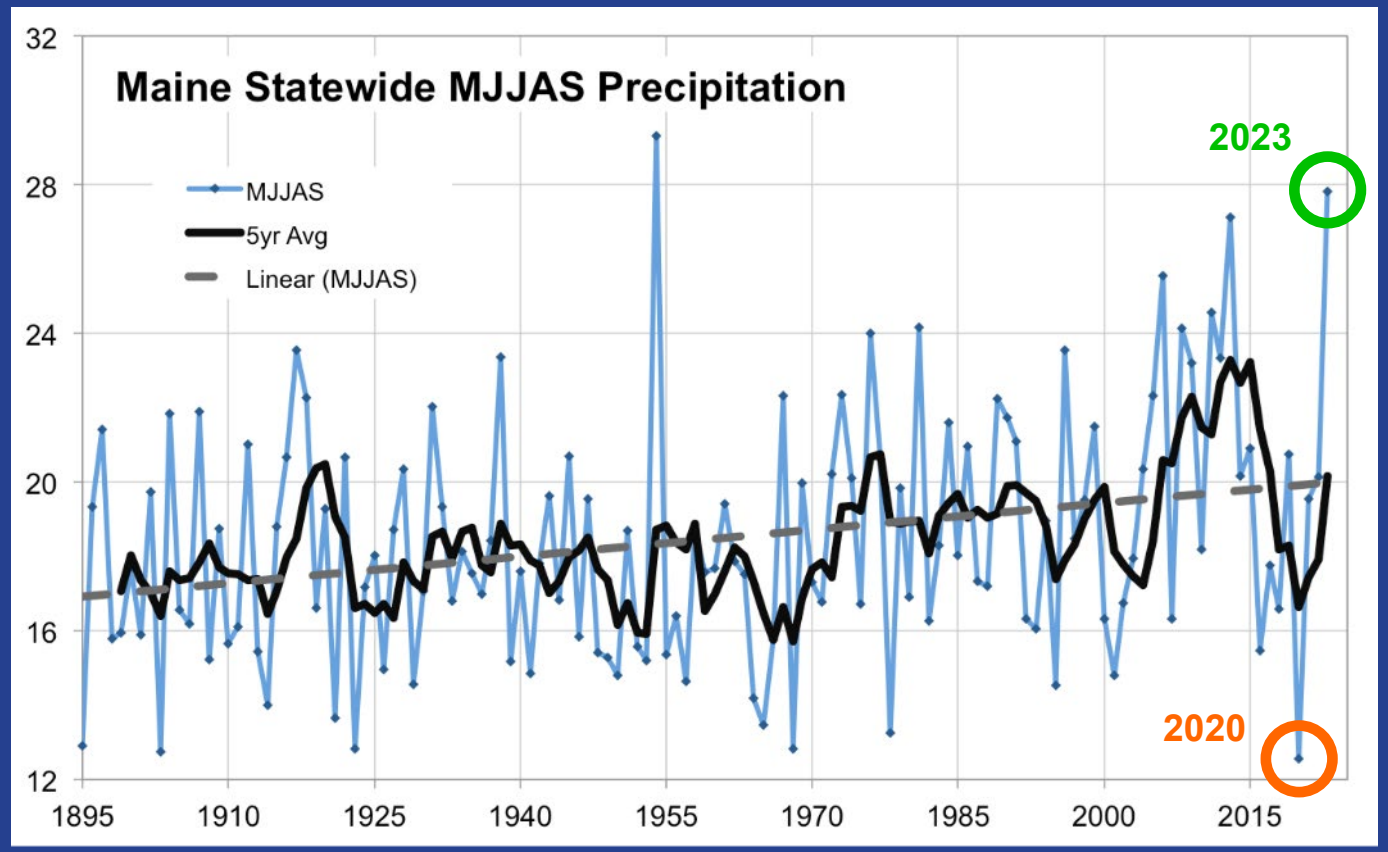




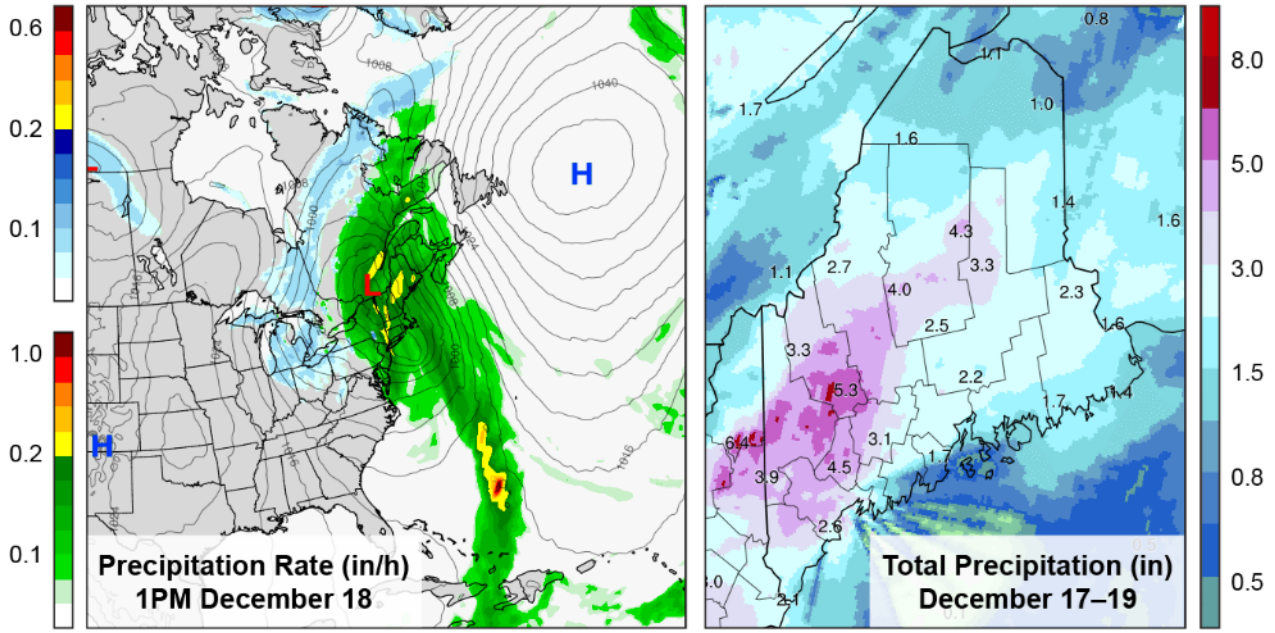
Season Extremes, May-Sep 2020 (driest), 2023 (2nd wettest)



- Recent studies find an intensified hydrologic cycle could produce "drier dry" periods, and "wetter wet" periods. Must manage both.
- Maine variously impacted by drought 2016-2022. The 2020 drought, May-Sep, culminated in drought disaster declaration before wet weather returned in October.
- In 2023, frequent rain led to flooding, erosion, difficult field access, and in some cases decreased yield or crop losses.

Warming is projected to increase storm intensities, but changes in frequency are uncertain

- Storms enhanced by warming-driven intensification of the hydrologic cycle. Also associated with weaker circulation and blocking patterns.
- Strong mid-autumn storms 1979–2019 found to have trend toward more accompanying precipitation; no trend in frequency or wind intensity.
- Most climate models project an overall decrease in extratropical cyclones along the U.S. East Coast, but with increasing intensity.
- More research is needed to understand both historical and projected storm trends in Maine.



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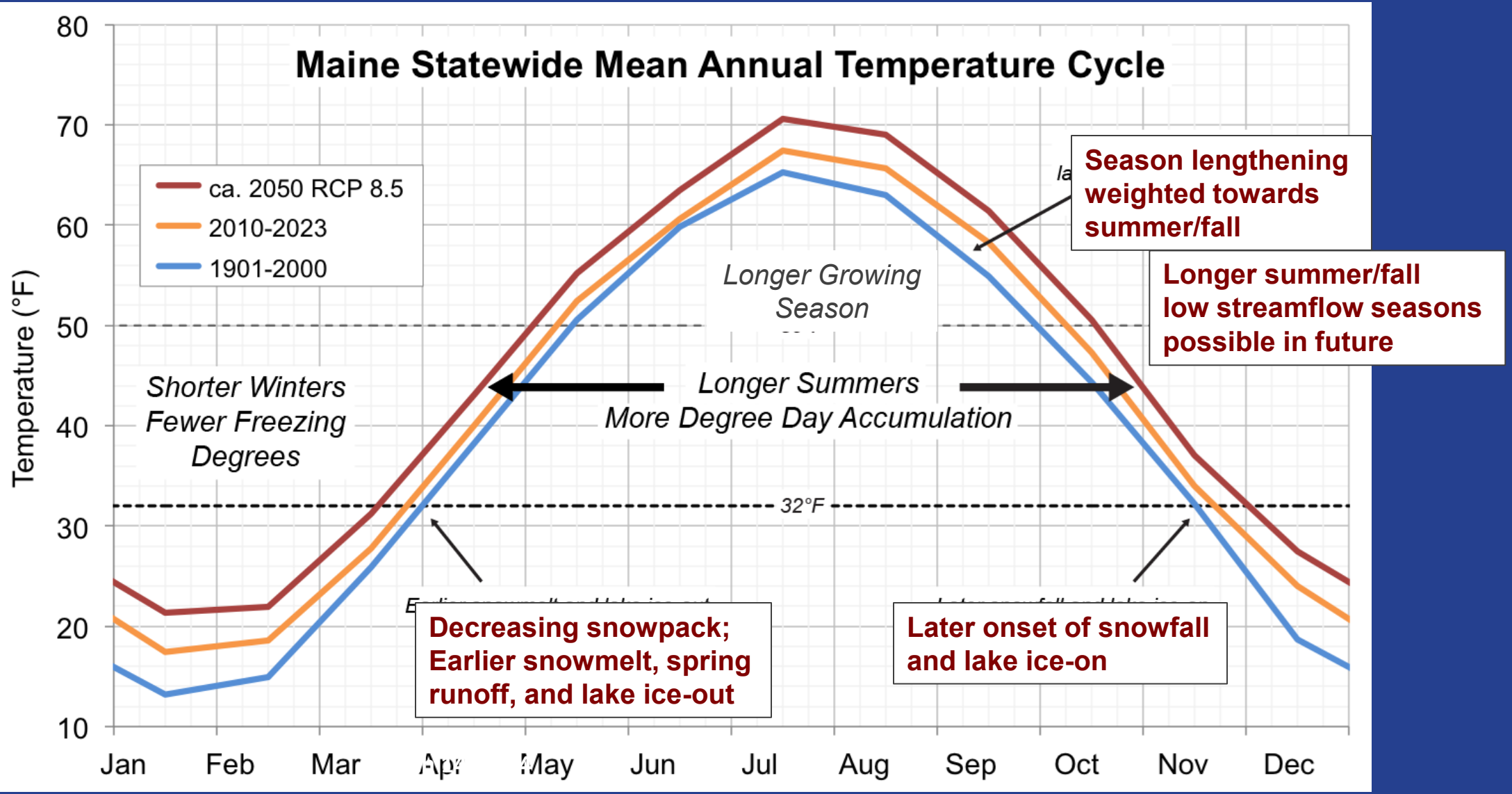
As temperature rises, the warm season lengthens and the winter snow and ice season shortens

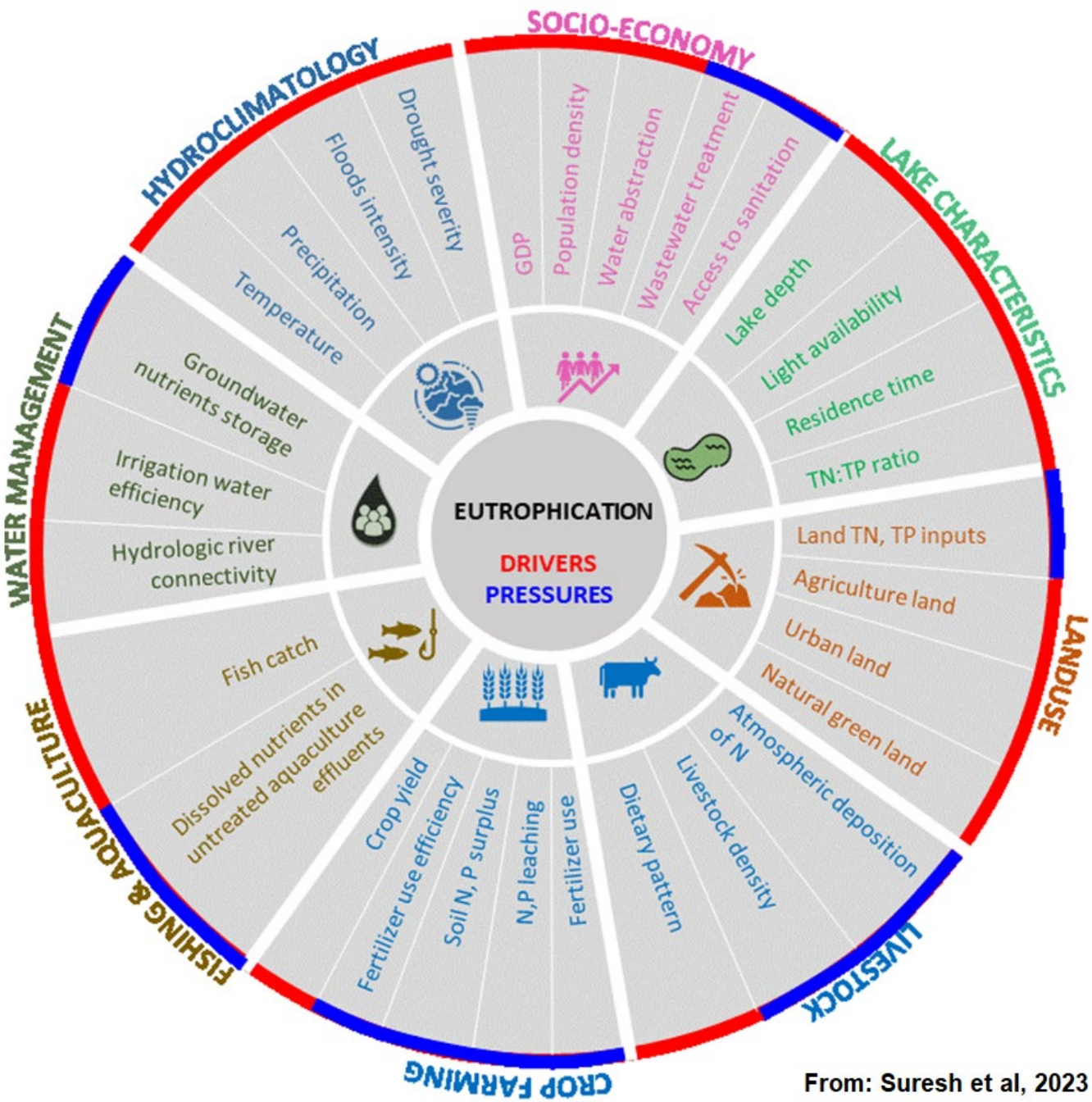


Freshwater Quality

Effects and Information Needs reported in the 2020 Scientific Assessment remain valid

2024 Additions:

- Lake Resilience – Subset of Watershed Resilience
- Lake & Resilience Indicator Compilation
  (see diagram to right)
- Vulnerable Waters
  - unmapped headwater streams
  - non-floodplain wetlands
  - more accurate maps needed
- "Socioecological" Resilience
- Actions & Planning for Resilience in Watershed Systems



From: Suresh et al, 2023

Human Dimensions

Cindy Isenhour
Professor of Anthropology and Climate Change
University of Maine

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Takeaway #1: Social & Economic impacts

Climate change is **already** affecting Maine's social and economic systems.

- Growing social costs of CO2 pollution
- More than monetary–impacts on place-based heritage and identity linked to well-being

Projections are uncertain.

- Projected increase in demand for civil and governmental services
- Market responses: some hopeful, others could present additional hardship (winter tourist markets, housing, solar, insurance)
  - e.g. Housing - market response to migration, impacts of storm events

Takeaway #2: Vulnerability

Mainers experience differential levels of vulnerability:

- Physical risk/exposure: coastal, inland, drought, heat, flooding
- Social vulnerability: rural, older populations, marginalized peoples, lower income
- Adaptive capacity: economic sensitivity, governance structure, information

Vulnerability matters

- can be exacerbated by poorly designed policy
- can be reduced through inclusive design (e.g. indigenous sovereignty)
- reducing vulnerability can result in co-benefits and lead to more effective climate action

Takeaway #3: Adaptation and Resilience

Science suggests resilience is linked to strong **social** infrastructures and institutions:

- importance of social capital
- collaboration and capacity building needed for municipalities
- linked to notions of care across scale
- infrastructures for participatory governance

Key enablers of adaptation success:

- good information about impacts and solutions
- political commitments
- institutionalization of planning frameworks
- policies with clear goals
- adequate financial resources
- inclusive governance

Human Health

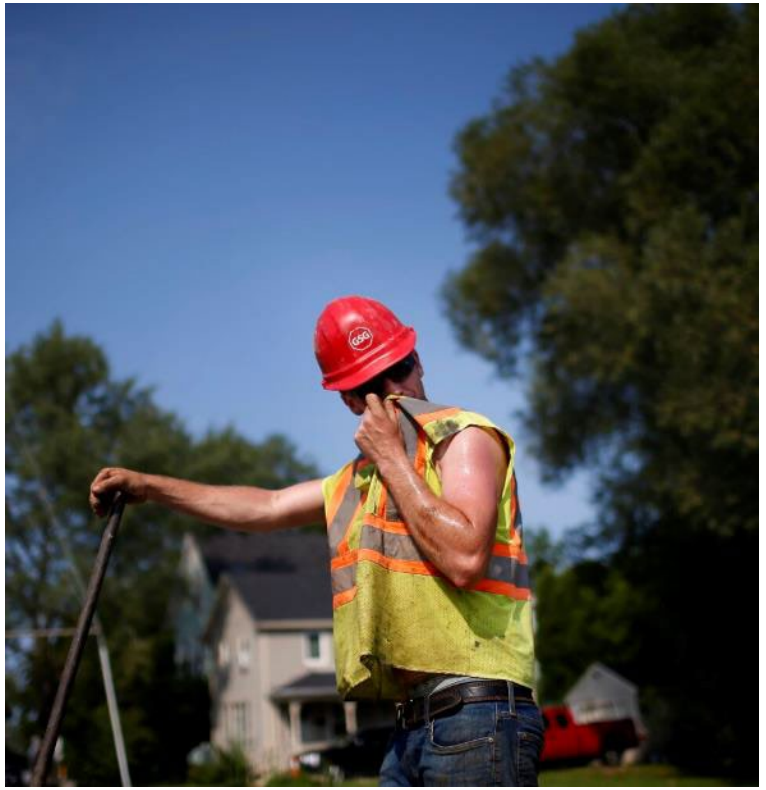
Rebecca Lincoln
Environmental Epidemiologist
Maine Center for Disease Control

Scientific & Technical Subcommittee Highlights

March 14, 2024

Takeaway #1: Extreme Weather & Health

- Maine is projected to experience more periods of **extreme heat**
  - **Men, middle-aged adults,** and those who **work outdoors/in a hot environment** are disproportionately affected
- Recent severe **heat waves** in **temperate areas** of the U.S. have caused significant morbidity and mortality and **illustrate the need for adaptation**
- Evidence for **health impacts of heat exposure** continues to expand
- **Other types of extreme weather** events can also have significant health impacts
  - The December 18, 2023, storm caused at least **4 confirmed deaths** and **dozens** of **Emergency Department visits**



Takeaway #2: Mental Health

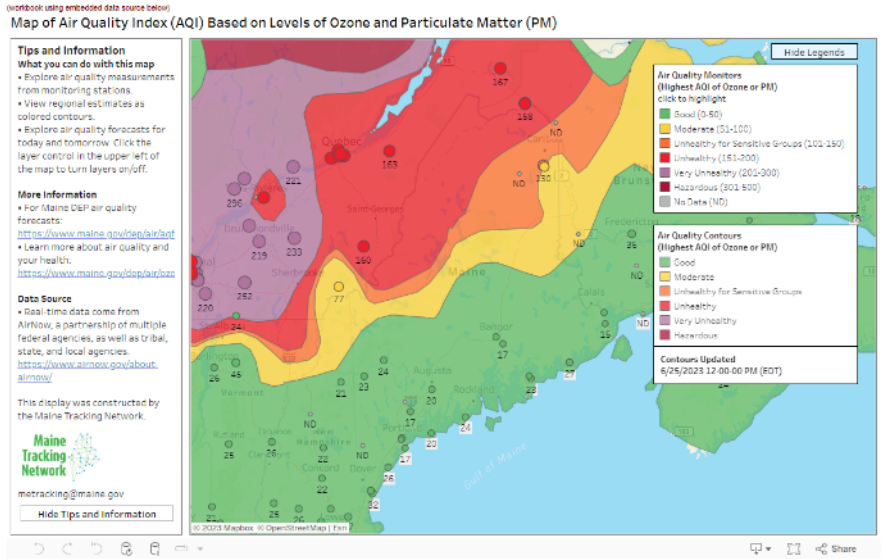
- There is **increasing evidence** for adverse **mental health** impacts of climate change
  - Direct **exposure** to **climate hazards** can **exacerbate existing conditions** or **cause new onset of symptoms**
  - Concern for current and future **threats posed by climate change** can produce **'climate anxiety'**
- Rates of **mental health disorders** remain **high in Maine**, and there are persistent **gaps between existing need** and **available services**
- Efforts to **expand and improve mental health services** should account for **climate-related impacts** and **climate anxiety**
- Efforts to **improve preparedness for climate hazards** should account for the likely **need for mental health services**

Takeaway #3: Vector-borne Diseases

- A **warmer, wetter Maine climate** is likely to support **increasing** populations of **ticks and mosquitoes**
- **Blacklegged (deer) ticks** are established in southern Maine and **increasing in northern Maine**
  - Carriers of Lyme disease, anaplasmosis, babesiosis, Powassan encephalitis, relapsing fever
  - **Lyme disease cases** in Maine continue to **increase**
- **Lone star ticks** are **appearing more frequently** in Maine
  - Carriers of ehrlichiosis, tularemia, alpha-gal syndrome (red meat allergy)
- **2023** was an **unusually active** year for **mosquito-borne diseases**
  - **Veterinary outbreak** of **Eastern Equine Encephalitis Virus (EEEV)**
  - **Mosquitoes** carrying **EEEV**, **West Nile Virus**, and **Jamestown Canyon Virus**

Takeaway #4: Air Quality

- In **2023**, the Eastern U.S. experienced periods of **poor air quality** due to wildfires in Canada and the Western U.S.
- **Most of the future health burden** from Western states' wildfire smoke is likely to be **on the East Coast** due to **higher population density**
- Other climate-related air quality issues of importance include increasing levels of **pollen/aeroallergens**
- **Maine Center for Disease Control (CDC)** is working with the Department of Environmental Protection **(DEP)** to develop tools for tracking **climate-related air quality** issues:
  - Developing a **wildfire** and **air quality data dashboard**
  - Implementing a statewide **pollen monitoring network**



Sea Level Rise & Storm Surge

Peter Slovinsky
Maine Geological Survey

Scientific & Technical Subcommittee Highlights

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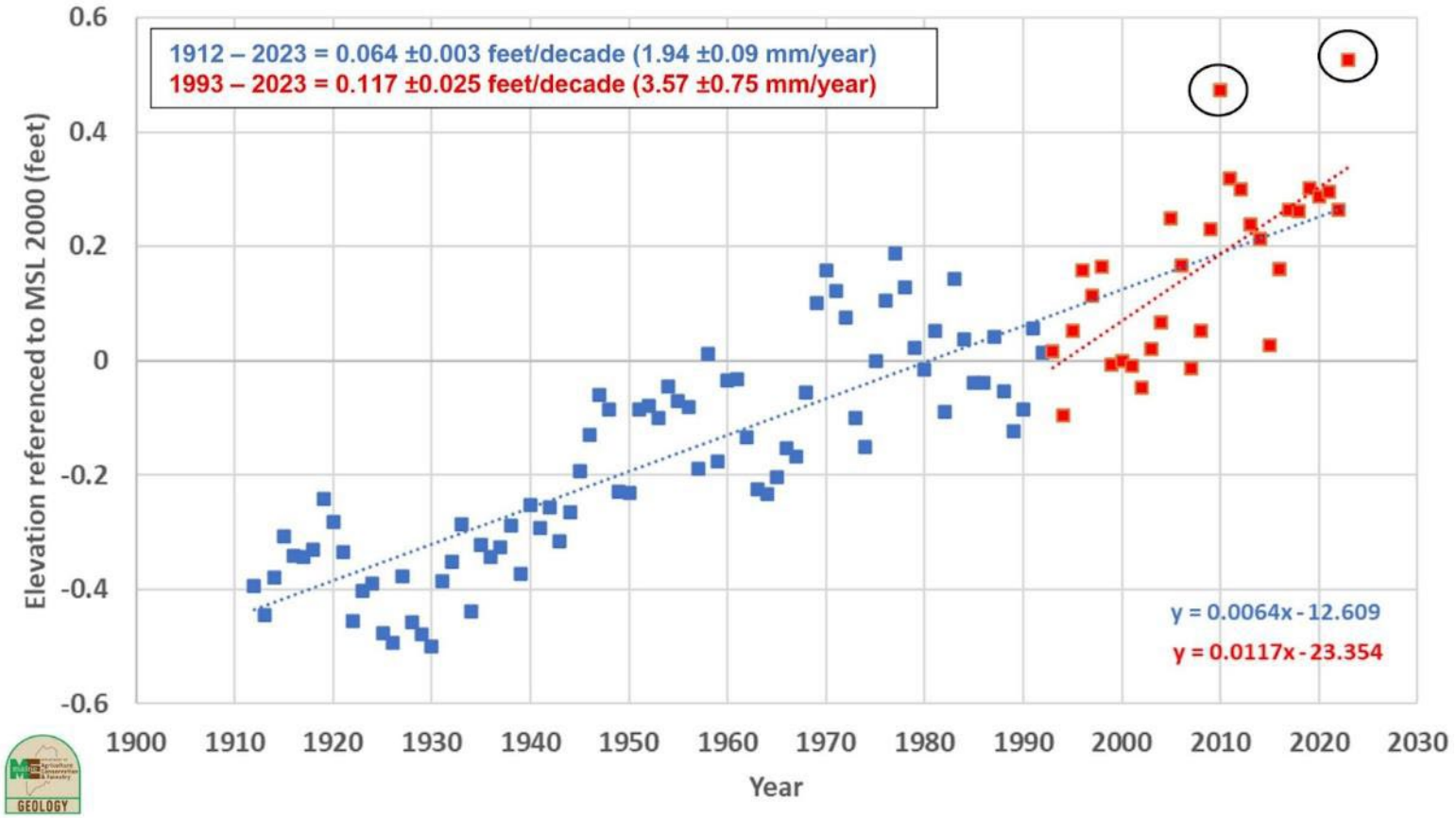
Higgins Beach, Scarborough. D. Lund-Yates

Sea Level continues to rise in Maine and 2023 set record mean sea levels for many months of the year

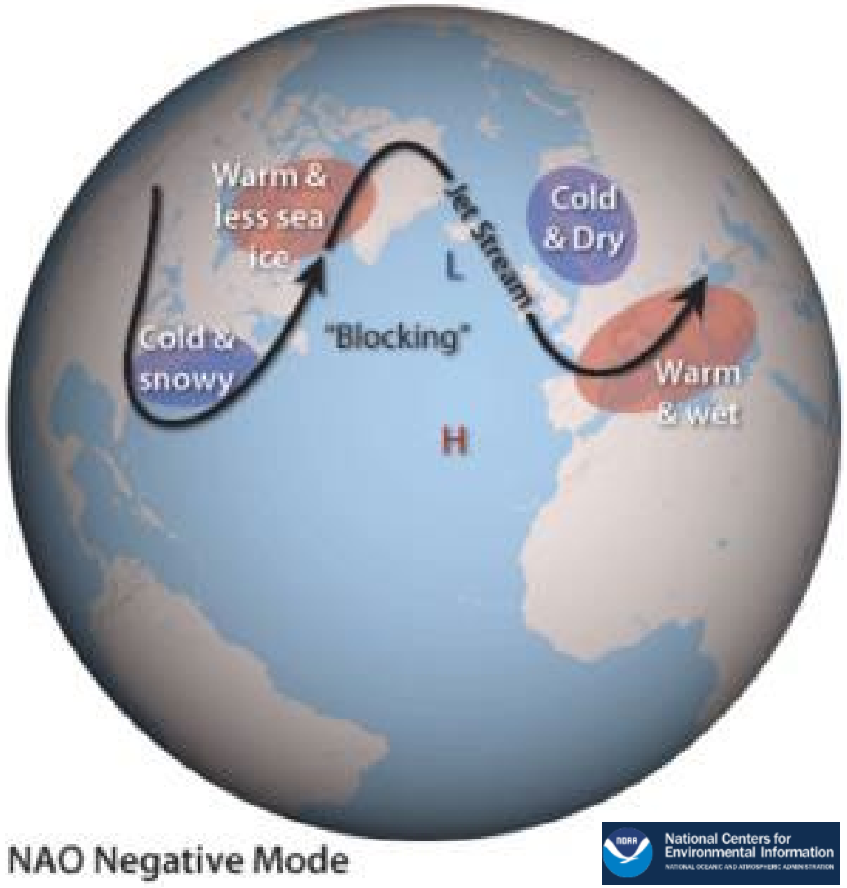


2023 Monthly Mean Sea Level Rankings			
Month	Portland	Bar Harbor	Eastport
	1912-2023	1947-2023	1929-2023
January	2nd	1st	3rd
February	5th	3rd	3rd
March	3rd	1st	1st
April	3rd	3rd	3rd
May	3rd	2nd	2nd
June	1st	1st	1st
July	1st	1st	1st
August	1st	1st	1st
September	1st	2nd	2nd
October	1st	1st	1st
November	1st	1st	1st
December	2nd	2nd	2nd
	2023 monthly water level is in the top 3 for that month		
	2023 monthly water level is the 1st for that month (Chart by P.Slovinsky, MGS)		

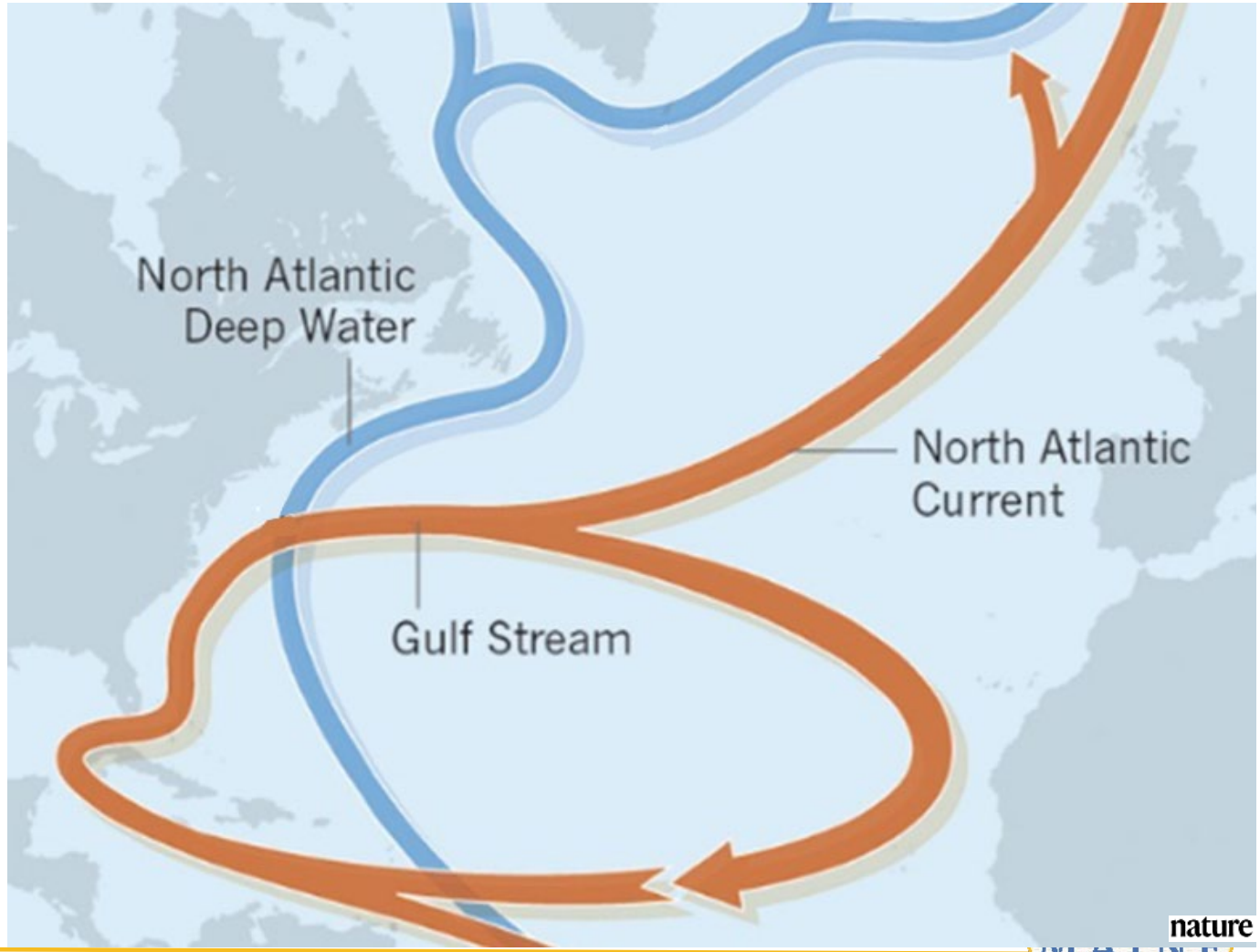
This high mean sea level trend **continues in 2024** with **new record mean sea levels recorded at all three tide gauges** in January.

Higher than normal mean sea levels in 2023…a repeat of 2010?

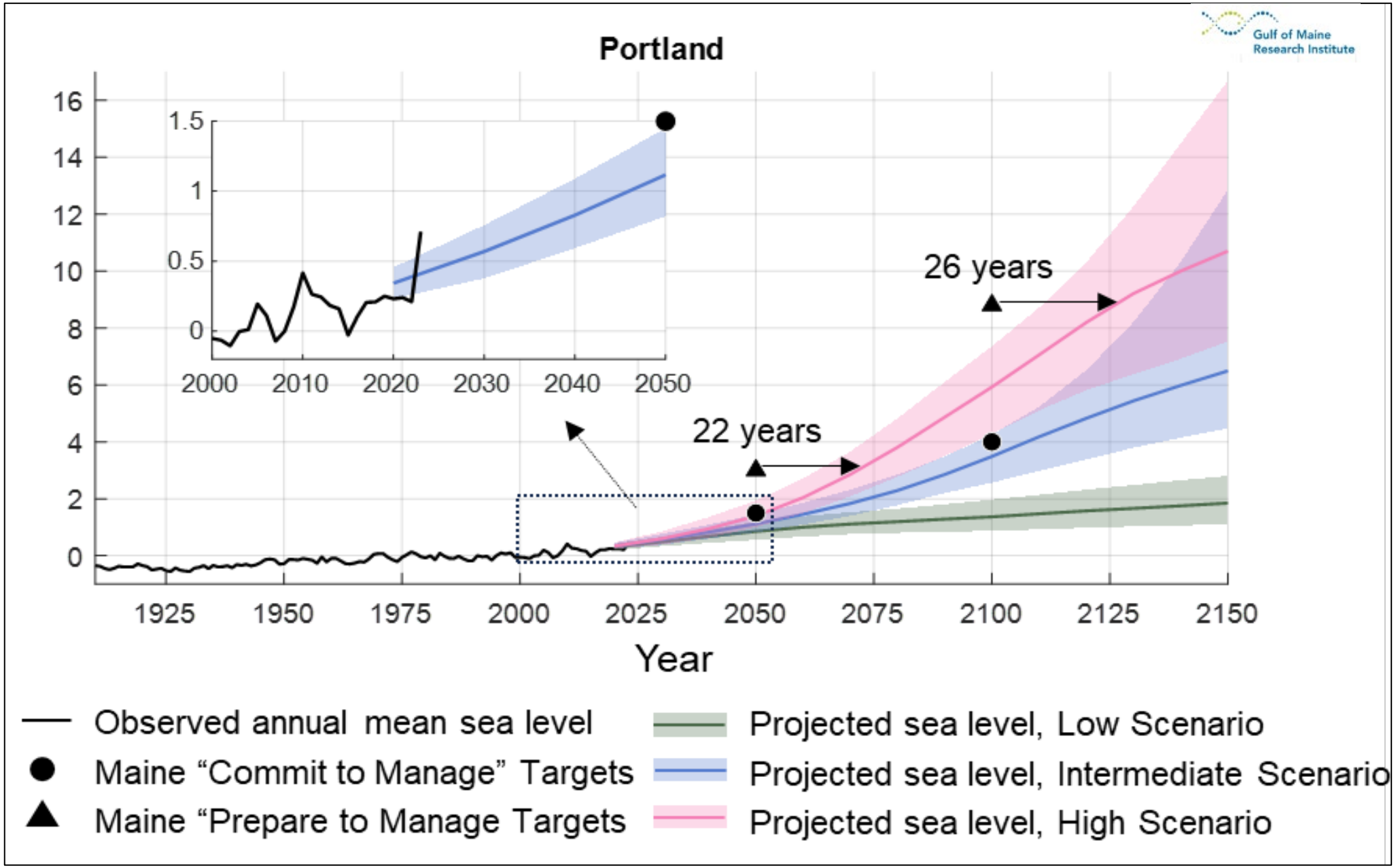
North Atlantic Oscillation (NAO)



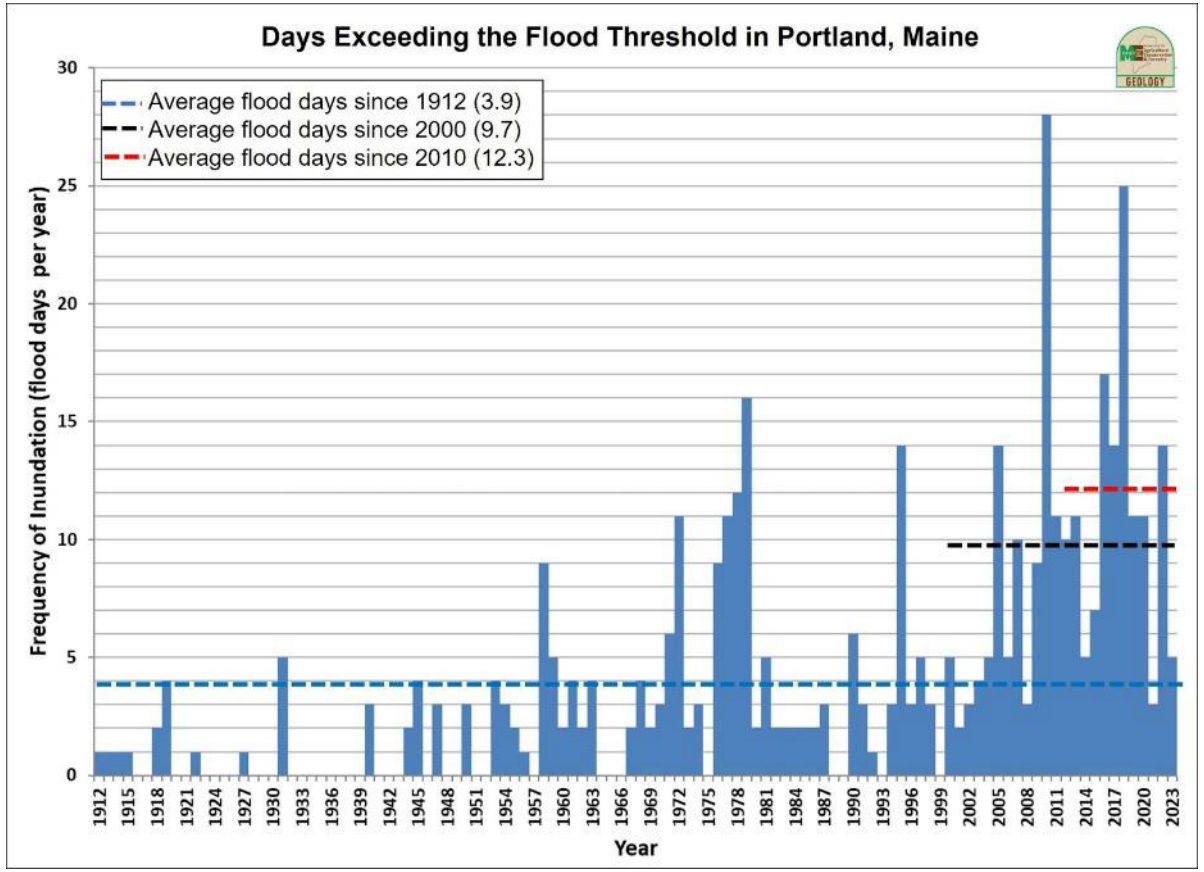
Atlantic Meridional Overturning Circulation (AMOC)

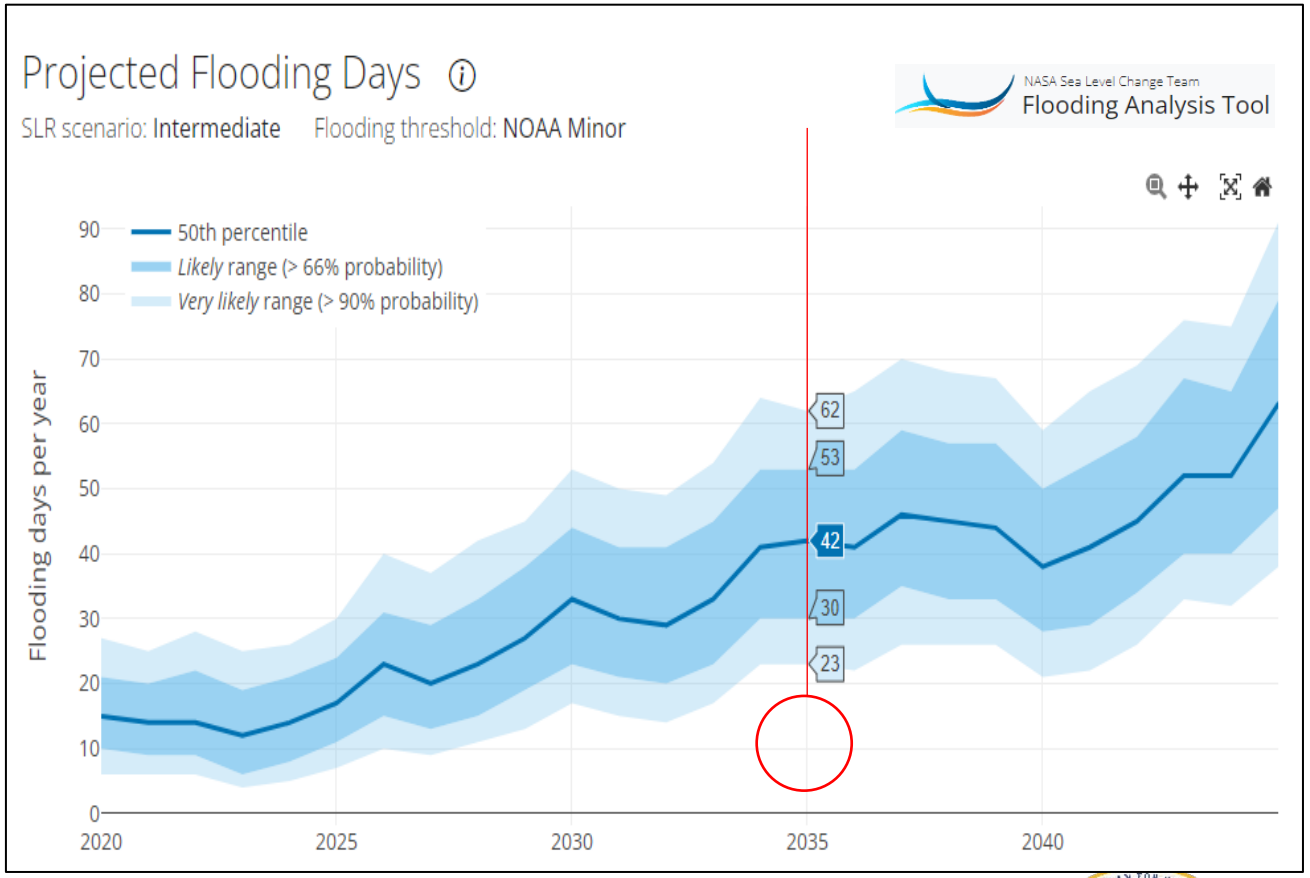


Maine's "commit to manage" sea level rise scenario remains valid
The "prepare to manage" scenario shifts two decades later

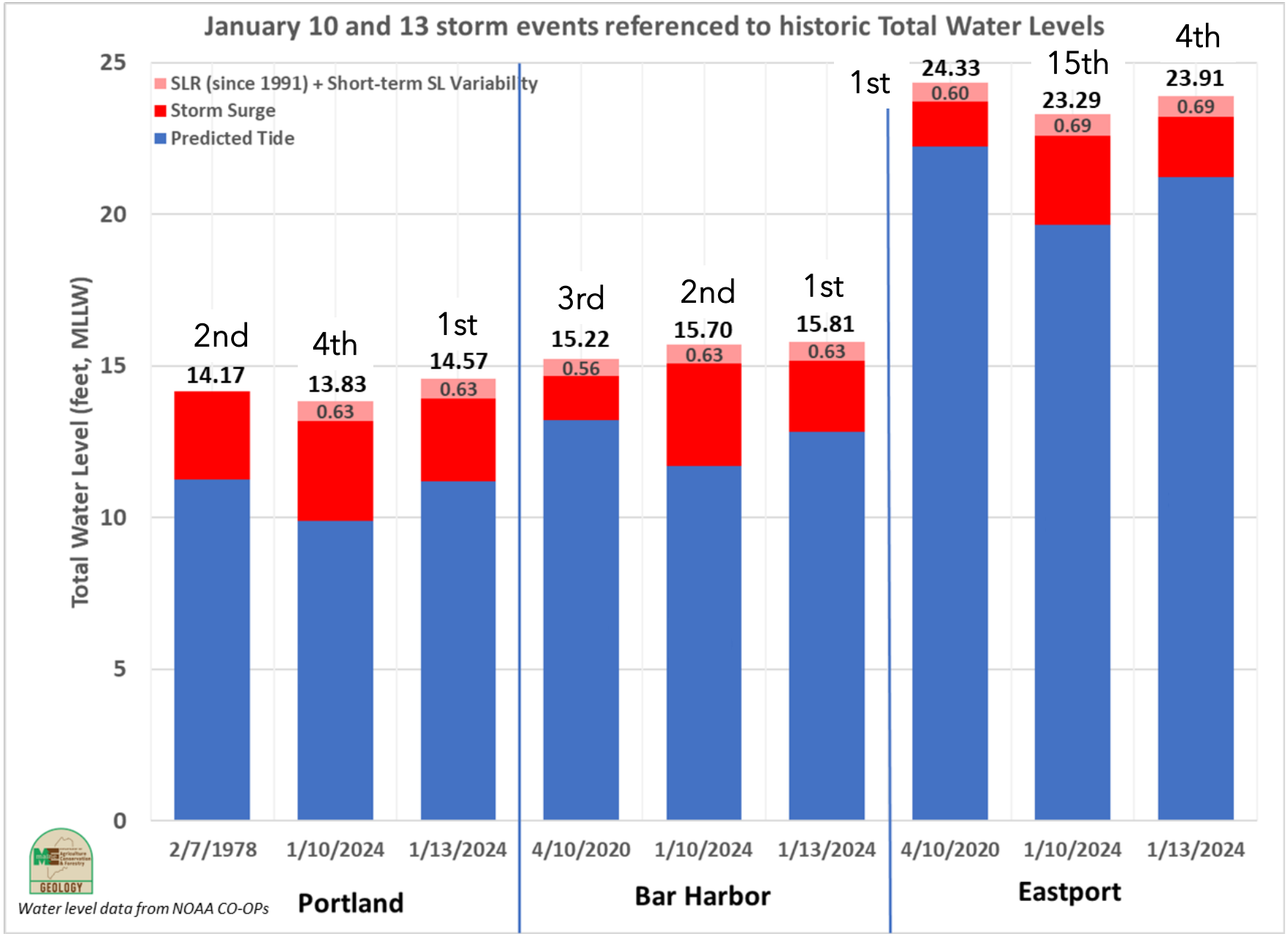


High Tide Nuisance Flooding along the Maine coast has increased and will continue to increase with sea level rise and a lunar nodal cycle.





The January 10th and 13th storm events set records along the Maine coastline, and were *enhanced by sea level rise*



3/10/24 Storm (prelims):
Portland:13.32 (8th)
Bar Harbor: 15.28 (3rd)
Eastport: 23.72 (7th)

Marine

Nichole Price
Bigelow Laboratory for Ocean Sciences

**Scientific &
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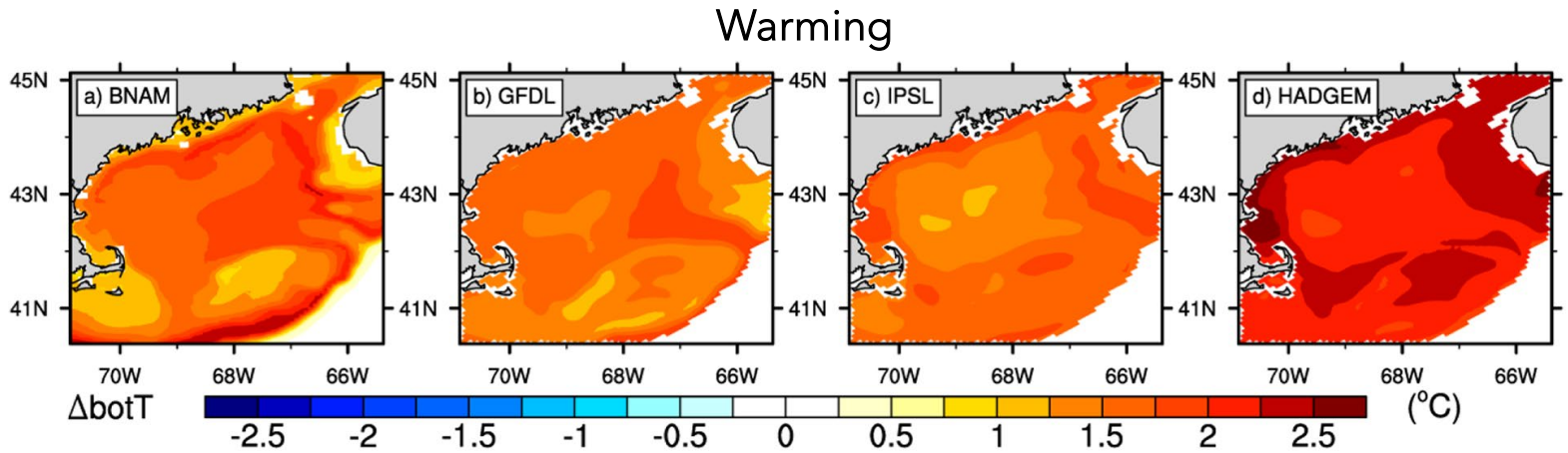
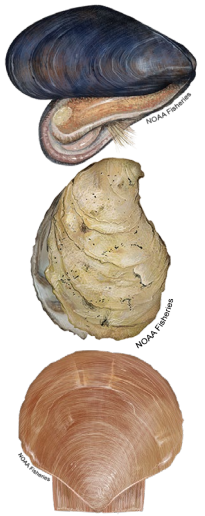
Acidification & Seawater Warming by 2050

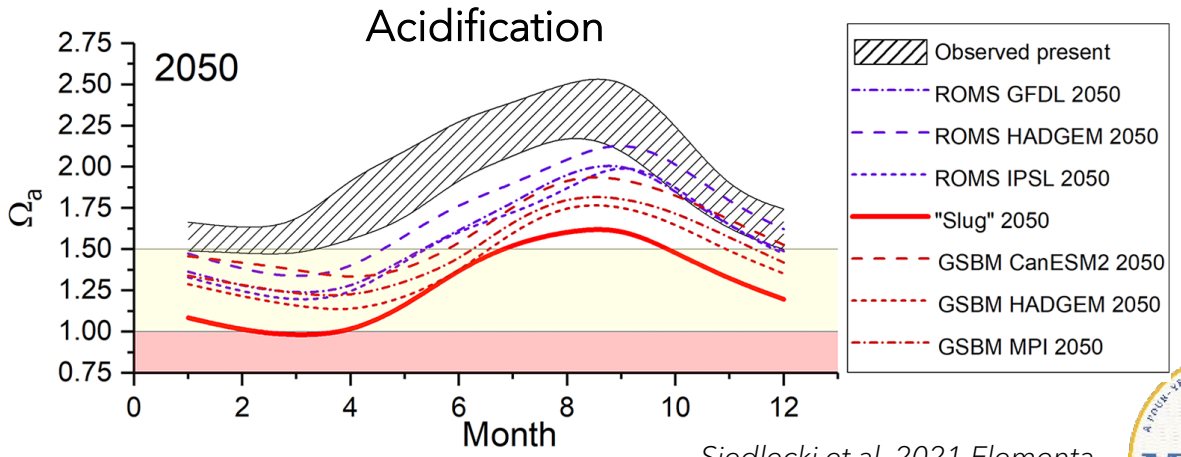
- Updated models project seafloor warming of up to 2.75 °C by 2050
- These same new models now project that aragonite saturation state will be below critical thresholds for shellfish for most of the year by 2050
- These projections for the STS 2024 report are more extreme that reported previously, particularly for acidification



Brickman et al. 2021 Elementa



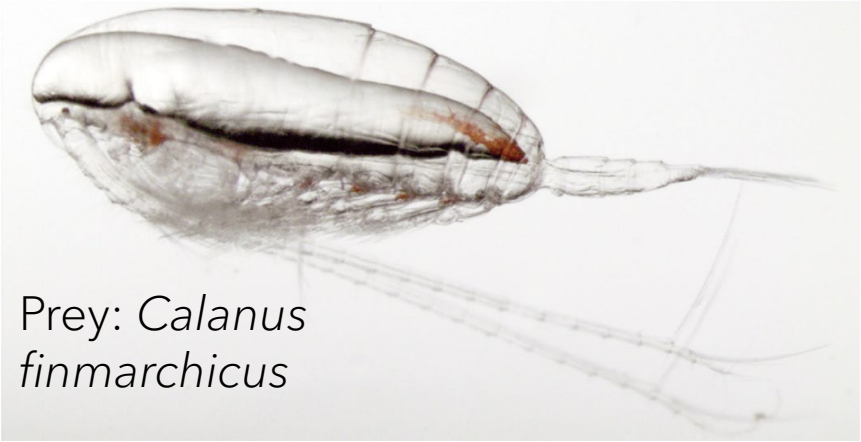
Shellfish Calcification Potential



Siedlecki et al. 2021 Elementa

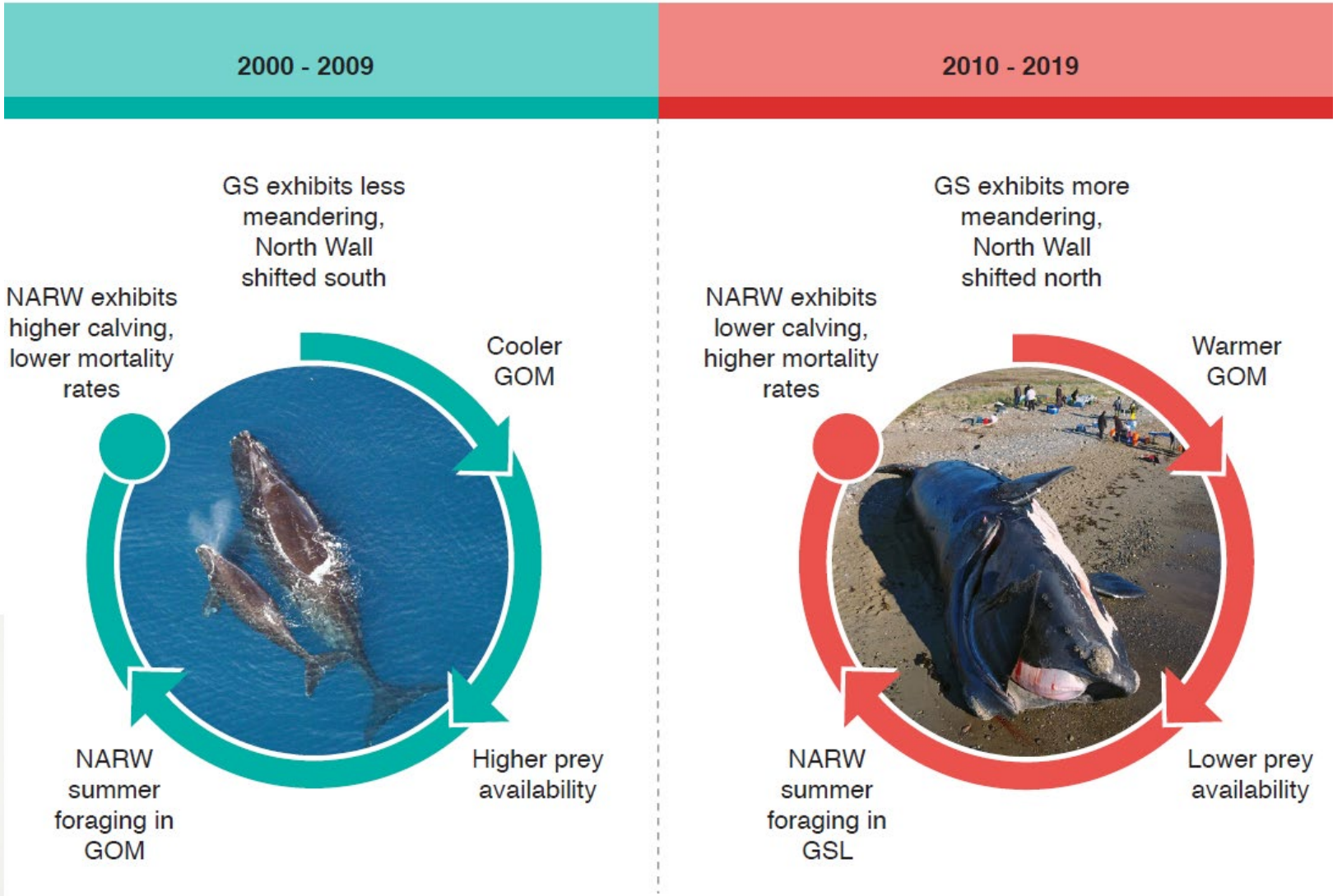
Right Whales

- Higher extinction risks are associated climate-driven changes in foraging environment and habitat use
- Modeling efforts to understand prey re-distribution patterns are now used to evaluate likelihood of strikes and entanglement in particular regions



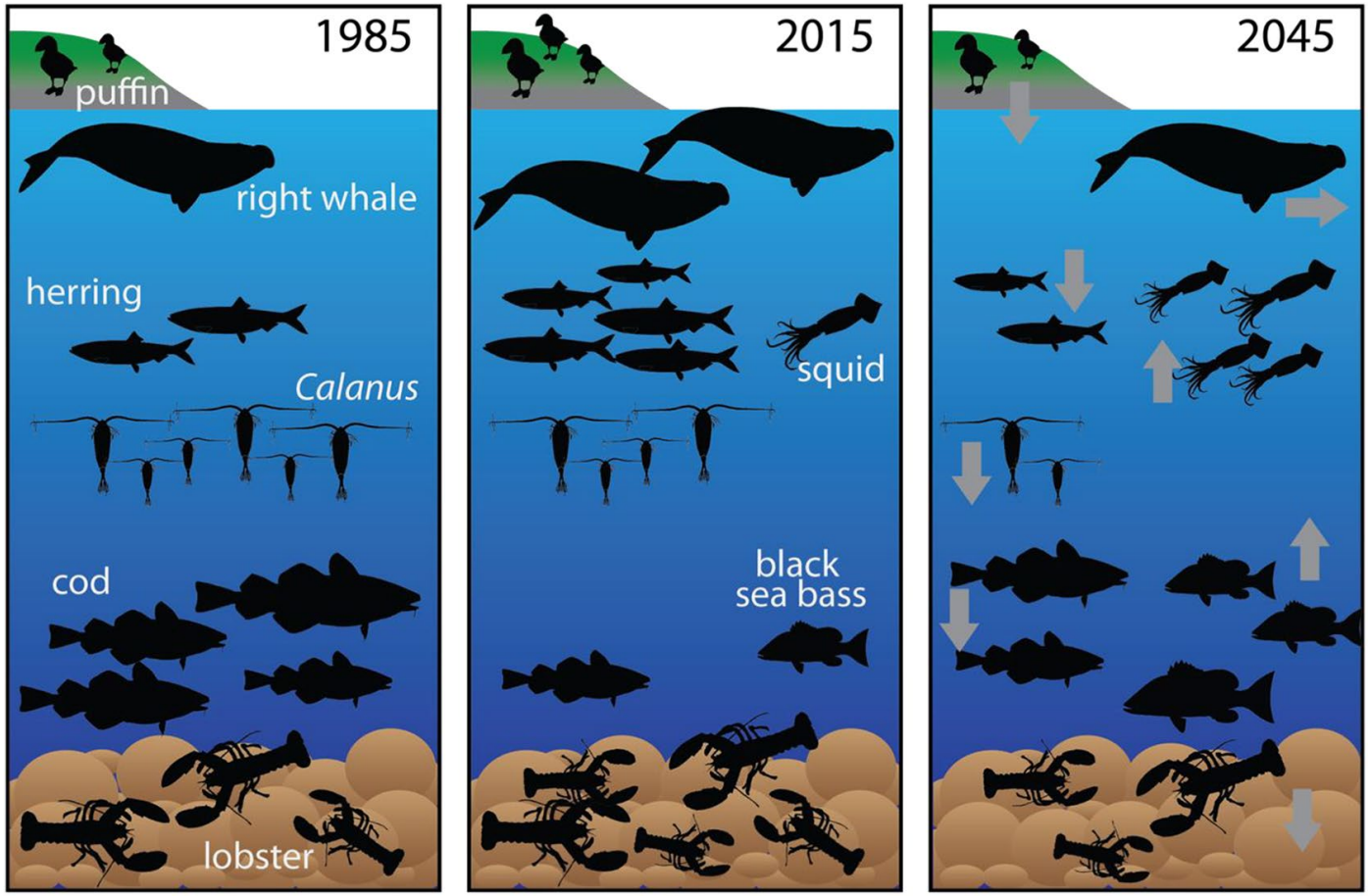
Prey: *Calanus finmarchicus*

Ross et al. 2023 Marine Ecology Progress Series



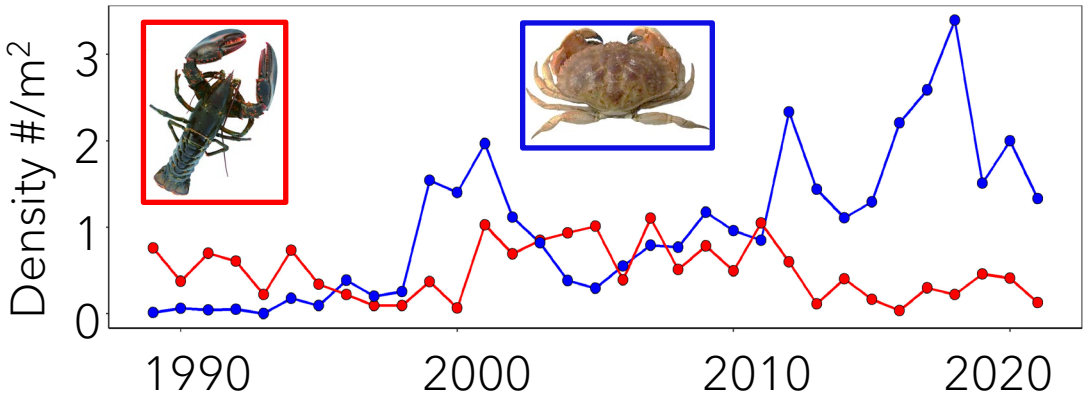
Meyer Gutbrod et al. 2021 Oceanography

Wild Capture Fisheries



Pershing et al. 2021 Elementa

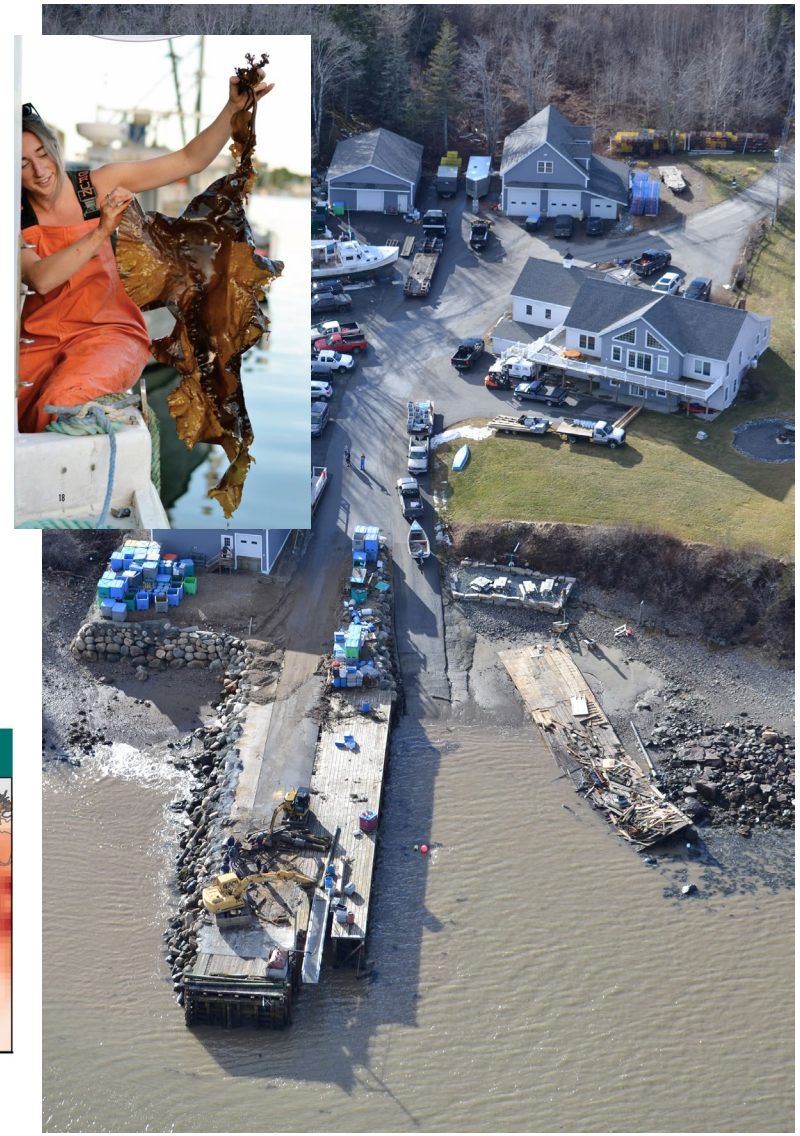
- Lobster fisheries continue to report relatively slowed landings, consistent with climate-driven predictions
- The timing of lobster egg hatch and zooplankton seasonality has become mismatched; shifted phenologies contribute to other species losses
- Subpolar species are projected to continue to decline, but certain valuable temperate species are rising in abundance, as predicted (e.g., squid, sea bass, Jonah crabs)



MacManus et al. 2023 Frontiers in Marine Science

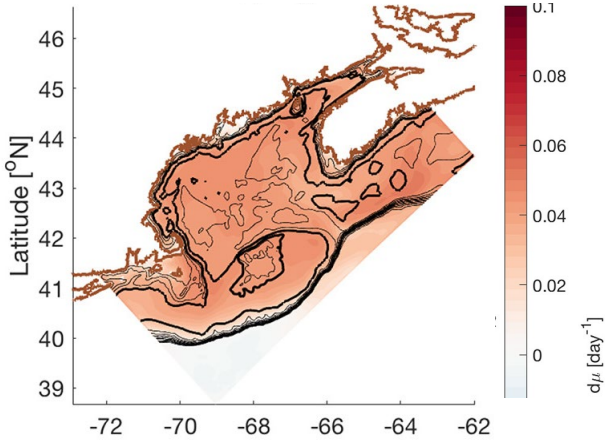
Aquaculture

- Storm Damage:
  - January storms caused significant flooding and surge along coastal Maine
  - $70.3 million in public infrastructure damage, largely working waterfront
- Heat Waves:
  - Further, sustained exposure to marine heat waves is impacting seaweed brood stock resources for seaweed nurseries
  - Harmful Algal Blooms (HAB) becoming more frequent, last longer, and shifting seasonality

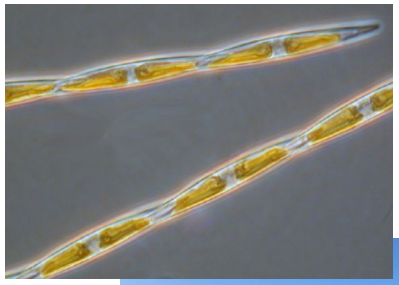


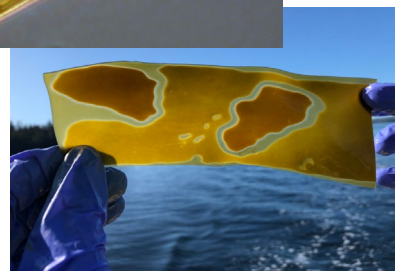
GMRI Annual Report

Projected HAB Growth

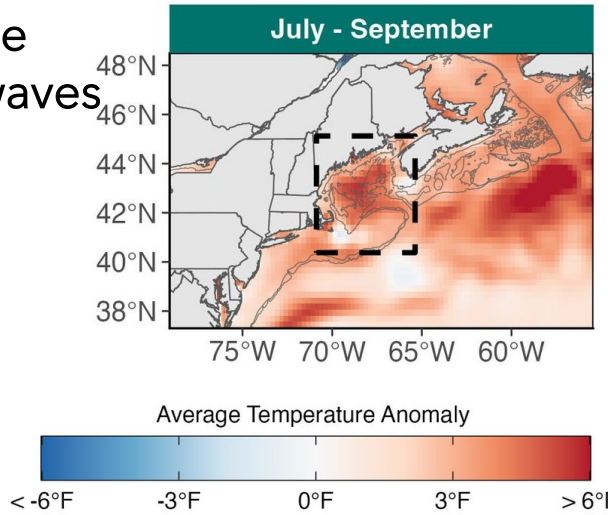


Clark et al. 2022 J. Marine Science



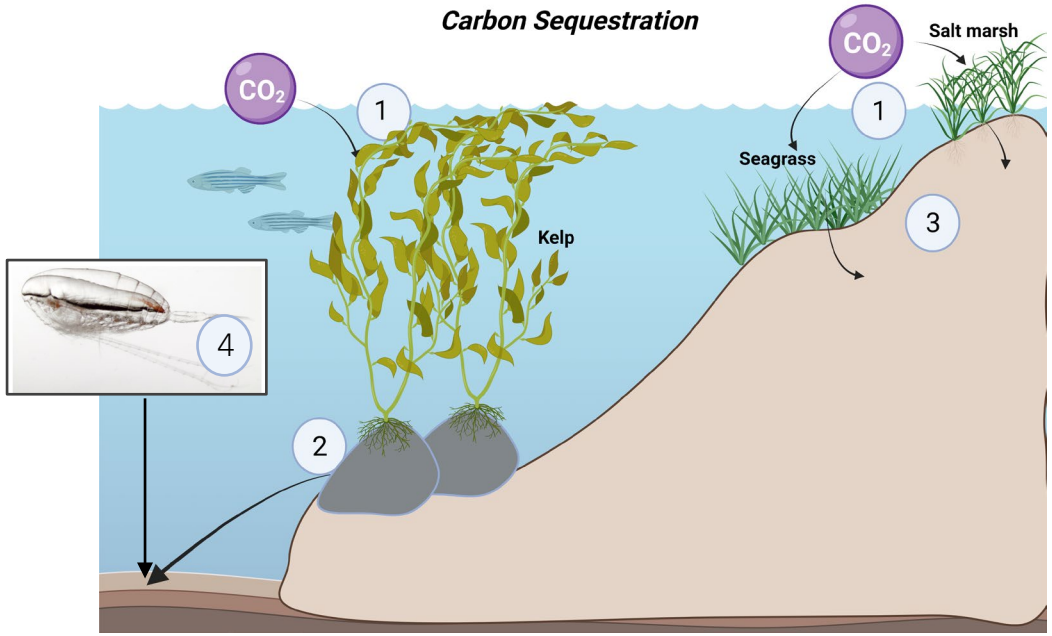


Marine heatwaves



Ocean Climate Mitigation Strategies

- Substantive research underway to establish requisite baselines
- Several funded projects underway to develop or apply tools to assess efficacy
- Continued evaluation of the carbon footprint of fisheries and aquaculture underway



1. Submerged aquatic vegetation captures carbon
2. Seaweed fragments *may be* stored in marine sediments
3. Sea plants transfer carbon to sediments via roots
4. Zooplankton *may* contribute to carbon storage

- **Ongoing exploration of potential ecosystem impacts**
- **Building evidence soundscapes will not disrupt fisheries**
- **Any impacts are likely to be extremely site specific and need to be evaluated case-by-case**

Agriculture & Food

Glen Koehler
Cooperative Extension
University of Maine

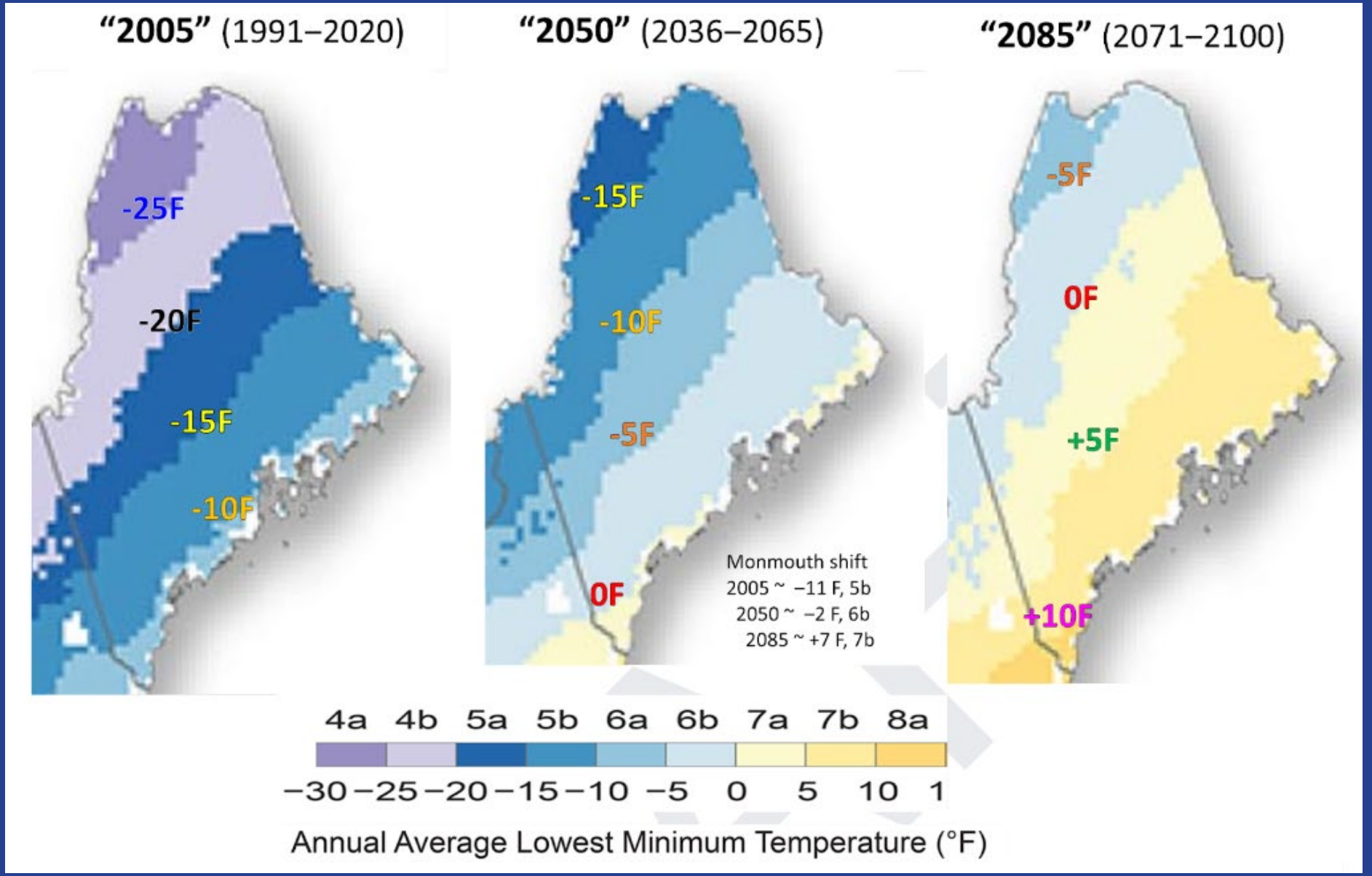
Scientific & Technical Subcommittee Highlights

March 14, 2024

Warming brings both benefits and costs

Higher average annual minimum temperatures allow a wider range of perennial crop options.

And may also increase winter survival of current and new insect, disease, and weed pests.

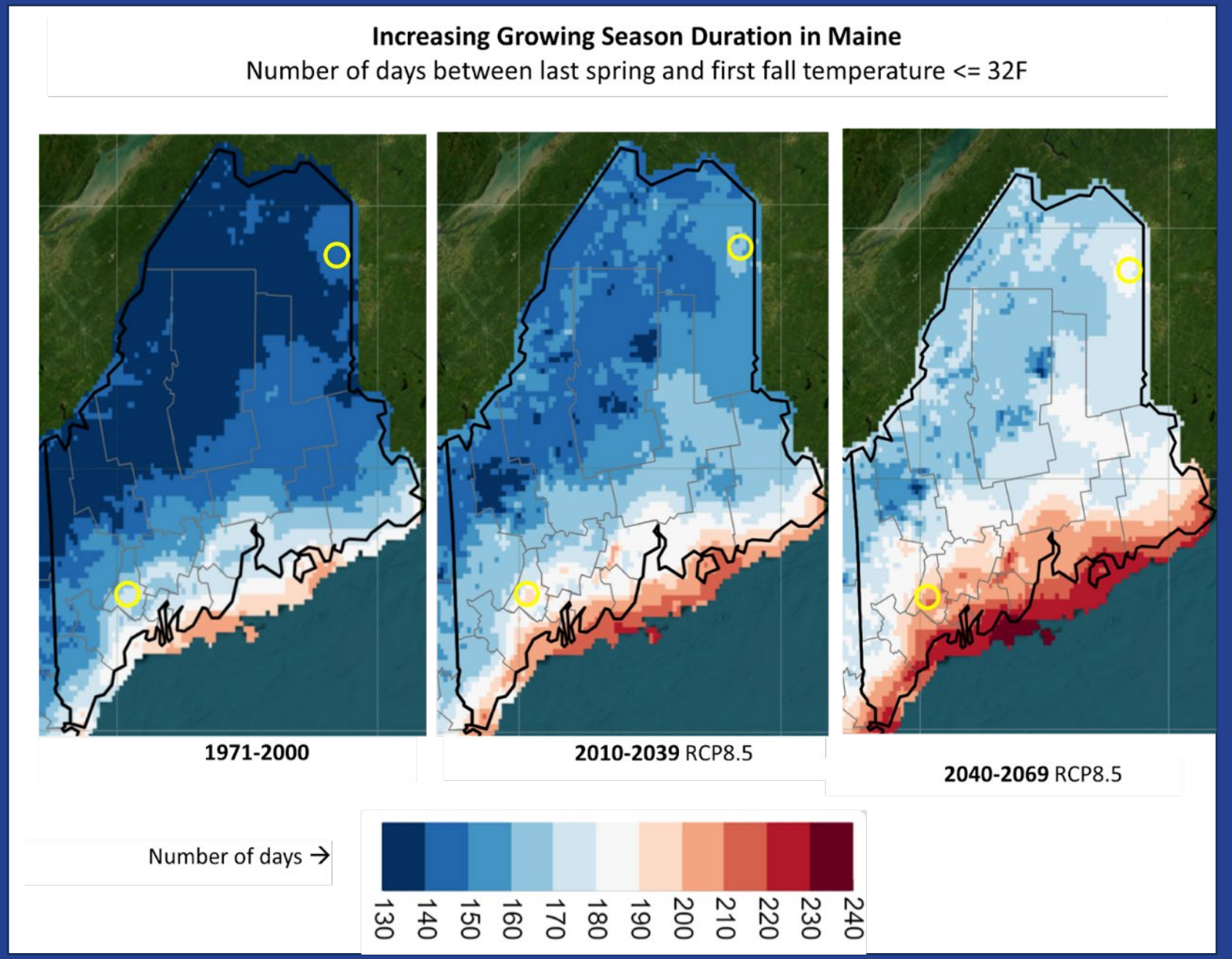


Adapted from USDA 2023

Longer and warmer growing seasons

allow for a wider range of annual and perennial crop options and potential for higher yields.

Observed and projected growing season duration: RCP8.5 future emissions scenario (difference from 1971-2000)				
	1971-2000	**2010-2039**	**2040-2069**	**2070-2099**
PRESQUE ISLE	**145**	**161 (+16)**	**183 (+38)**	**196 (+51)**
LEWISTON	**176**	**195 (+19)**	**212 (+36)**	**223 (+47)**



Adapted from ClimateToolbox

But…Variable and Extreme Weather can counteract any agricultural gains from warming

Apples rendered unsaleable by combination of an early bloom followed by unusually late frost on May 18, 2023

Photos: Glen Koehler

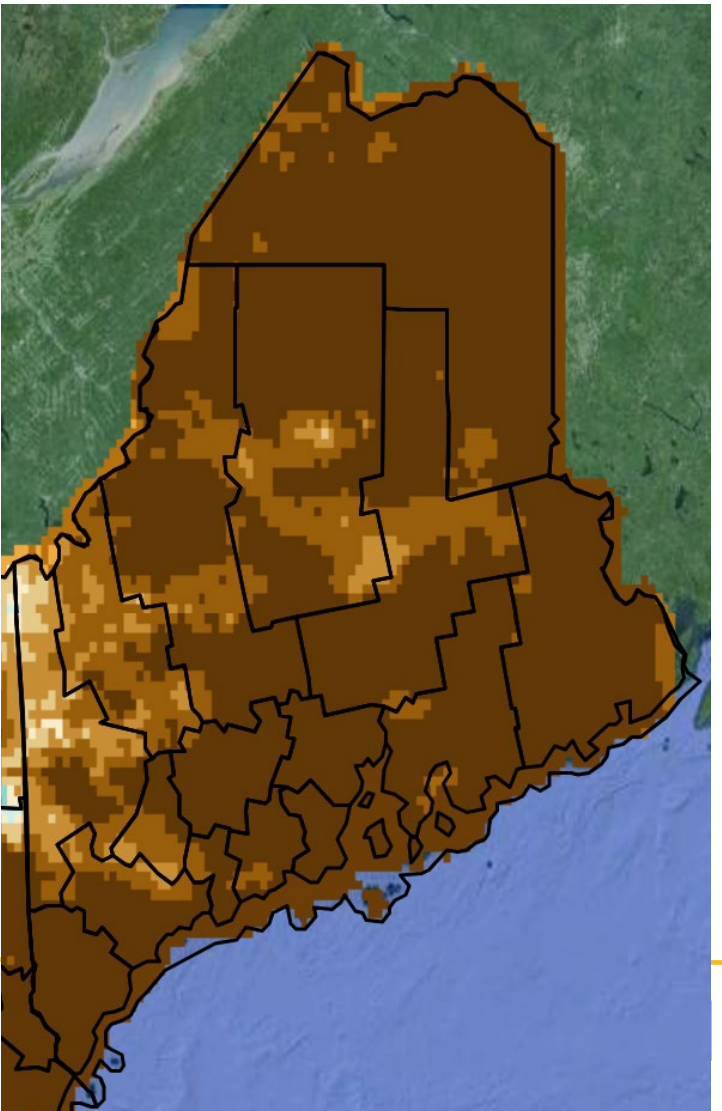
A tale of two seasons

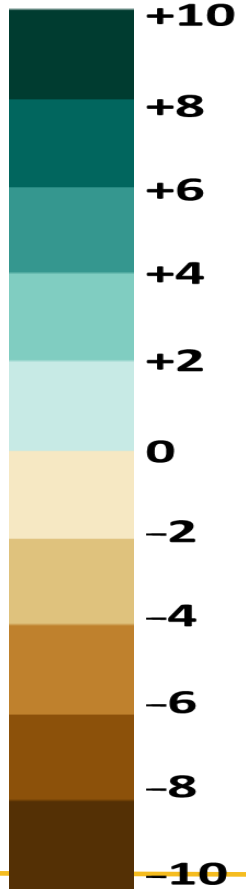
June 1 to September 30

Inches Precipitation minus Evapotranspiration

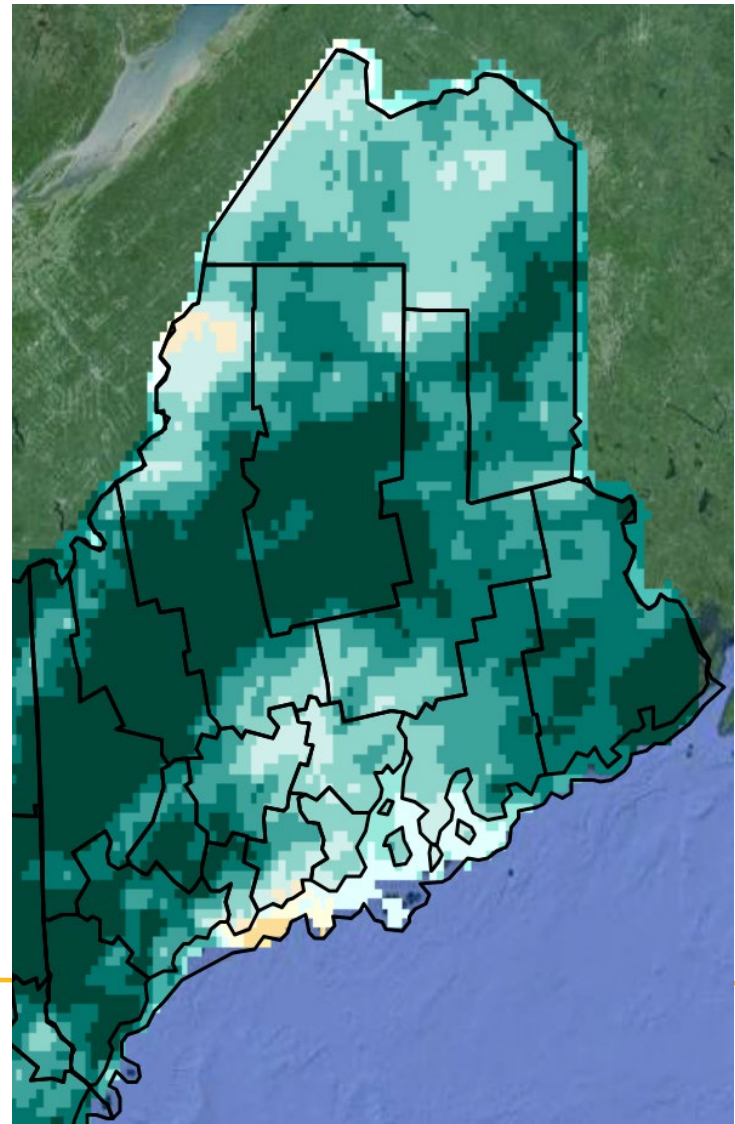
vs. 1990 – 2019 average

2020

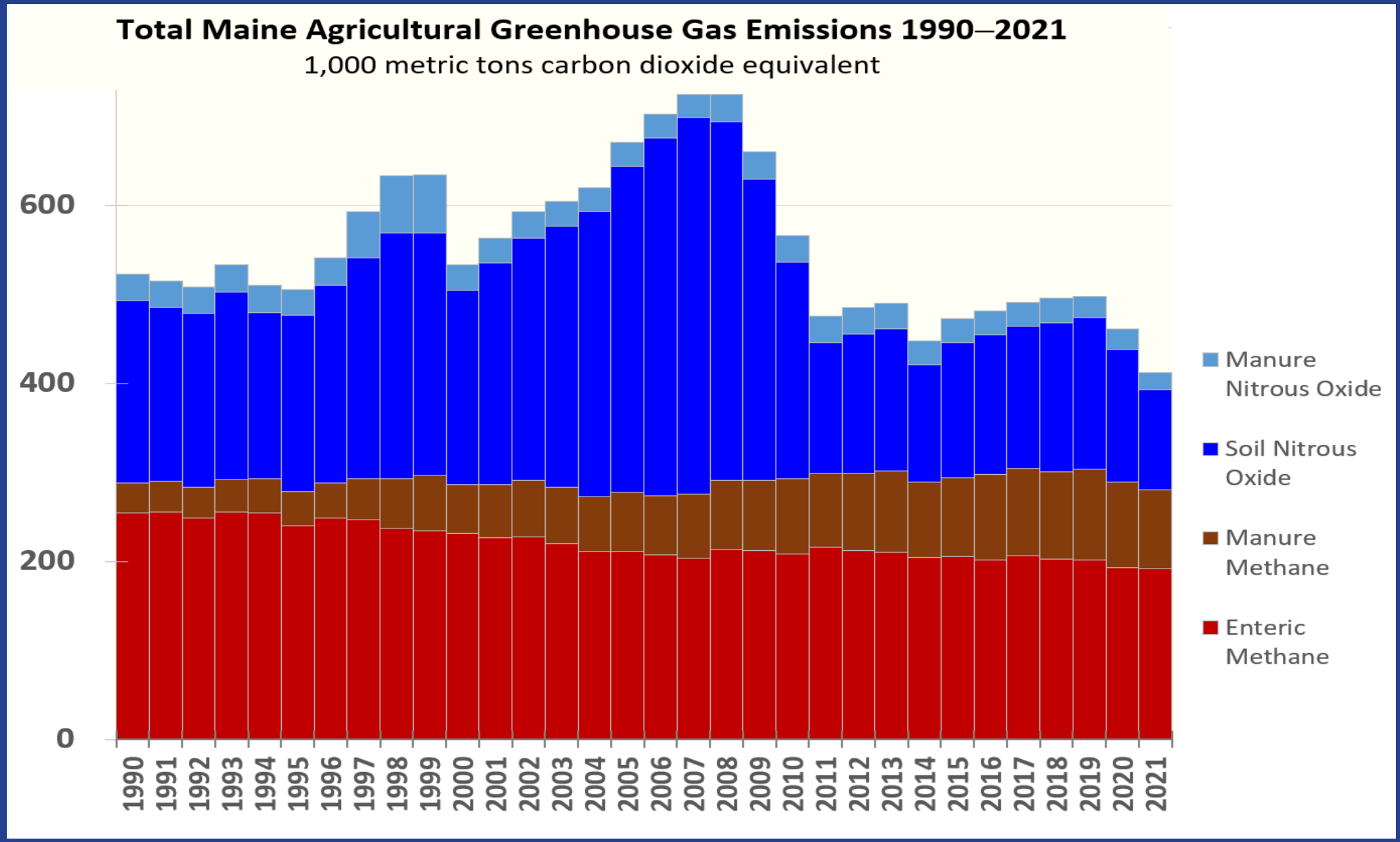




2023

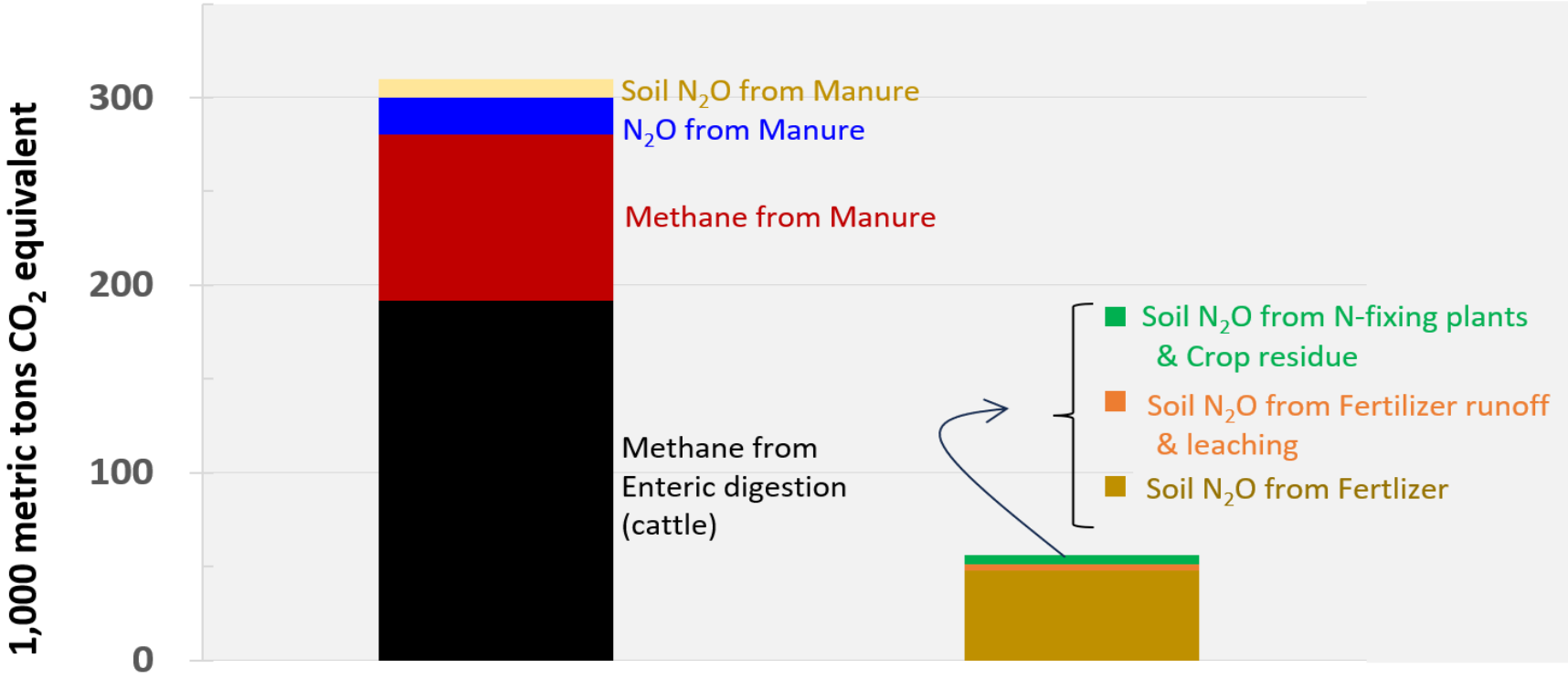


Data and map, ClimateEngine.org, 2024.


Total Maine Agricultural Greenhouse Gas Emissions 1990–2021
1,000 metric tons carbon dioxide equivalent
600
400
200
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Manure Nitrous Oxide
Soil Nitrous Oxide
Manure Methane
Enteric Methane

Maine 2021 Agricultural Greenhouse Gas Emissions: Livestock-only vs. Other Agricultural sources

1,000 metric tons carbon dioxide equivalent



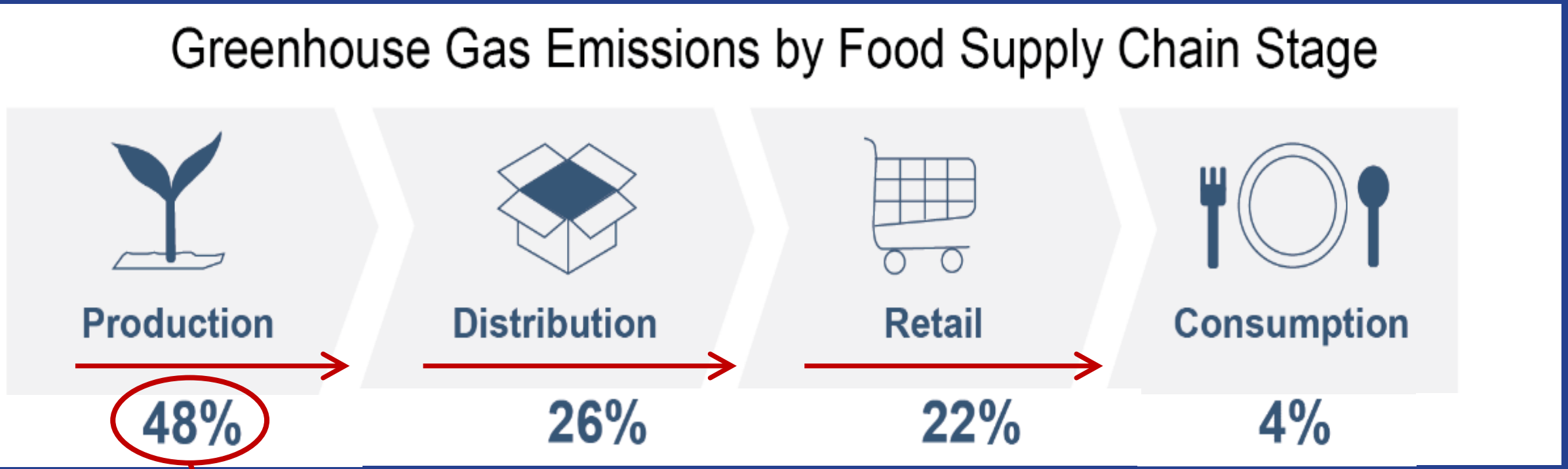
Livestock-only

- includes emissions directly from livestock animals and manure management.

Other Ag sources (including livestock feed)

Hay, pasture, and livestock forage account for ca. 75% of Maine crop acreage, so a large portion of fertilizer use is also livestock-related. CO_2 emissions are 1.1 metric ton from urea fertilizer and too small to display.

Data: Stacy Knapp, Graph: Glen Koehler



Nationally, more than half of food greenhouse gas emissions are off-farm

and in the end…
30+% of food is lost as waste

Data and graph adapted from 5th National Climate Assessment

Forests & Biodiversity

Kristen Puryear
Maine Natural Areas Program

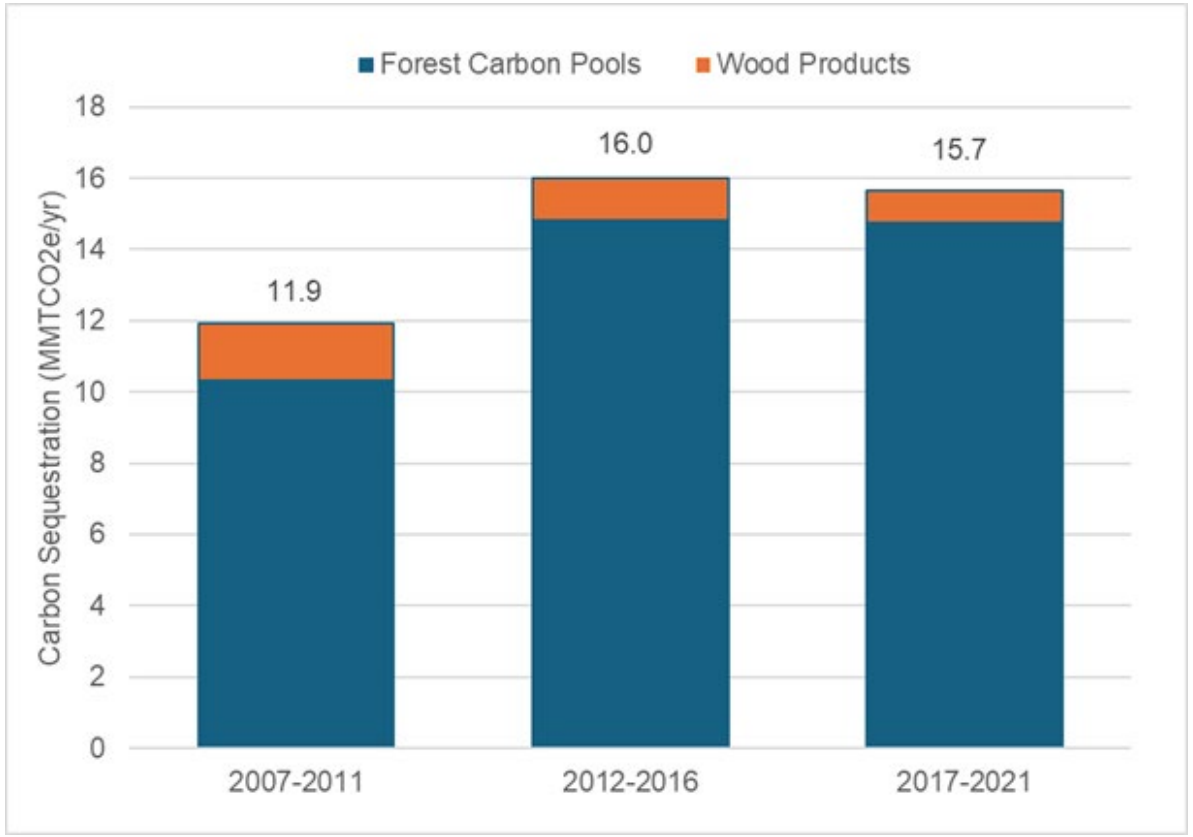
Scientific & Technical Subcommittee Highlights

March 14, 2024

Photo: K. Puryear

Maine Forest Carbon

Maine forest ecosystem and harvested wood product annual average carbon stock change for the last three FIA inventory periods (MMTCO2e/yr)



Maine's forests currently sequester nearly 15 million metric tons of CO2-equivalent per year (MMTCO2e/yr)

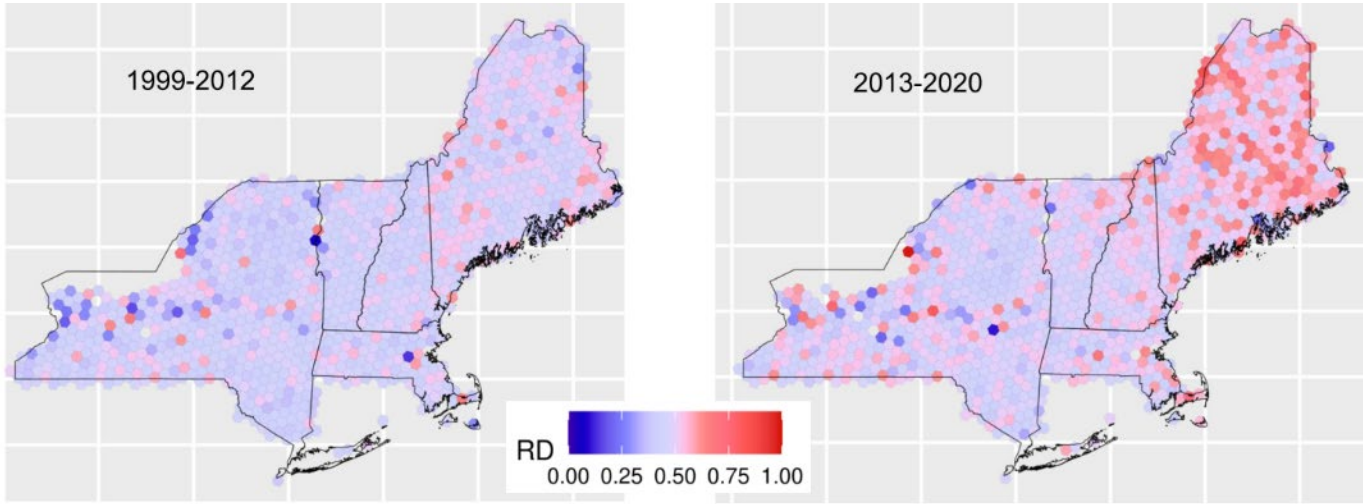
Harvested wood products ~1 MMTCO2e/yr

Together, forests + products offset nearly all of Maine's fossil fuel greenhouse gas (GHG) emissions

Persistently high rates over 10+ years, but emerging threats of pest, disease, fire, etc. could reverse this trend.

Persistent and Emerging Threats: Forests

Forest Relative Density (RD)



Maine's forest at a biological tipping point with ongoing threats from climate change, natural disturbances (e.g. wind, fire), and invasive species

Wildfire Threat

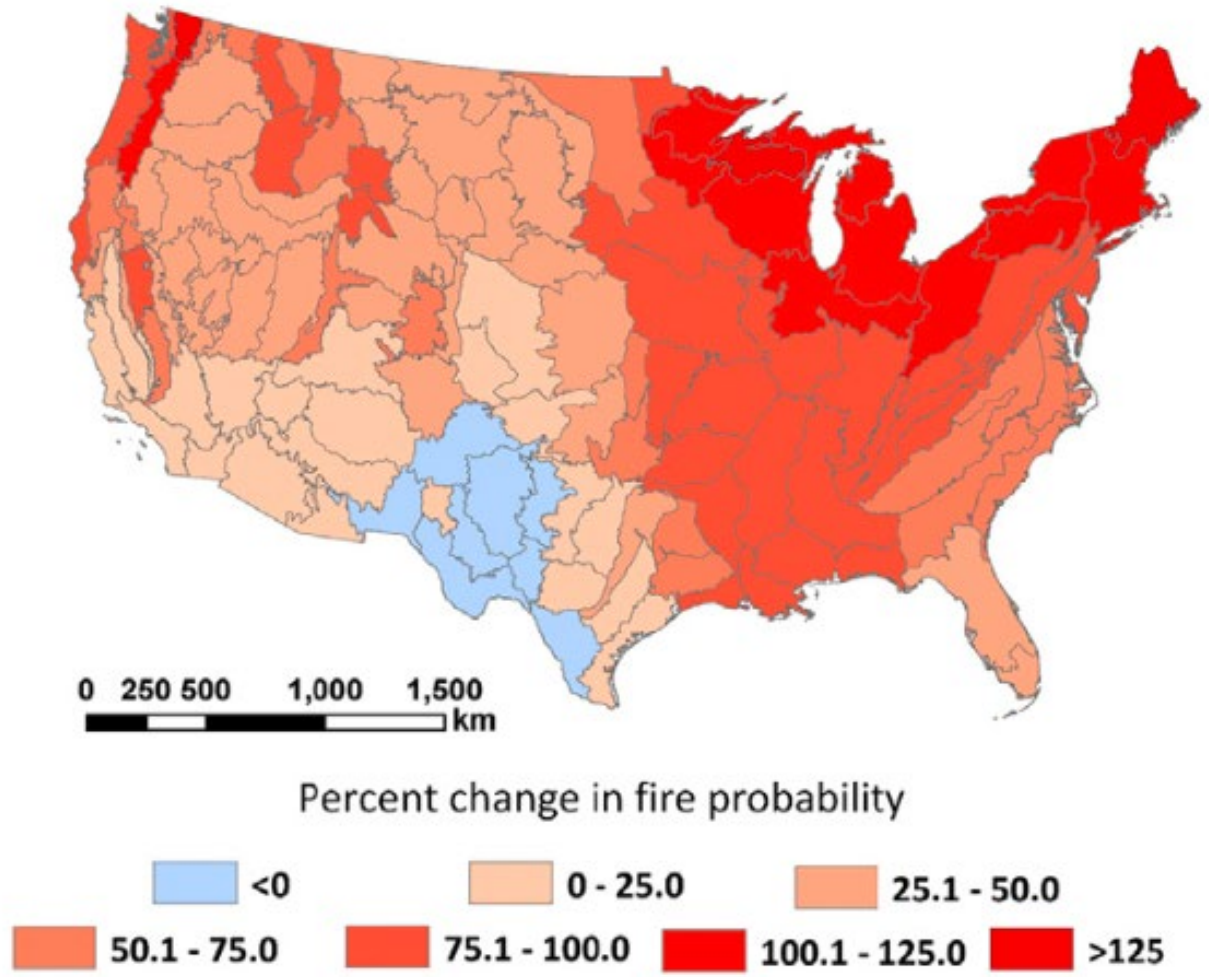
Despite its low fire risk, serious wildfires occurred in Maine, especially during droughts (e.g., 1947)

2023 Nova Scotia wildfires burned 60,000 acres, similar ecosystem

Risks: dense forest fuels, houses in forest interface, lack of wildfire fighting capacity

Relatively low, but increasing wildfire probability in Maine due to climate change

For the most pessimistic emissions scenario, northeastern fire risk is expected to more than double



Projected changes (%) in annual fire probability from baseline (1971-2000) to late century (2070-2099) based on Greenhouse Gas Emissions Scenario RCP 8.5.

Opportunities and Barriers to Adaptation

Active & passive adaptation can enhance, maintain, and restore the mitigation value of forests.

Rural foresters were concerned most with warming winters and declining tree vigor; urban foresters cite extreme weather and safety hazards from storm-damaged trees as highest concerns.

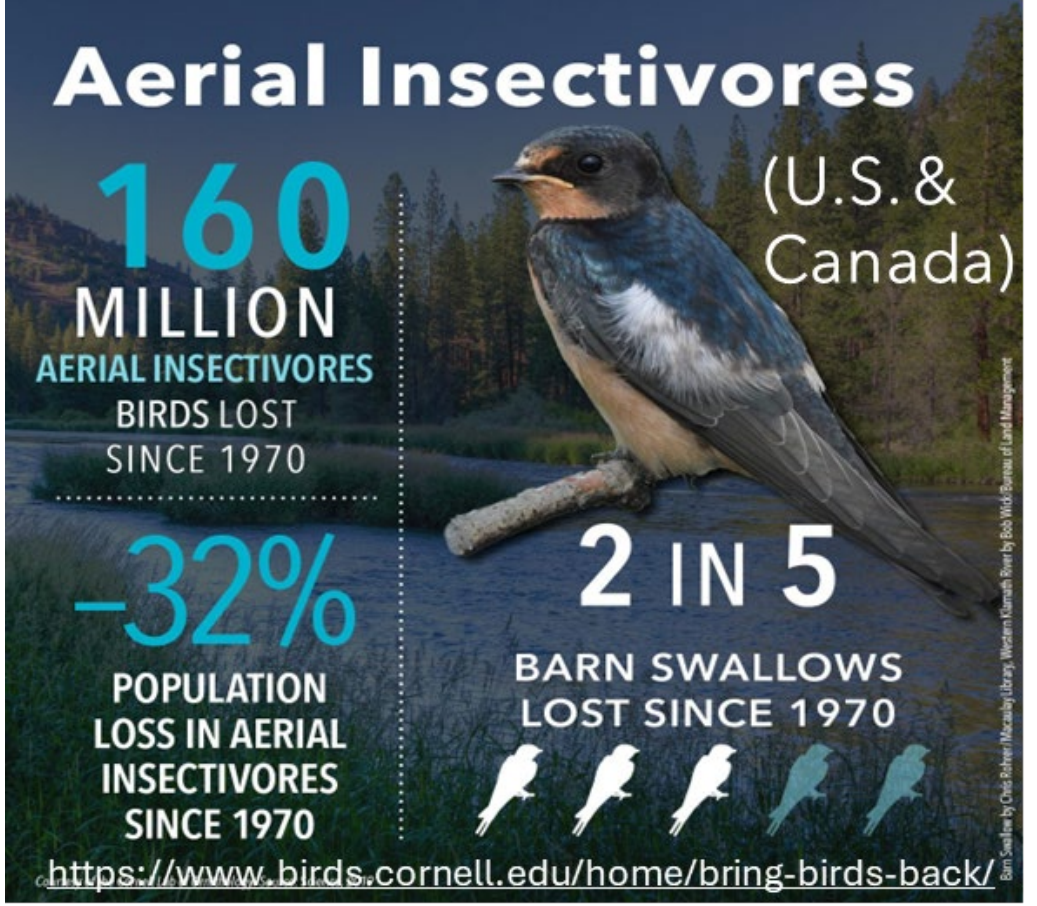
Many forest managers believe adaptation is a priority, however there are many barriers that they face:

- Increased public use on conserved lands
- Public opposition to harvesting
- High costs of treatments & limited timber markets
- Information at relevant spatial scales
- Determining appropriate on-the-ground management

Status of Biodiversity

Species impacts

- 8 wildlife species added to Maine's Endangered and Threatened Species List (in 2023)
- 21% of Maine's butterflies are listed rare/threatened/endangered/extirpated (25% due to climate change)
- With 3°C warming, range shifts predicted for 100 N. American bird species (including Loons)



Habitat impacts

- Temperature - seasonal mismatch, parasites, diseases
- Food webs & interspecies response - invasive plants and animals


Invasive green crab

Persistent and Emerging Threats

Habitat loss is still the primary driver of species loss

Direct and compounding climate-related effects are increasing, including:

- Invasive species - new and expanding
- Stream temperature increases
- Sea level rise
- Stream flooding

Japanese stiltgrass (photo: MNAP)

Saltmarsh sparrow (photo: B. Bienvenuti)

Brook trout

Spring salamander (photo: T. Parsons)

Opportunities and Considerations

Diverse landscapes support species diversity

Biodiversity protection yields nature-based solutions

Connected landscapes and corridors buffer climate impacts

Borestone view (photo: D. Cilley)

Walton's Mill dam removal (photo: B. Emerson)

Information Needs

Stephen M. Dickson
Maine Geological Survey

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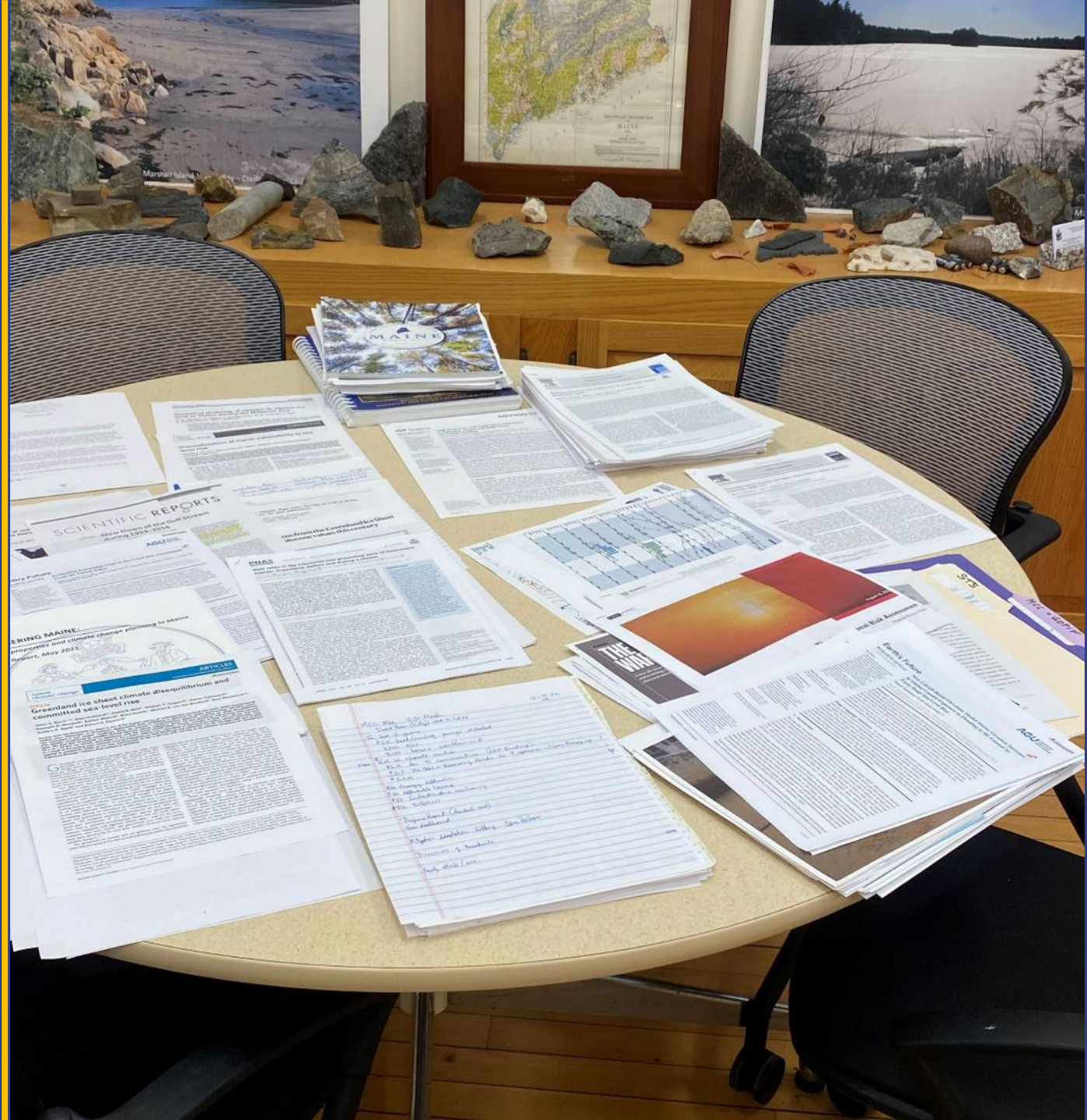

Land & Air

a. **Agriculture** – Interpreting weather forecasts to support decisions by growers; site-specific trends in seasons and frost matter
b. **Biodiversity** – Projections of invasive species; track range and populations of endangered and threatened species; map forest changes
c. **Forests** – Projected health / biomass / tree carbon / soil carbon / Indigenous knowledge included in assessments
d. **Climate** – Study high-impact storms & trends; real-time hydrology & drought monitoring; track solar irradiation & clouds
e. **Air** – Expand monitoring statewide for particulate matter (PM), ozone & pollen

Water

f. **Water Quality** – Predict harmful algal blooms (HABs); develop fast toxin sensing; understand bioaccumulation up the food chain; connect to human health and advisories; expand stations and data types

g. **Hydrology** – Wetland hydrology & water balance; expand stream gauges and snowpack monitoring; improve detailed river flood mapping and forecasting

h. **Marine** – Better local monitoring of deep-water temperatures, coastal nutrients, marine HABs & bacteria; expand water level sensors; model future erosion from sea level rise (SLR); improve guidance for storm preparedness and coastal adaptation

People

i) Human Dimensions –
   a) Address mental health from extreme physical conditions; inability to adapt; loss of cultural heritage; develop public health interventions and care
   b) Project climate migration and tourism; relate demographics to housing, transportation, power grid & economics
   c) Evaluate vulnerability and readiness in terms of both socioeconomics and infrastructure
   d) Understand ticks & pathogens

The Science of Hope

Susie Arnold
Island Institute

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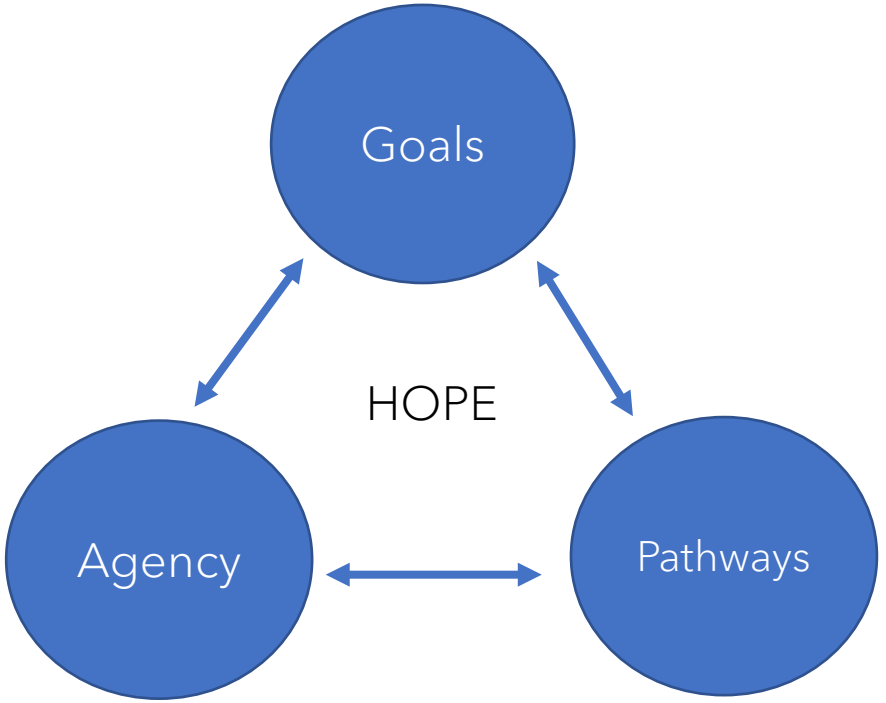
March 14, 2024

3 Primary Components of Constructive Hope

HOPE = Goal Setting + Agency Thinking (Willpower) + Pathways Thinking (Waypower)



- **Goal**- do you have a meaningful goal?
- **Agency**- do you have the knowledge or determination that gives you confidence you can achieve your goals
- **Pathways thinking**- do you have a plan and willingness to tweak your plan

Hope-Based Communications

Where hope is activated mitigates where anxiety is activated

Global Environmental Change 76 (2022) 102569

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Climate anxiety: Conceptual considerations, and connections with climate hope and action

Julia Sangervo [a,*,3], Kirsti M. Jylhä [b,1,4], Panu Pihkala [c,2,5]

- Climate anxiety can lead to both action and paralysis
- *Hope increased climate action more than anxiety*
- A need to promote feelings of constructive hope to encourage climate action

Comment | Published: 10 May 2023

Climate change anxiety in young people

Janis Whitlock

Nature Mental Health **1**, 297–298 (2023) | Cite this article

- Coordinate opportunities for discussion, supply opportunities to exercise agency, and avenues for meaningful action

PRACTICE BRIDGE | JULY 30 2021

Empowering hope-based climate change communication techniques for the Gulf of Maine

Collections: Knowledge Domain: Sustainability Transitions , Special Feature: Gulf of Maine 2050: Visioning Regional Resilience and Sustainability

Aimee Bonanno, Megan Ennes, Jennifer A. Hoey, Emily Moberg , Sarah-Mae Nelson, Nette Pletcher, Richelle L. Tanner

* Email: emily.a.moberg@gmail.com

Elementa: Science of the Anthropocene (2021) 9 (1): 00051.

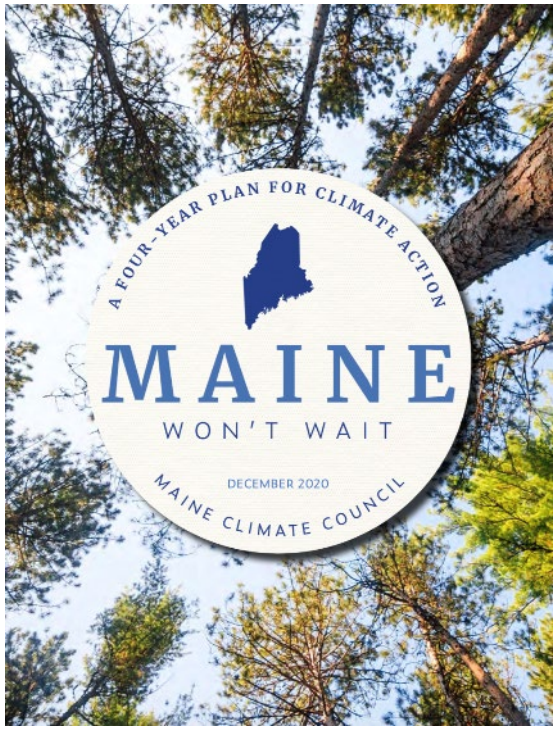
- Communications models that further engagement in climate conversations involve:
  - Head (understanding climate change)
  - Heart (hope through agency and efficacy)
  - Hands (intentions to participate in action)

Social Connectedness- A Predictor of Hope & Important for Building Resilience in Rural Communities

NNOCCI National Network for Ocean and Climate Change Interpretation

Hope is a Framework for Action

Illustration by Ashley Quay



Reflections

2024 Maine Climate Council Meetings

- **June 18, 2024** – In person, Augusta Civic Center
- **September 25, 2024** – Zoom
- **October 23, 2024** – Zoom
- **November 21, 2024** – In person, location TBD


A FOUR-YEAR PLAN FOR CLIMATE ACTION
MAINE
WON'T WAIT
DECEMBER 2020
MAINE CLIMATE COUNCIL