# Climate Change in the Great Lakes Region

## Starting a Public Discussion

Tonight:

# Effects of Climate Change on the Fish and Fisheries of the Great Lakes Basin


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www.seagrant.wisc.edu/ClimateChange

# OVERVIEW

**PART 1 - PAST AND FUTURE CHANGES IN CLIMATE**

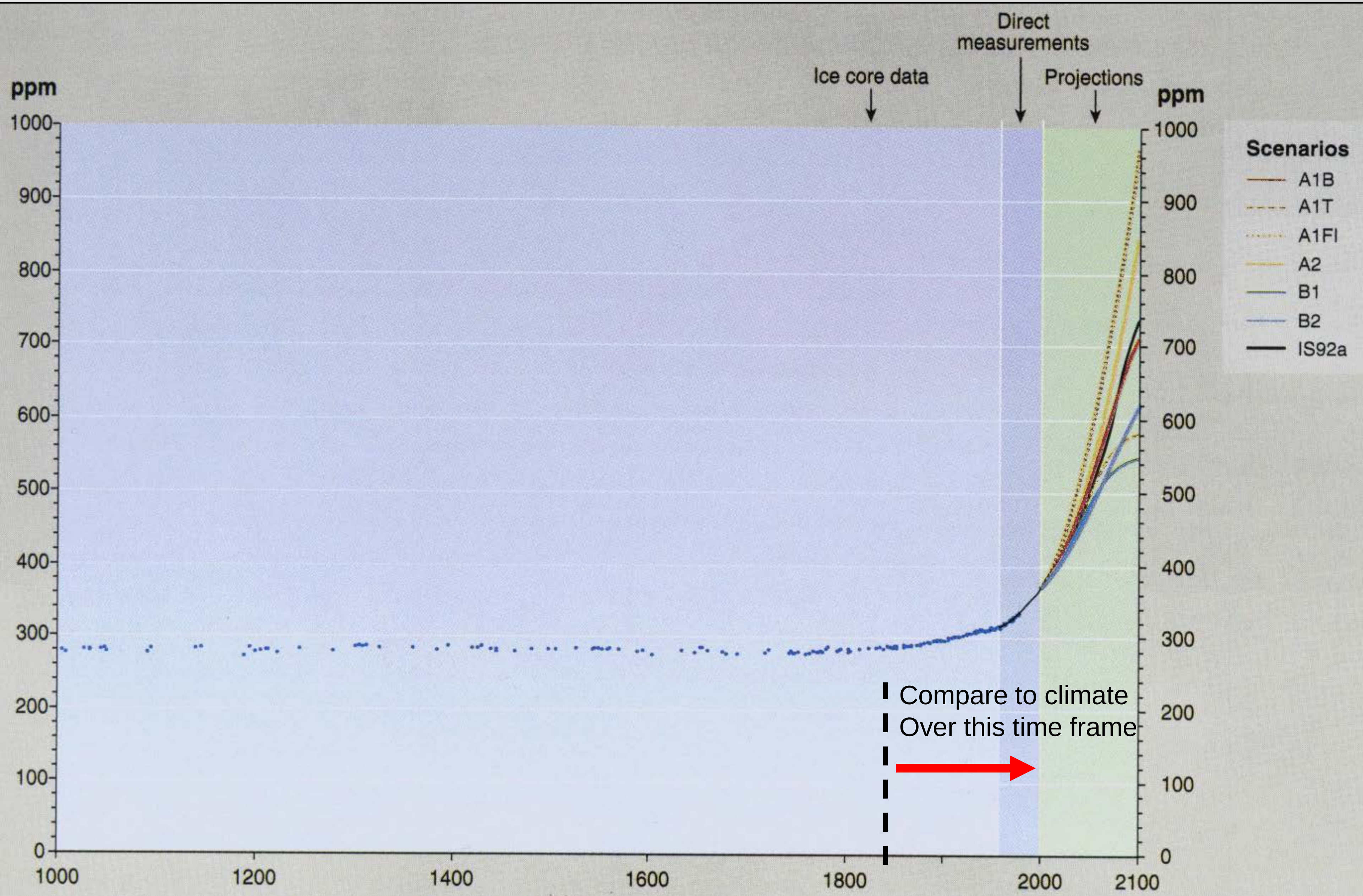
**PART 2 – IMPACTS ON LAKE ENVIRONMENTS**

**PART 3 – IMPACTS ON FISH AND FISHERIES**

# PART ONE

# PAST AND FUTURE CHANGES IN CLIMATE

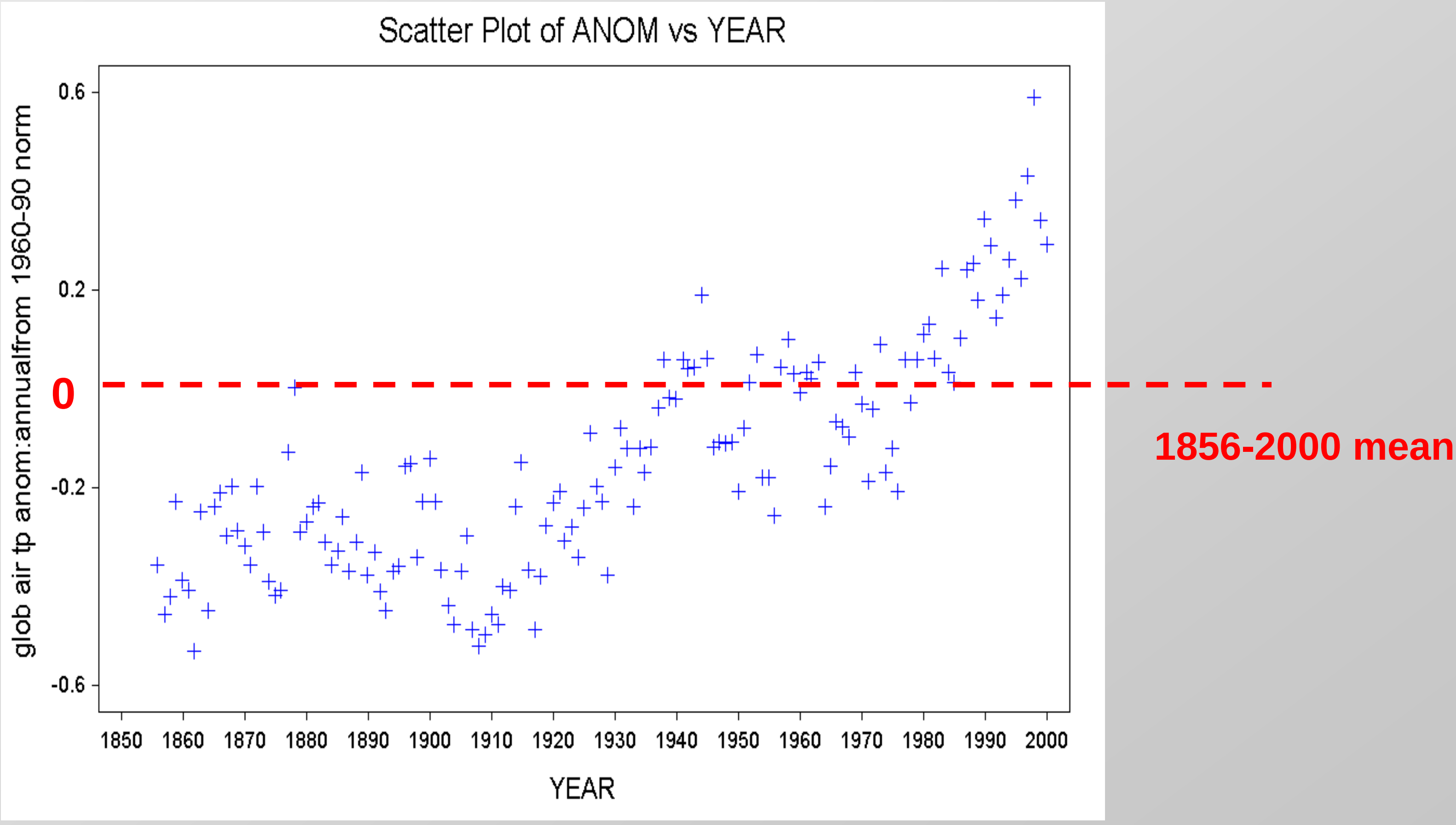
# Past and Present $CO_2$ Levels in the Atmosphere




(Source: IPCC, 2001. Climate Change 2001: Synthesis Report - Figure SPM-10a on Page 33)

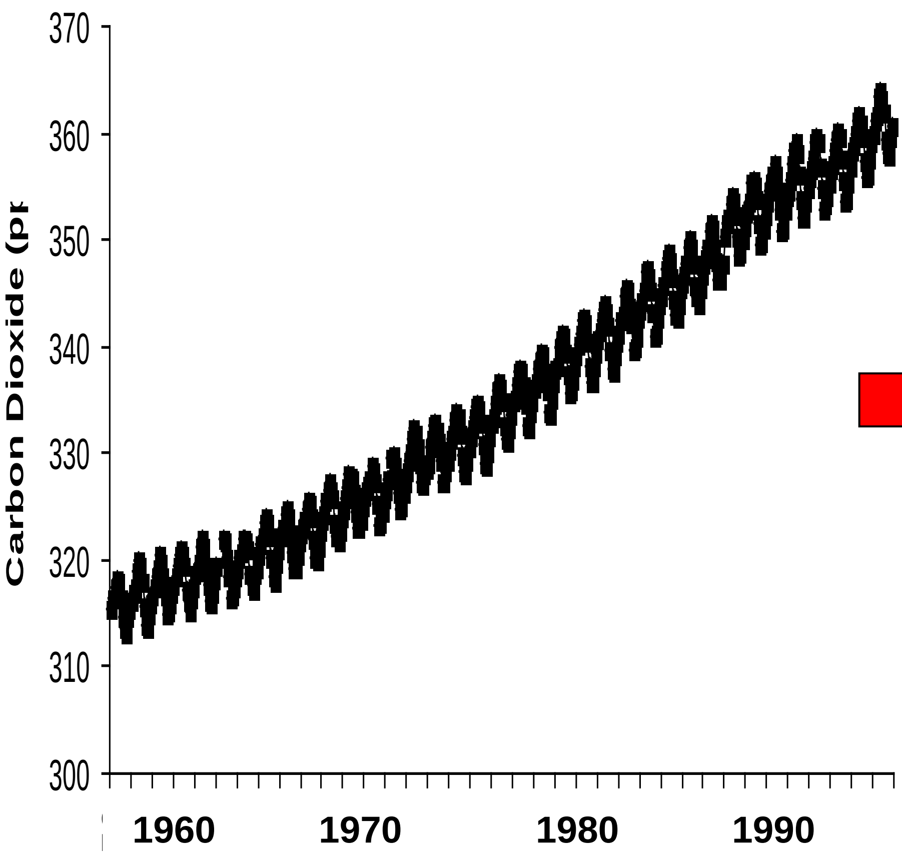
# Global Annual Air Temp Index 1856-2000

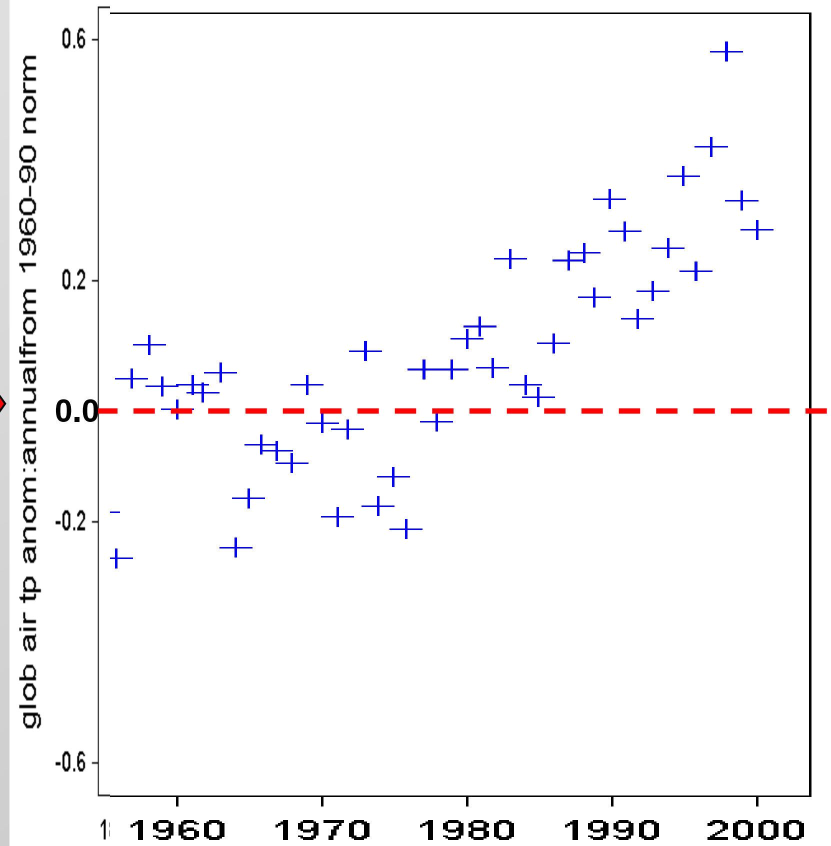
(global annual air temp, measured as deviations from the **1856-2000 mean**)



# Recent (1960- present) Trends Match ………

**Carbon Dioxide** **Global Air Temp**

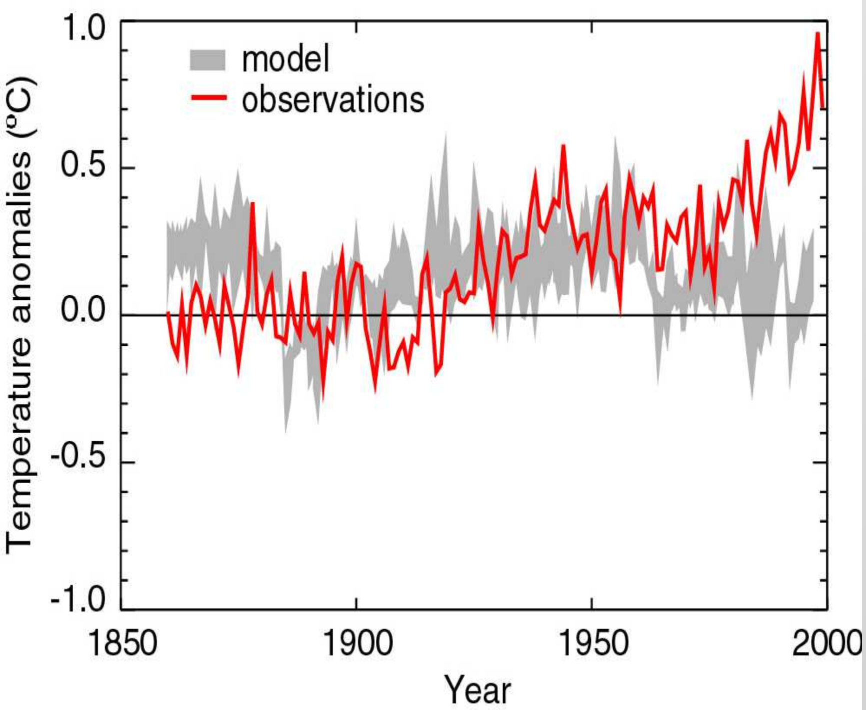


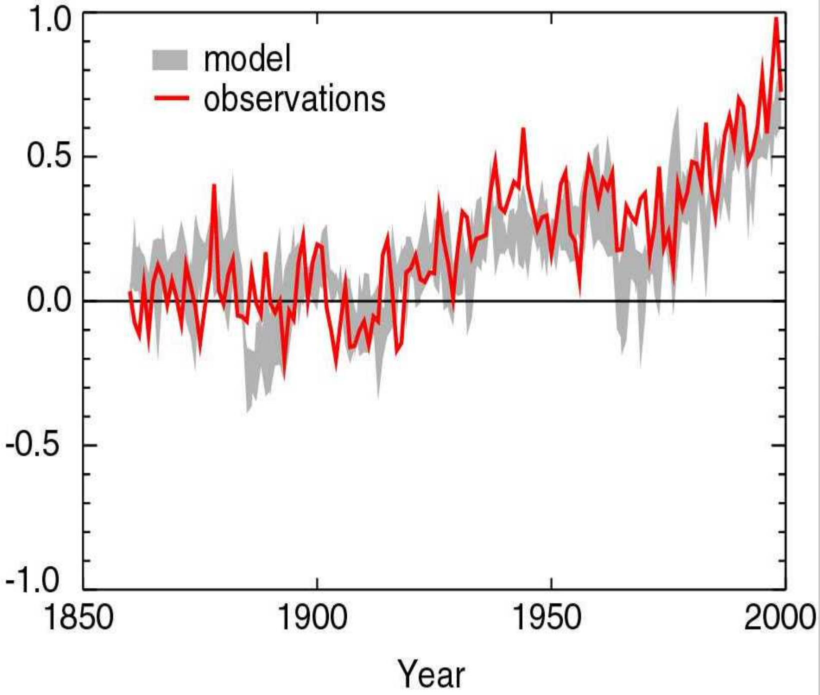




**YEAR**

**Natural forcings alone do not explain observed warming in 2nd half of century…simulations including JUST natural forcings cannot predict recent warming trends.**

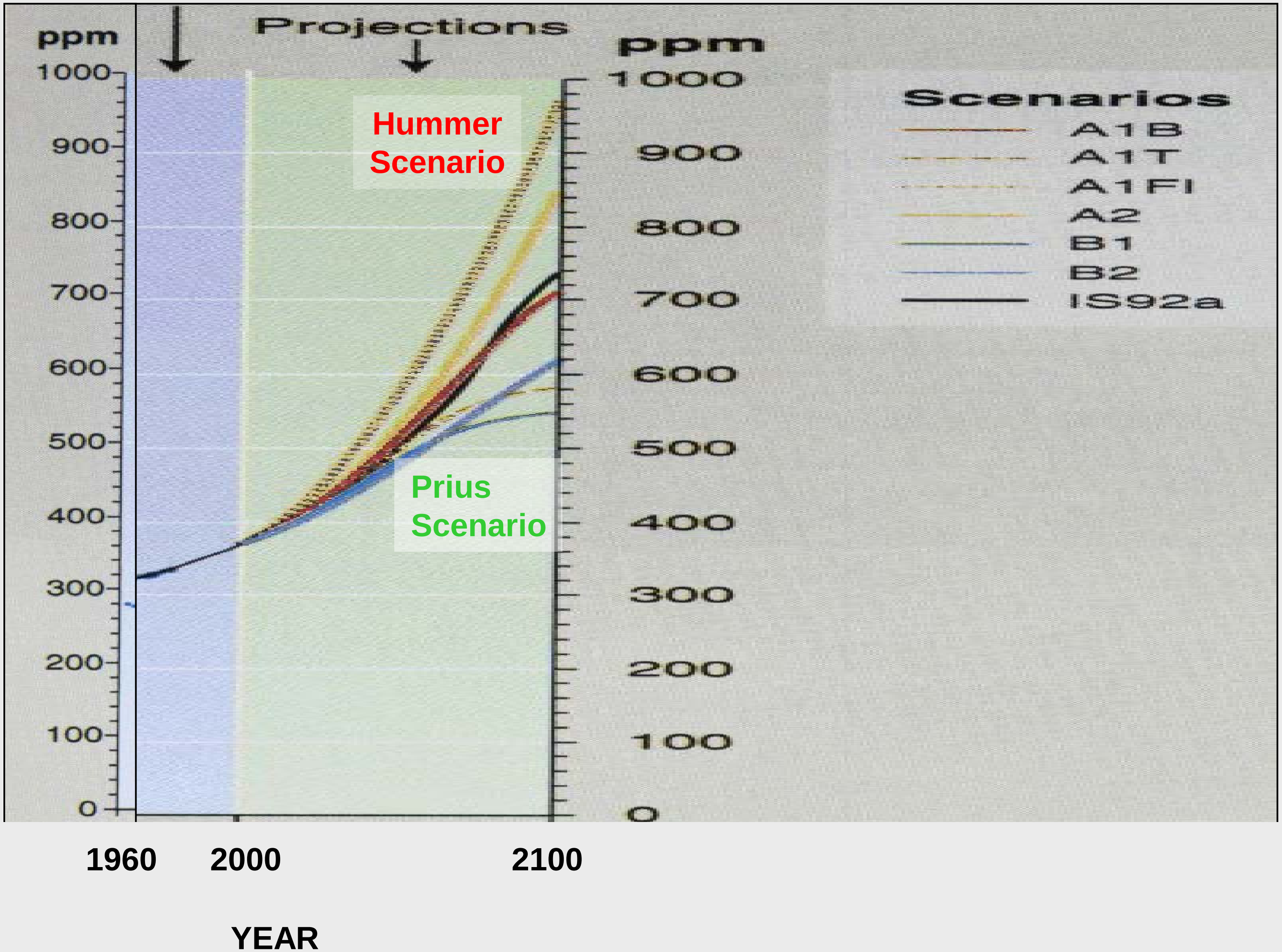
**Add recent trends in greenhouse gas and Sulphate aerosol concentrations and recent warming trends are accounted for.**



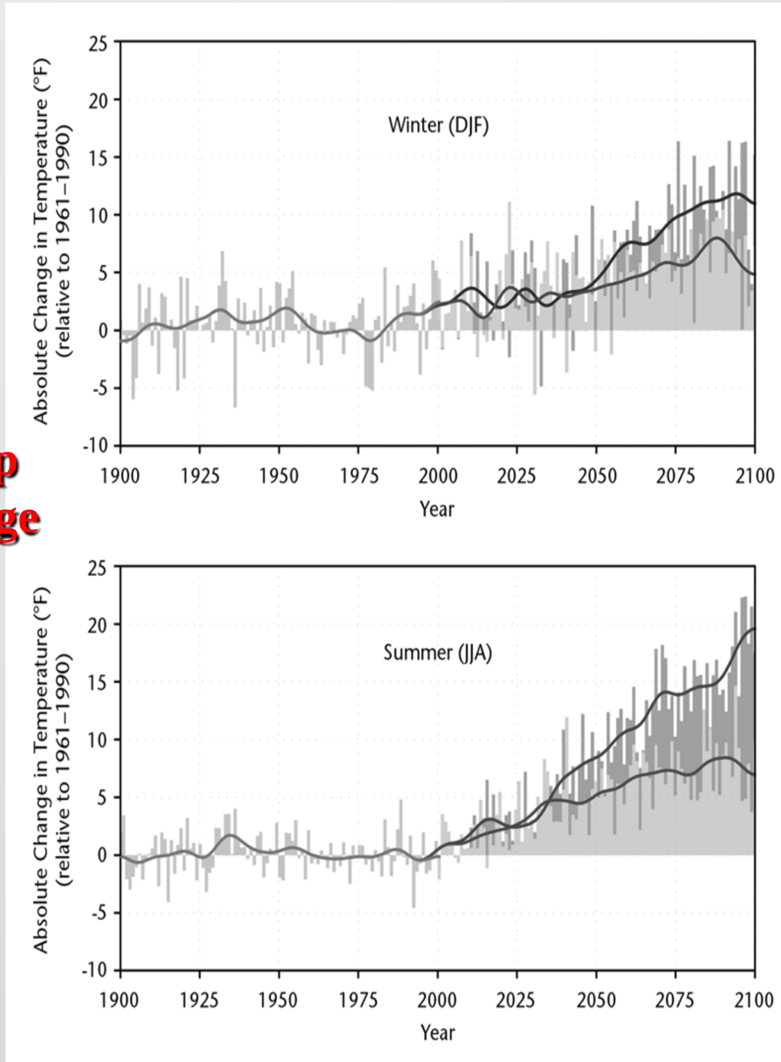

….the overall large-scale pattern of observed near-surface temperature change over the 20th century is consistent with our understanding of the combined impacts of natural and anthropogenic forcings. Natural forcings were relatively more important in the early-century warming and anthropogenic forcings have played a dominant role in warming observed in recent decades ……global mean temperatures continue to increase at a rate similar to that observed over the last three Decades [in response to predicted future trends in greenhouse gas emissions]  Stott et al. 2000.  Science 290:2133-2137.

# How Will Future $CO_2$ Levels Drive Climate?



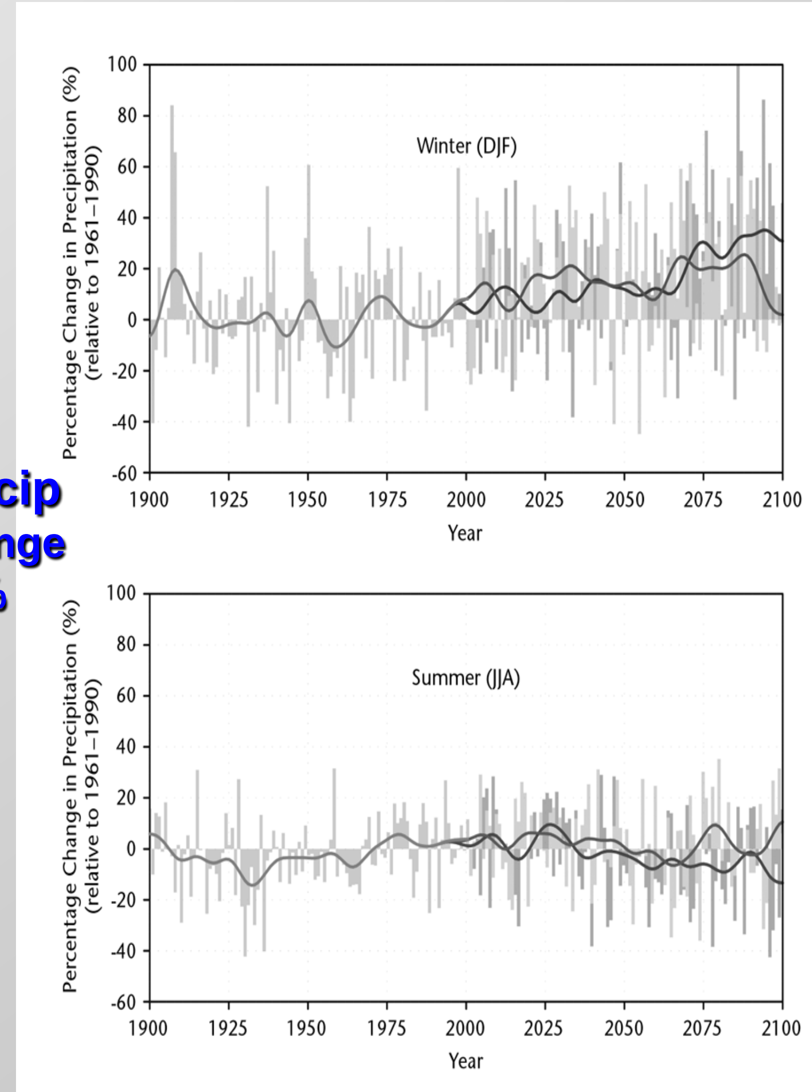
# Past and Future Changes in Great Lakes Region Climate

## DAILY MAX AIR TEMPERATURE




**Temp Change °F**

## RAINFALL




**Precip Change %**

## Conservative Estimate of Climate Change by 2090

**(i) 10 to 20% increase in rainfall**
**(ii) 2 to 4 C increase in temperature**

# PART TWO
# IMPACTS ON LAKE ENVIRONMENTS

## Conservative Estimate of Climate Change by 2090

(i) 10 to 20% increase in rainfall

(ii) 2 to 4 C increase in temperature

## IMPACTS ON LAKES

***Rule of Thumb***

A 10% increase in rainfall is needed for each $1^0$ C of warming In order to maintain existing water levels.

### Therefore

**(i) reduction in water levels**

**(ii) increase in ice free periods**

**(iii) increase in summer surface water temperatures**

**(iv) increase in stratification period**

# DECREASE IN LAKE WATER LEVELS

| Lake | 2 × $CO_2$ (range of 4 simulations) | 2030 (range of 4 simulations) | 2090 (range of 2 simulations) |
|---|---|---|---|
| Lake Superior | – 0.23 m to – 0.47 m | – 0.01 m to – 0.22 m | + 0.11 m to – 0.42 m |
| Lakes Huron & Michigan | – 0.99 m to – 2.48 m | + 0.05 m to – 0.72 m | + 0.35 m to – 1.38 m |
| Crystal Lake Wisconsin | – 1.00 m to – 1.90 m | | |
| Groundwater near Lansing, Michigan | | + 0.1m to – 0.6m | |

Less Fresh Water

**Warmer, Open Waters**

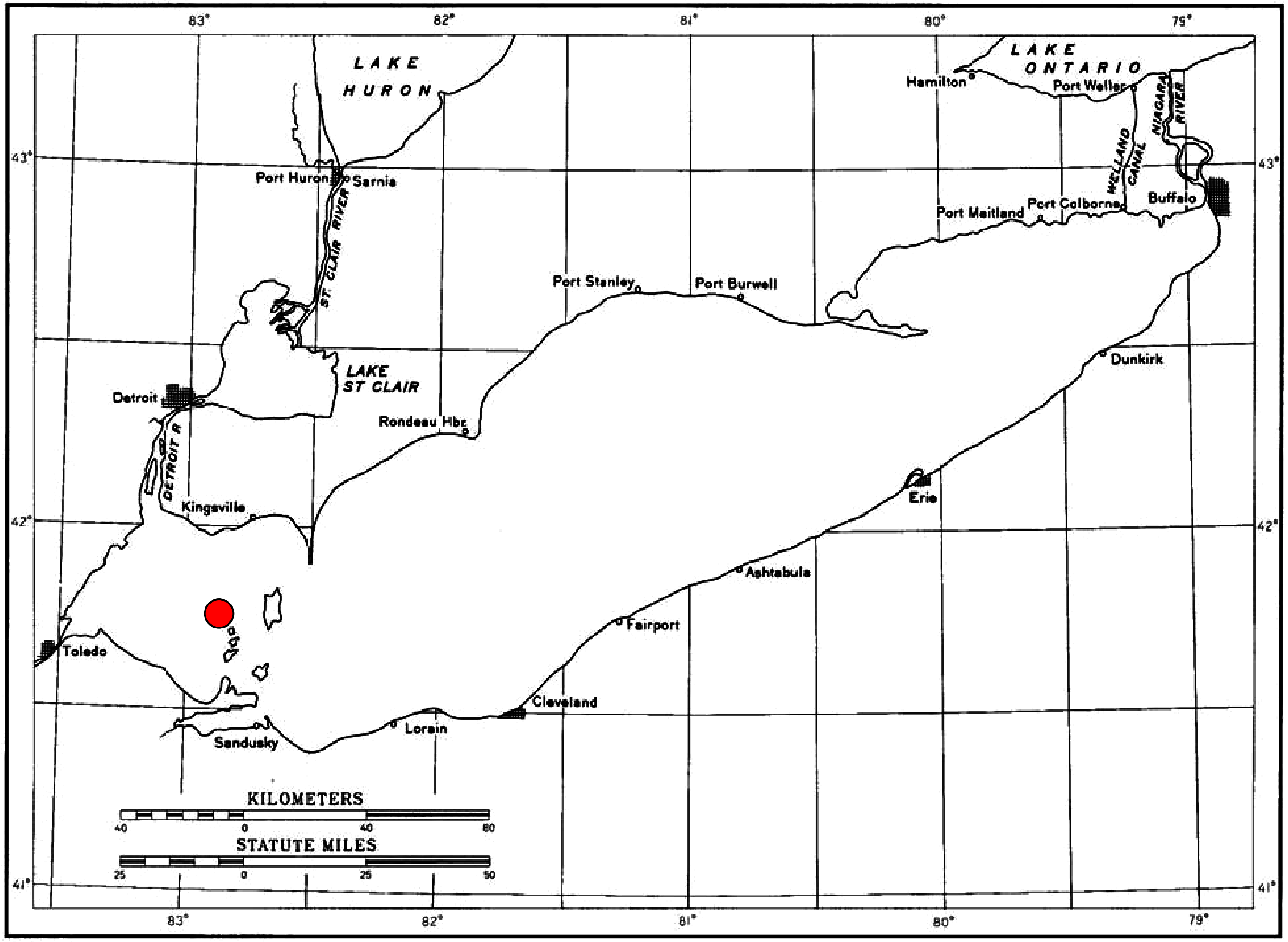
**Longer Ice Free Period**

## Expected Decreases in Ice Cover

| Lake | Current Situation | Future Scenarios | |
|---|---|---|---|
| | | By 2030 | By 2090 |
| **Lake Superior (3 basins)[a]** | **No ice-free winters** | **Increase ice-free winters to as much as 4%** | **Increase ice-free winters to as much as 45%** |
| Lake Erie (3 basins)[a] | 2% of winters are ice free | Increase ice free winters to as much as 61% | Increase ice free winters to as much as 96% |
| Small inland lakes[b] | ~90–100 days of ice cover | Decrease ice cover by 45–60 days with a doubling of atmospheric $CO_2$ | |

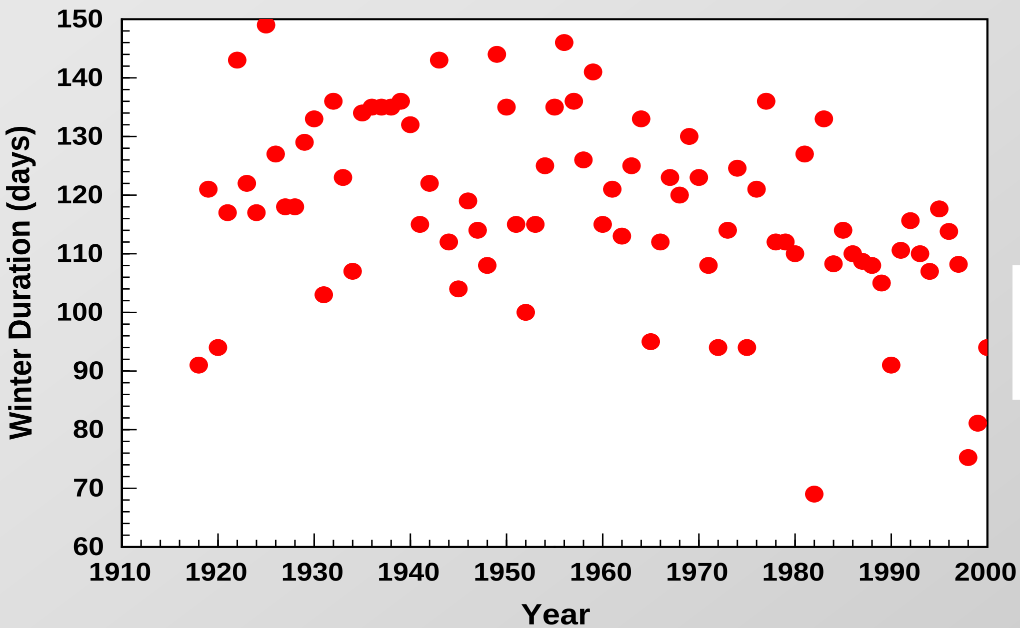
**Do recent historical trends reflect these projections for the future???**

# Lake Erie: Historical Changes in Winter Duration and Summer Surface Temperatures



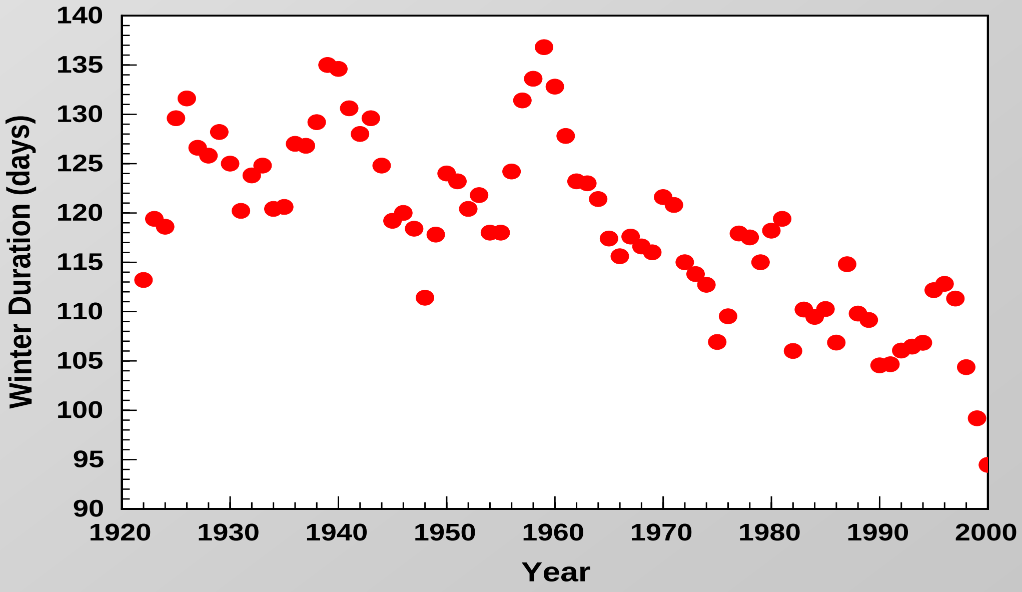

From: Jones, M et al. 2006. Canadian Journal of Fisheries and Aquatic Sciences

# WINTER DURATION: *Monitoring the Intensity and 'Visibility' of Change*




***Annual***

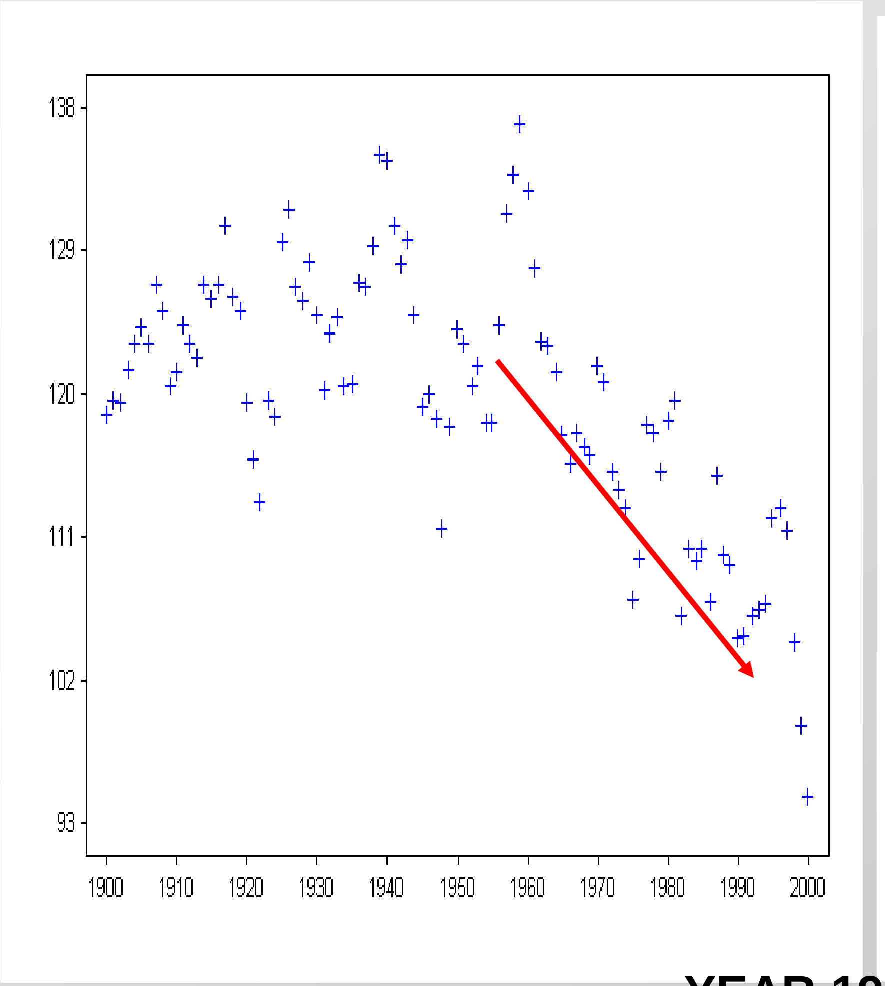
….smoothing annual observed variation reveals longer term trends……



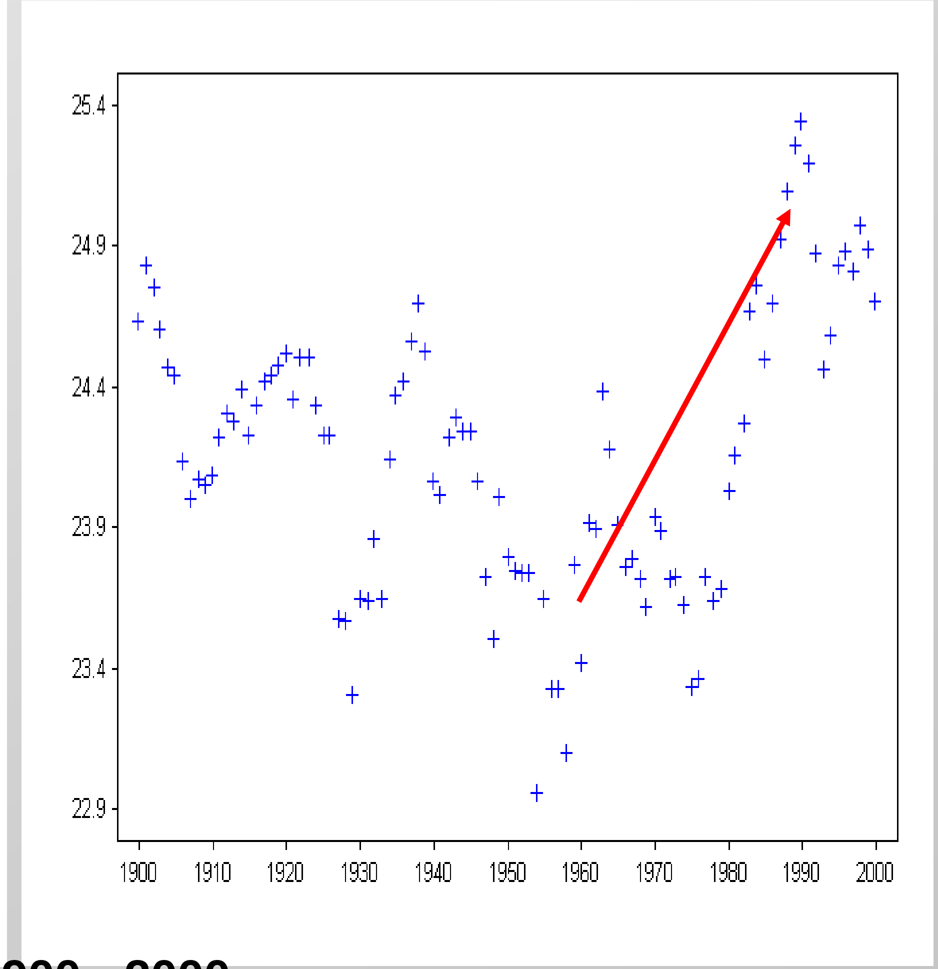

***5 Year Moving Average***

# Lake Erie 1900-2000: Winter Duration – Summer Water Temperature

**Winter Duration 1900-2000**
*5 year running averages*

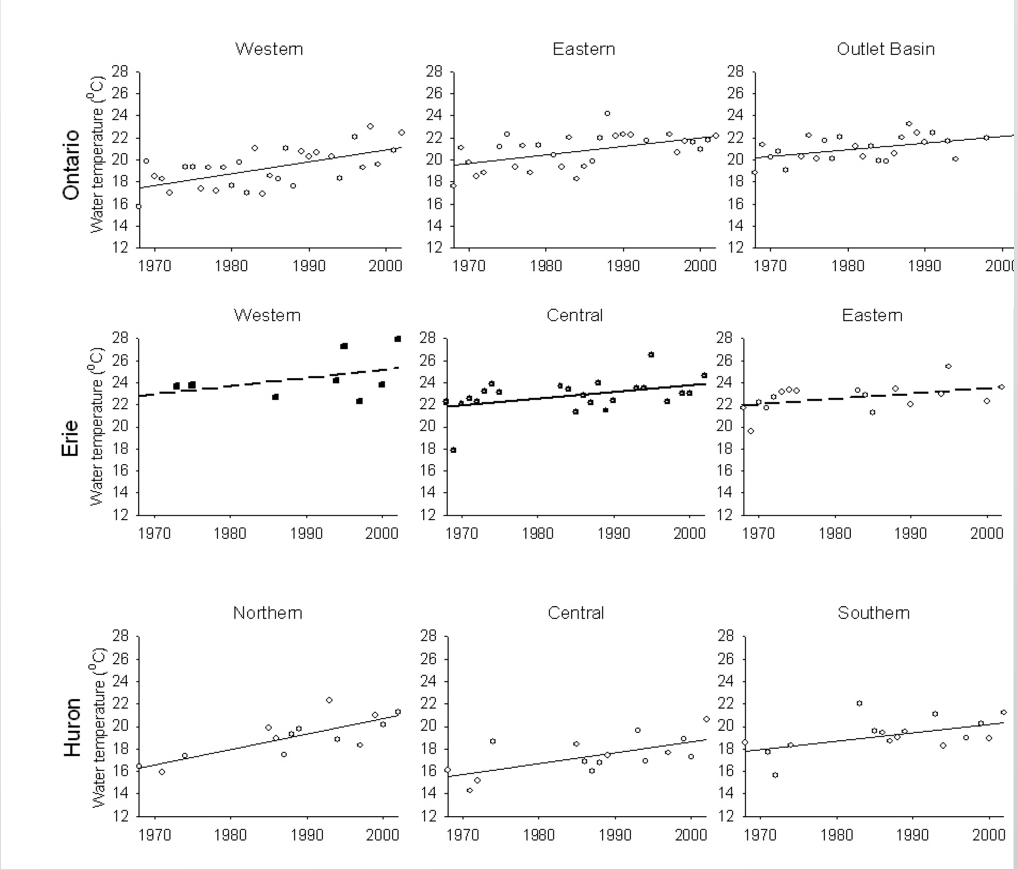



**Mid-Summer Surface Temperature 1900-2000**
*5 year running averages*




**YEAR 1900 - 2000**

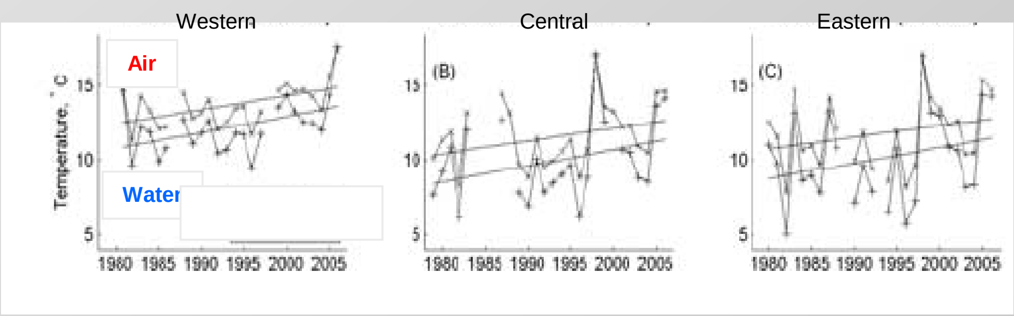
# Summer Mean Surface Temperature Versus Year by Basin For 4 Great Lakes




**ONTARIO***
**1970-2000**
**Summer Surface Water Temps**

**ERIE***
**1970-2000**
**Summer Surface Water Temps**

**HURON***
**1970-2000**
**Summer Surface Water Temps**




**SUPERIOR****
**1980-2005**
**Summer Temps: Air & Surface Water**

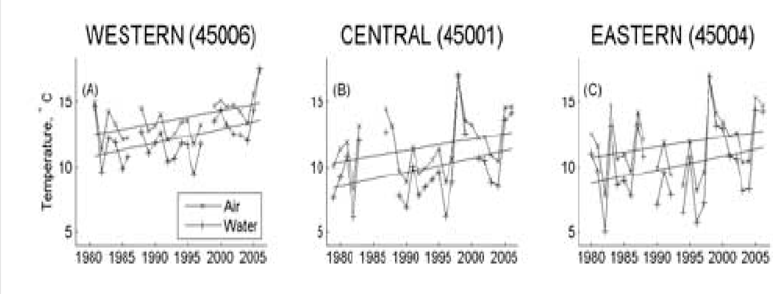
•Dobiesz and Lester, In Prep.
**Austin and Colman, 2007, Geophysical Research Letters,Vol. 34.

# LAKE SUPERIOR
## (1980-2005)

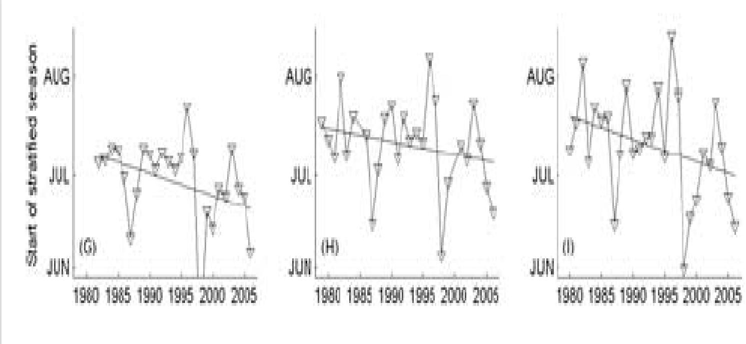
**SUMMER**

**WINTER**

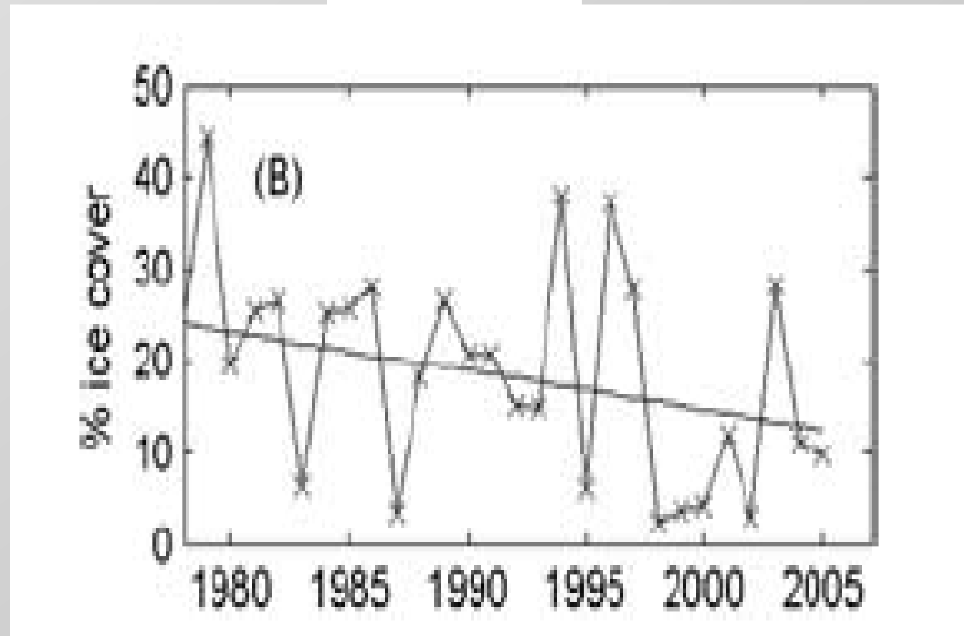
### Summer Air and Water Temps




### Spring Stratification Date




### Ice Cover



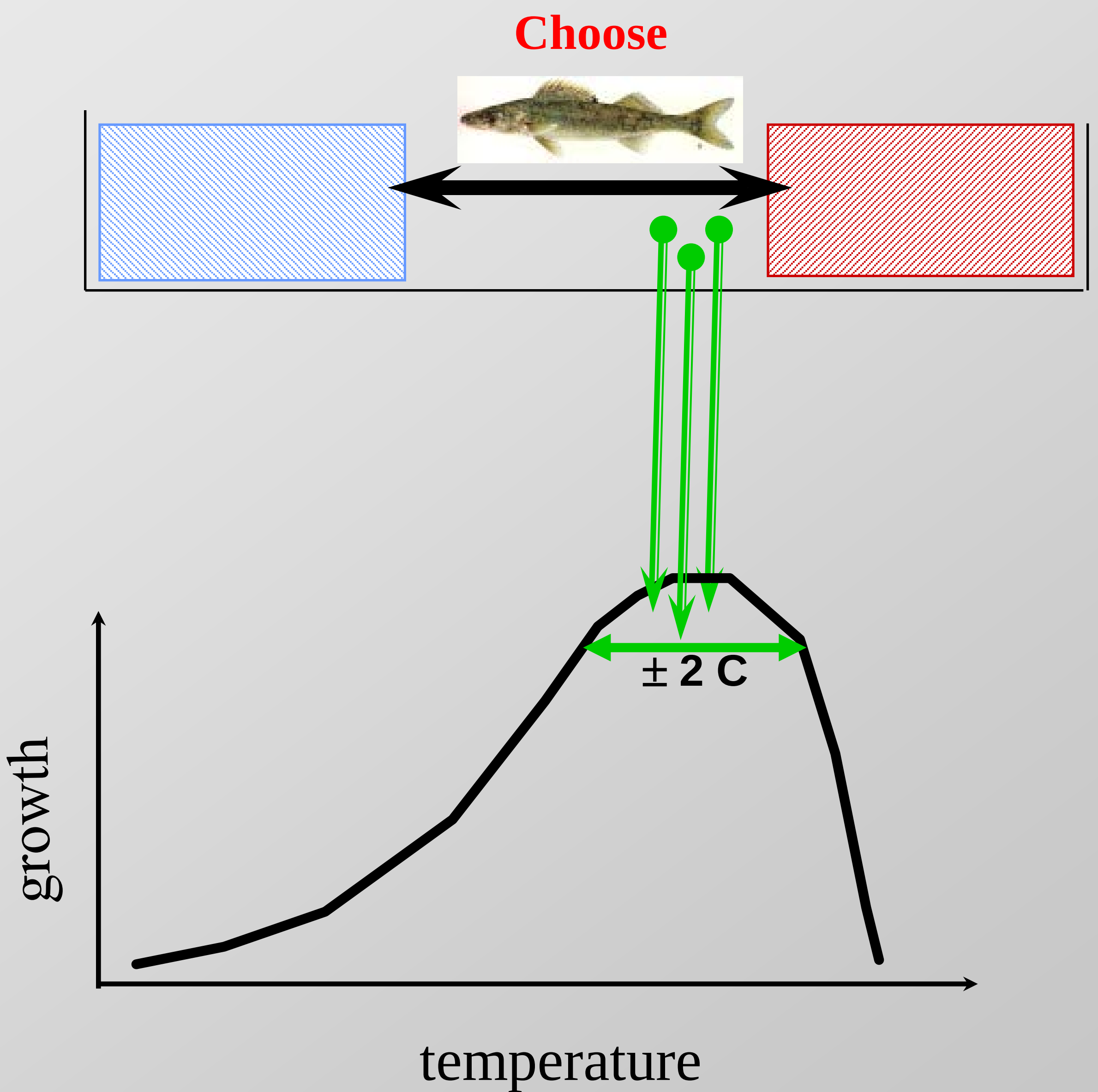

From: Austin and Colman, 2007, Geophysical Research Letters, Vol. 34.

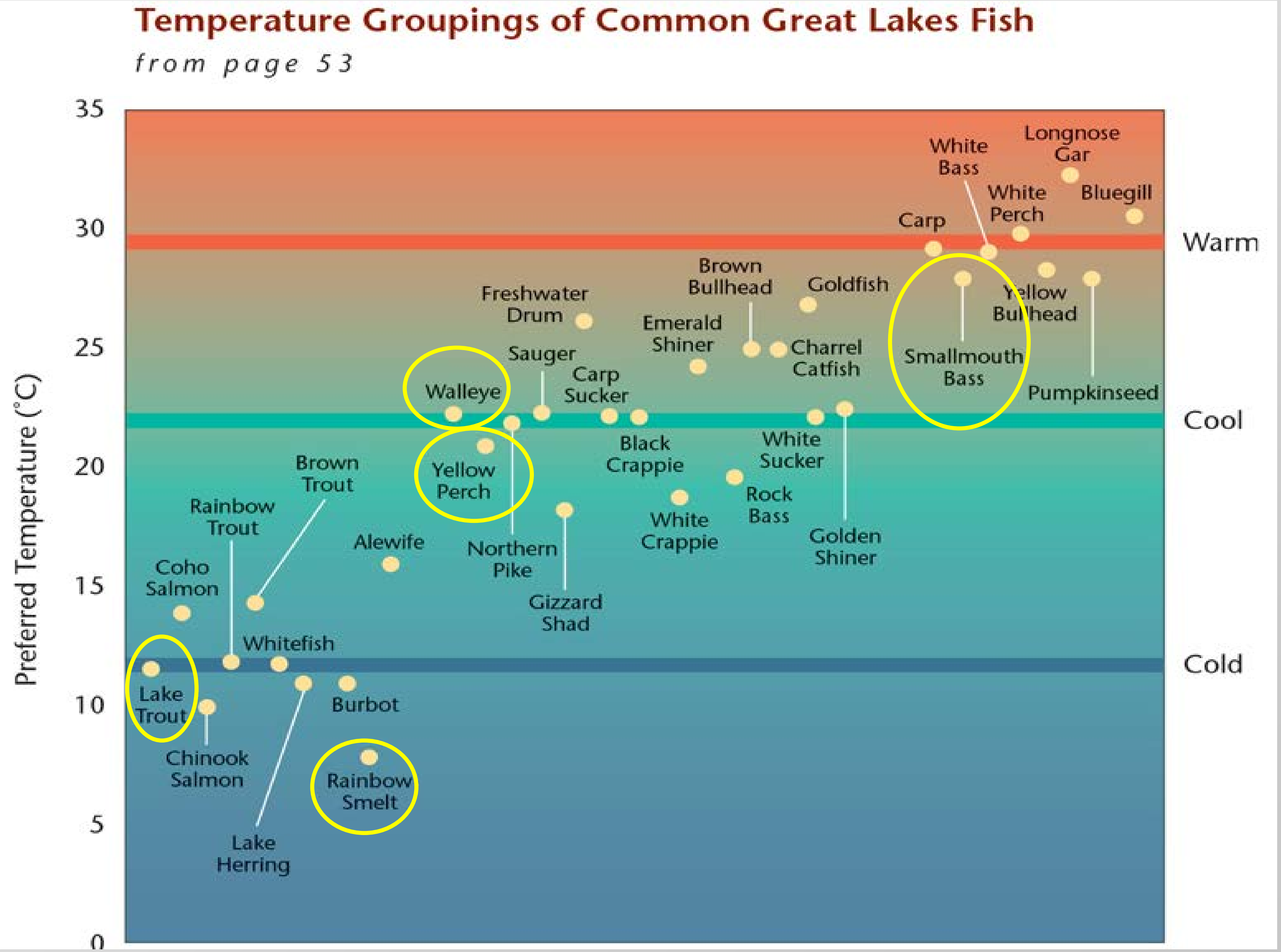
## PART THREE

*IMPACTS ON FRESHWATER FISH OF:*

- Less water,
- Longer ice free periods
- Warmer surface water temperatures *

# Preferred Temperature

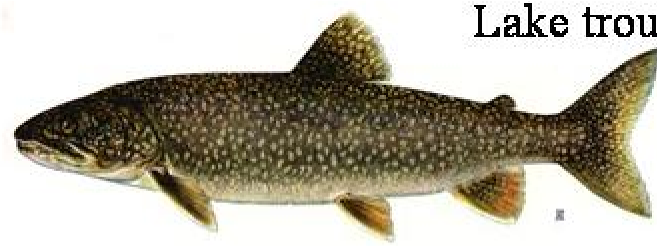





Kling, G.W. et al.. 2003. Confronting climate change in the Great Lakes Region. Union of Concerned Scientists and Ecological Society of America, Washington, D.C.

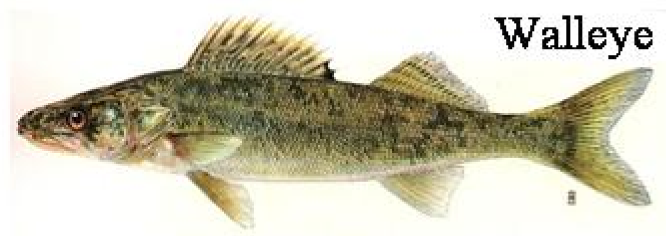
# Typical Representatives of Each Thermal Guild

**Cold**



Lake trout - **preferred temperature range 10 - 15 C**

**Cool**



Walleye - **preferred temperature range 20-25 C**

**Warm**

Smallmouth bass - **preferred temperature range 26 - 31 C**

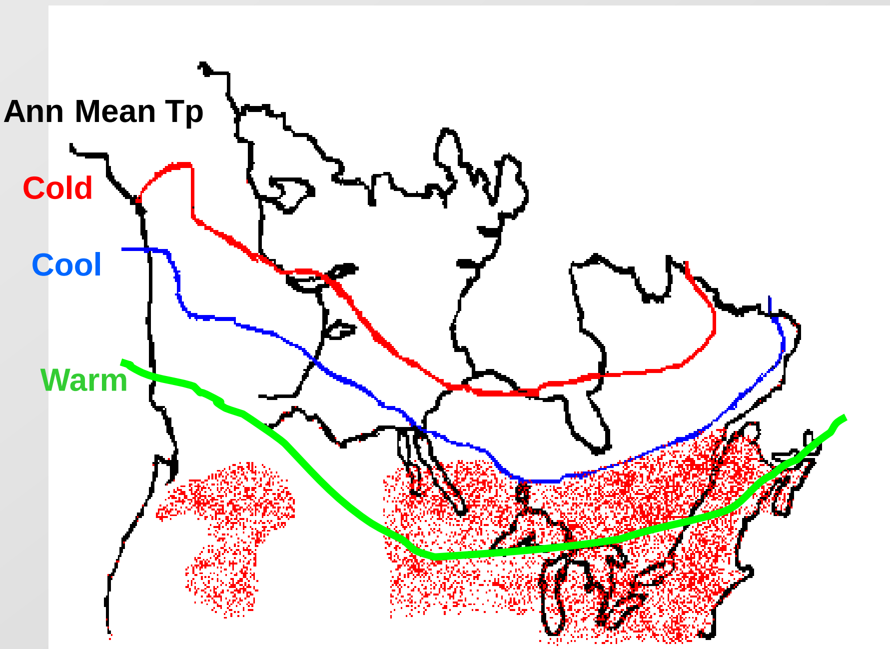
# Biogeographic Ranges

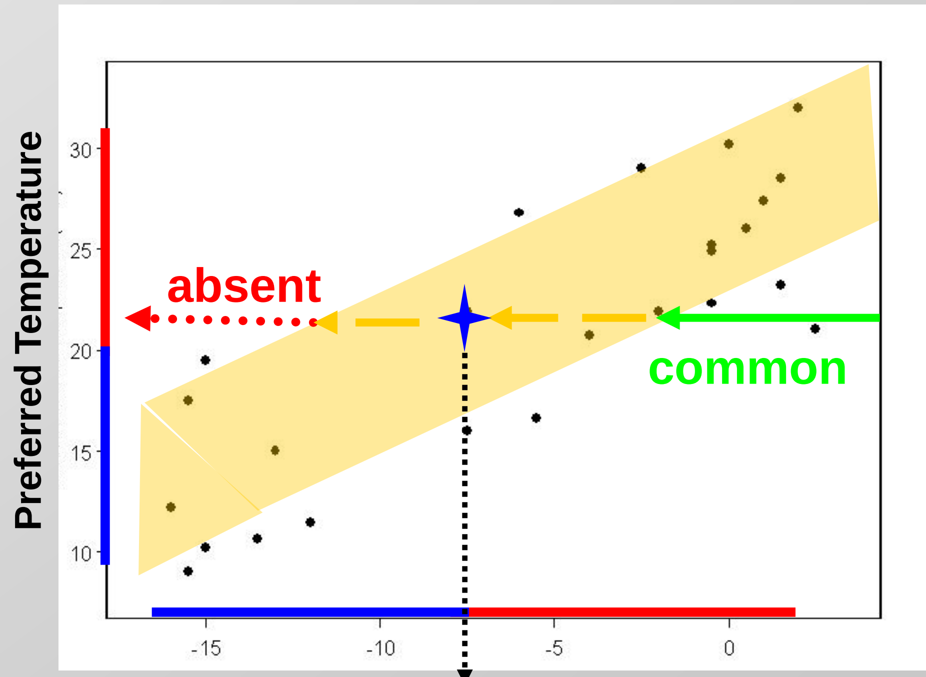
**Lake Trout:** *42 - 72 N. Lat*

**Walleye:** *30-70 N. Lat.*

**Smallmouth bass:** ***33-50 N.Lat.***

# Correspondence Between Physiological Preference and Climate at Northern Limit of Range



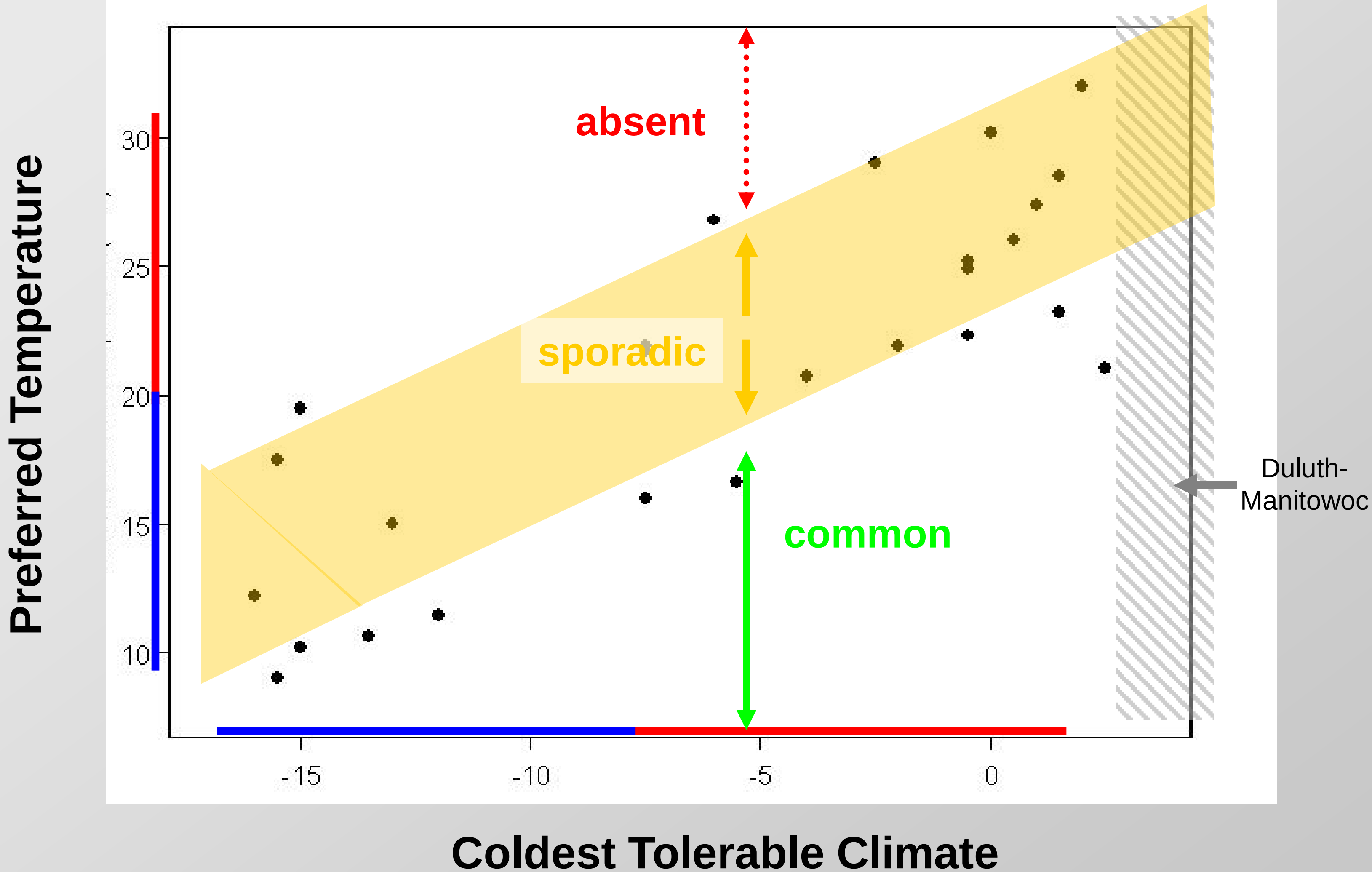




Impose a Climate Map of annual Air temperature Isotherms on the Distribution Map For a Species

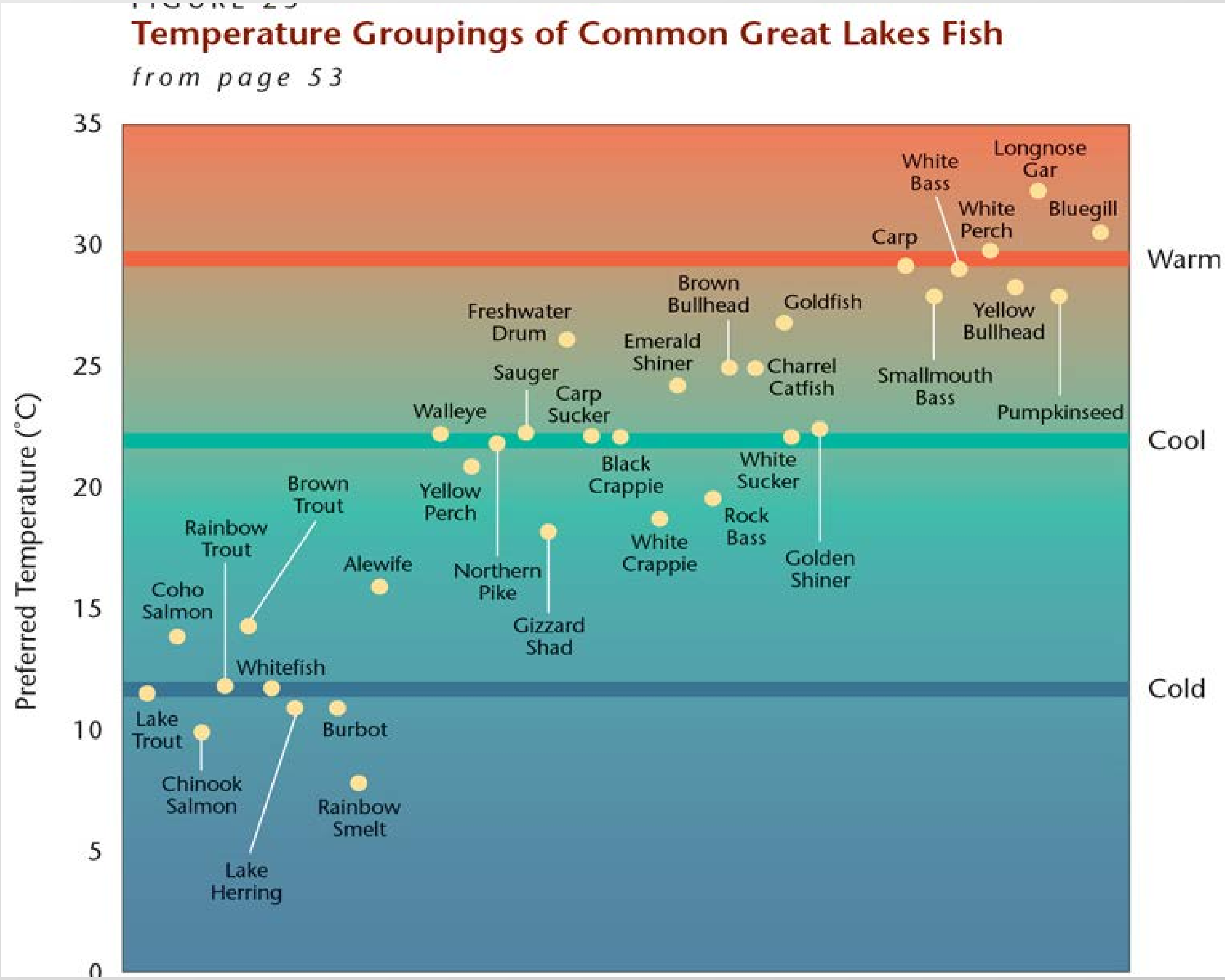
and identify the

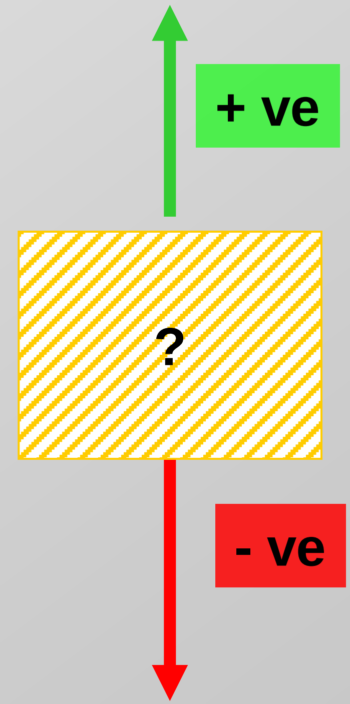
Lowest Yearly Mean Air Temp Where Species Found

# Physiological Preference and Climate at Northern Limit of Range




Duluth-Manitowoc climate data from: http://data.giss.nasa.gov/gistemp/station_data/


Temperature Groupings of Common Great Lakes Fish
from page 53
Preferred Temperature (°C)
35
30
25
20
15
10
5
0
Warm
Cool
Cold
Longnose Gar
White Bass
White Perch
Bluegill
Carp
Brown Bullhead
Goldfish
Freshwater Drum
Emerald Shiner
Yellow Bullhead
Charrel Catfish
Smallmouth Bass
Sauger
Carp Sucker
Walleye
Pumpkinseed
Black Crappie
White Sucker
Brown Trout
Yellow Perch
Rainbow Trout
Rock Bass
White Crappie
Alewife
Northern Pike
Golden Shiner
Coho Salmon
Gizzard Shad
Whitefish
Lake Trout
Burbot
Chinook Salmon
Rainbow Smelt
Lake Herring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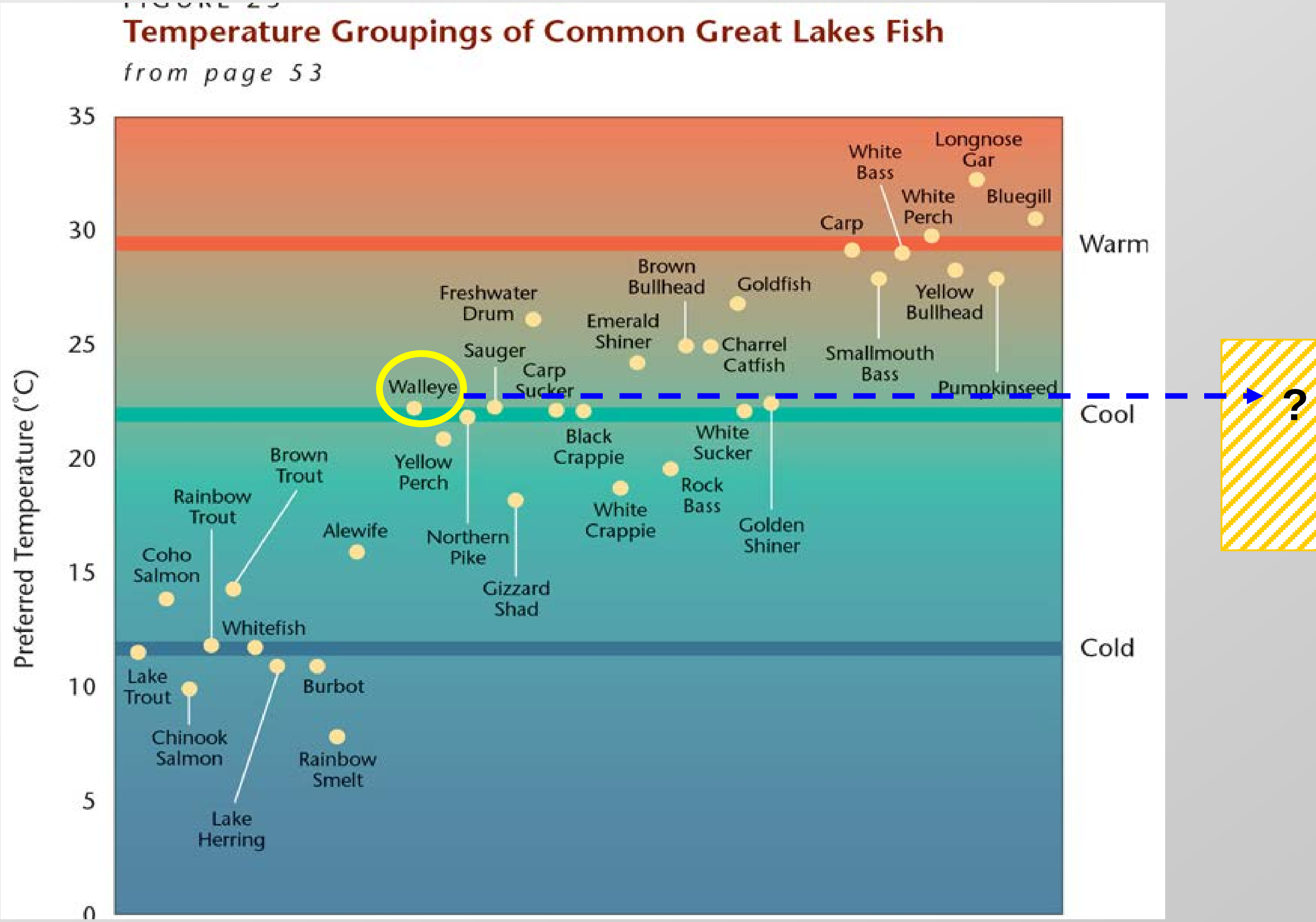
# Some Winners and Losers …..

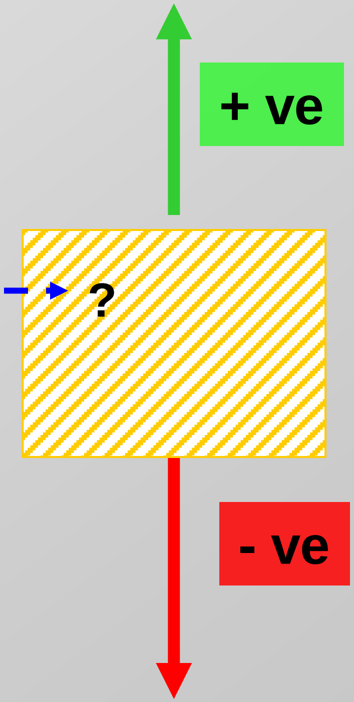
*TABLE 2. Some fishes which could alter their range within the Great Lakes basin under conditions of climate warming.*

| Winners | | Losers |
|---|---|---|
| river carpsucker | white catfish | brook trout |
| lake chubsucker | white perch | lake trout |
| bigmouth buffalo | mud sunfish | lake whitefish |
| black buffalo | redbreast sunfish | round whitefish |
| river redhorse | warmouth | burbot |
| grass carp | orangespotted sunfish | slimy sculpin |
| comely shiner | flier | |
| red shiner | banded sunfish | |
| blacktail shiner | bantam sunfish | |
| black bullhead | banded pygmy sunfish | |
| brindled madtom | blackbanded sunfish | |
| northern madtom | | |
| flathead catfish | | |
| blue catfish | | |

From: Mandrak, N. 1989. Journal of Great Lakes Research.

# Assessing impacts of warming on a walleye population……

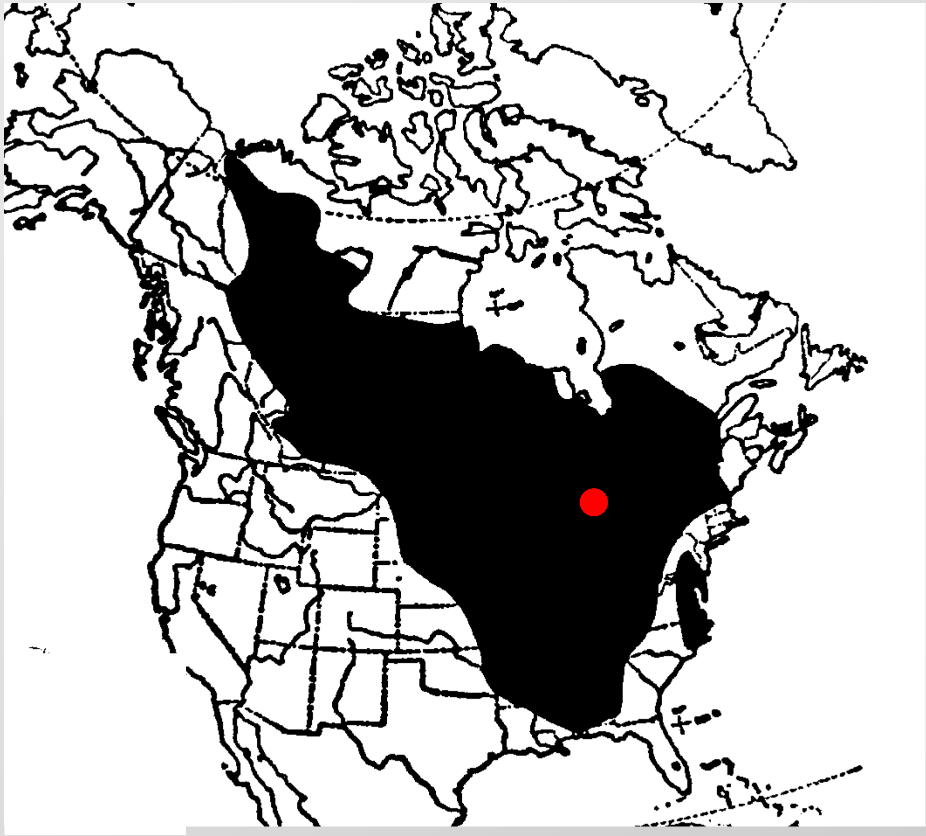


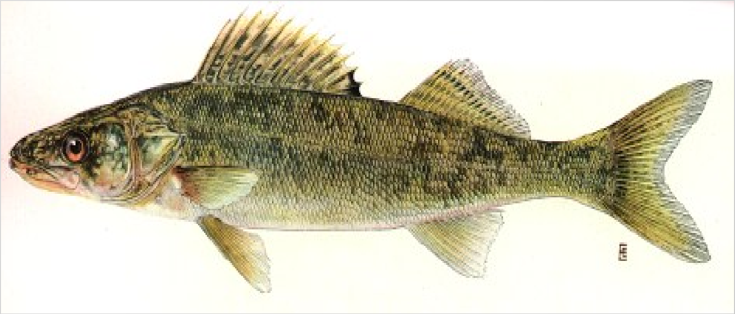



# Example: Walleye in Lake Erie

*Zoogeographic Range:*
**30 to 70 North Latitude**

*Preferred temperatures:*
**20-25 C**





# Impact of Climate Change on Supply of Suitable Walleye Habitat in Lake Erie

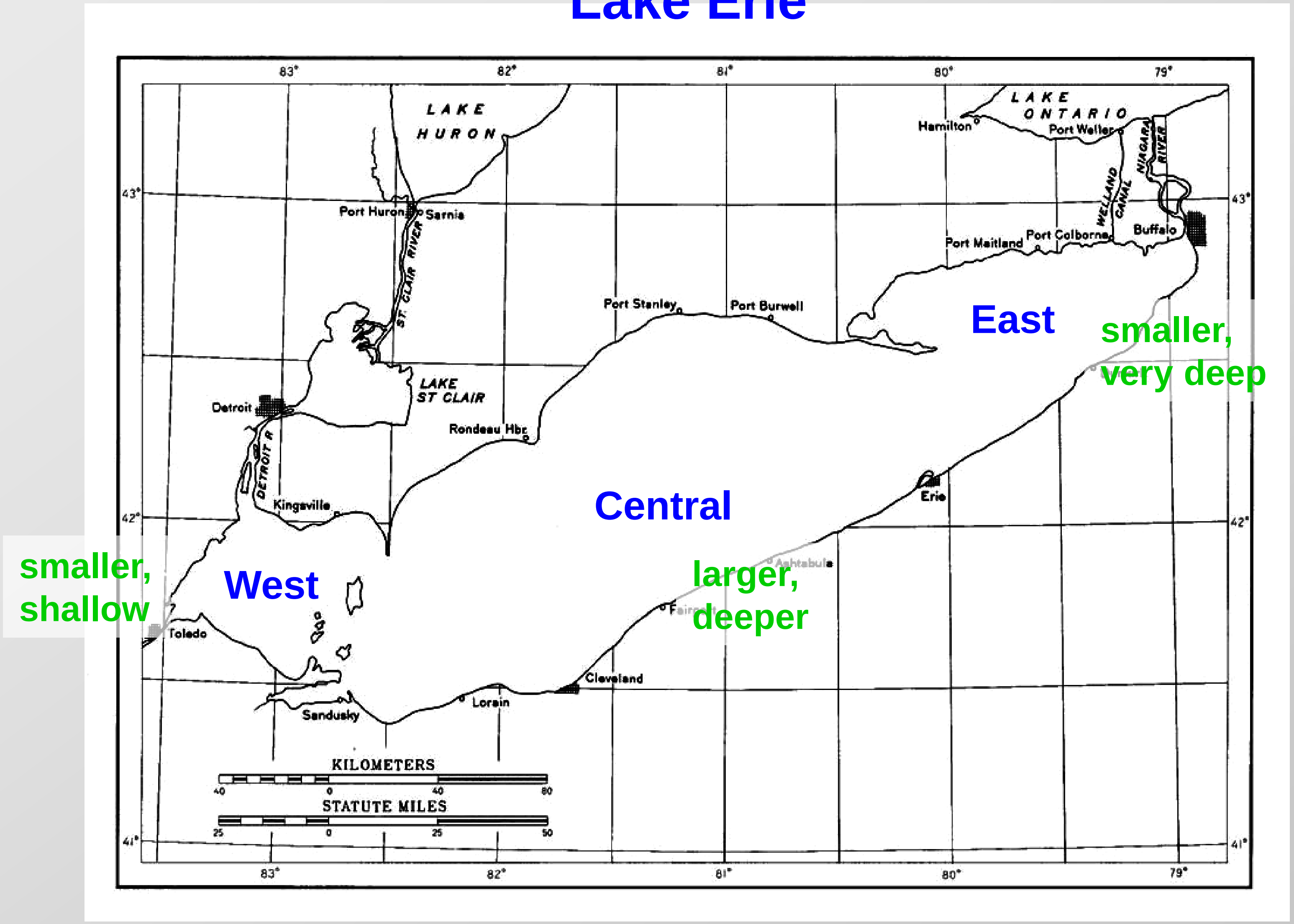
**LAKE ERIE**

**Three Basins: west = smaller and shallow**
**central = largest and a bit deeper**
**east = smaller and very deep**

**Less Water**
**Longer Ice Free Period**
**Warmer, Open Waters**

SEE: Jones et al. 2006. Canadian Journal of Fisheries and Aquatic Sciences 63:457-468.

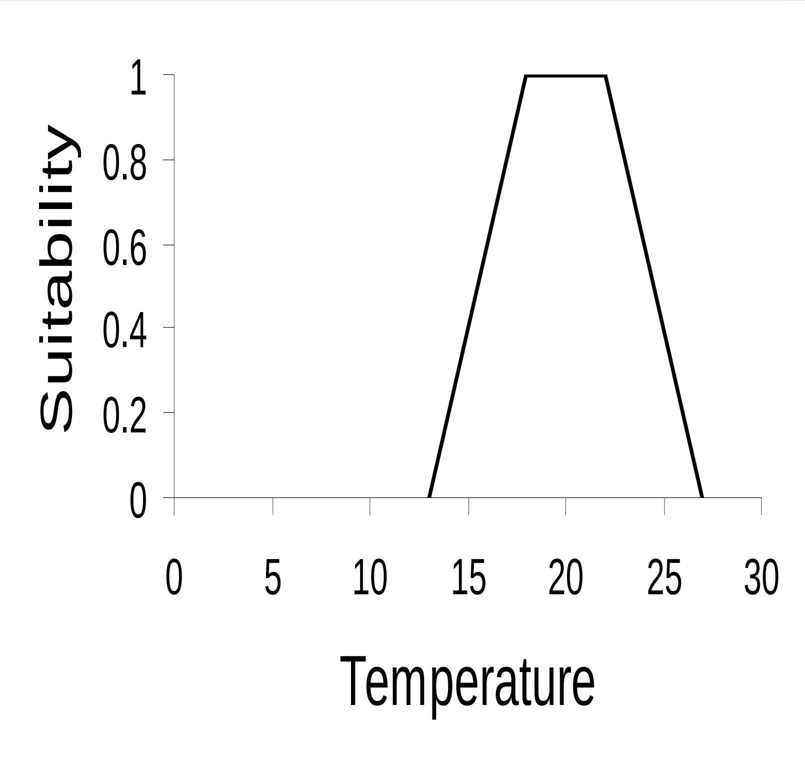
# Lake Erie



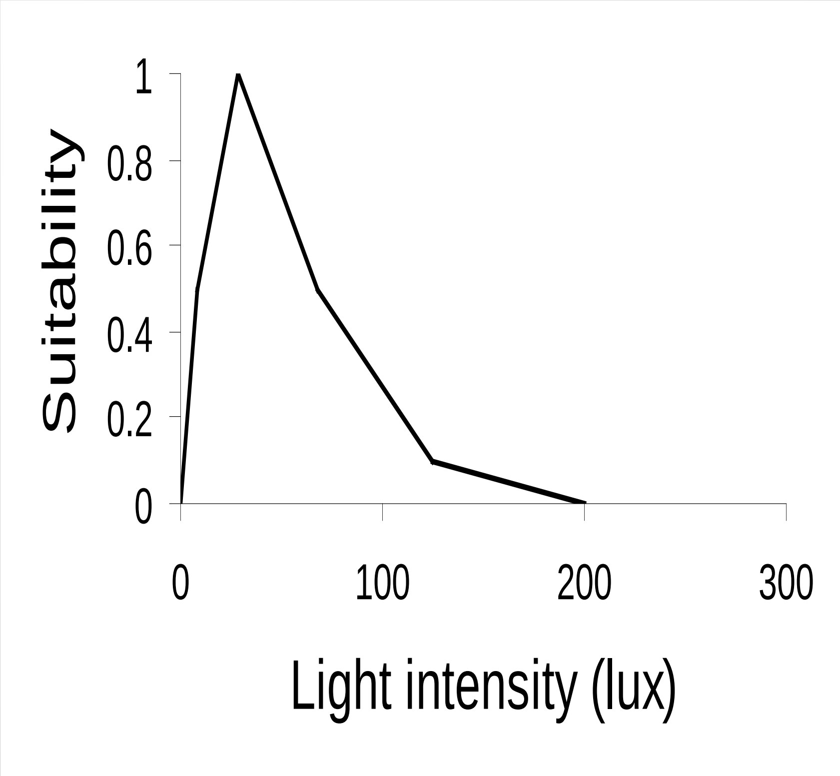
83°
82°
81°
80°
79°
43°
42°
41°
LAKE HURON
LAKE ONTARIO
Hamilton
Port Weller
WELLAND CANAL
NIAGARA RIVER
Buffalo
Port Colborne
Port Maitland
Port Huron
Sarnia
ST. CLAIR RIVER
Port Stanley
Port Burwell
LAKE ST CLAIR
Detroit
DETROIT R
Rondeau Hbr
Kingsville
Erie
Toledo
Cleveland
Lorain
Sandusky
KILOMETERS
40
0
40
80
STATUTE MILES
25
0
25
50
East
Central
West
smaller, very deep
larger, deeper
smaller, shallow

# WALLEYE PREFERENCES

**Defining Suitable Thermal Habitat**




**Defining Suitable Optical Habitat**



## Percent Change in Suitable Habitat (= Habitat Supply) Given:

* 2C increase in surface temperature
* 2m drop in water level

| Basin | Weighted Habitat Area | | | Weighted Habitat Volume | | |
|---|---|---|---|---|---|---|
| | Optical | Thermal | Combined | Optical | Thermal | Combined |
| East | -5 | 22 | 32 | -10 | 4 | 7 |
| Central | -9 | 8 | 3 | -20 | -9 | -16 |
| West | -29 | -13 | -26 | -38 | -26 | -38 |

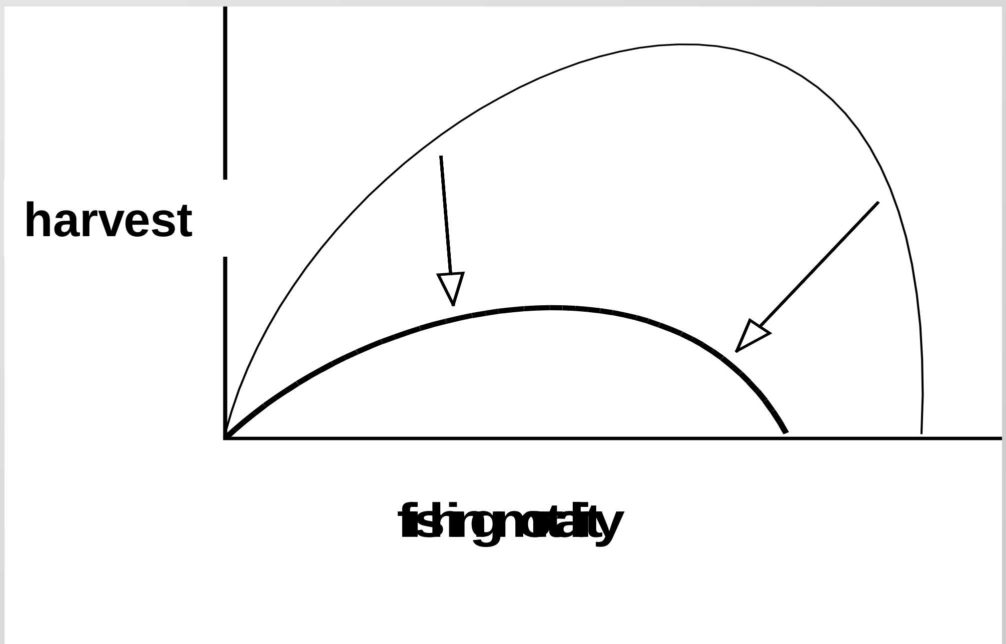
**IF**

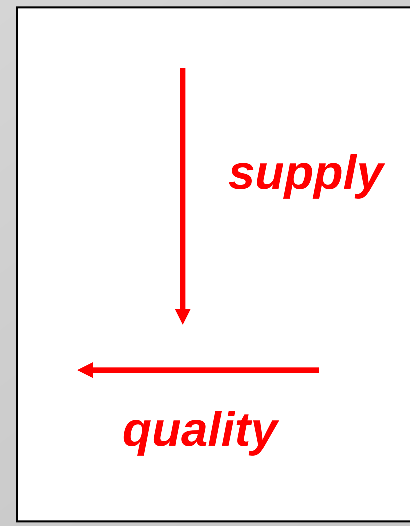
**Changes in Climate Affect the Quantity and Quality of Habitat Available to Individual Populations**

**THEN**

**How Will Sustainable Harvests Change?**

**Impacts of Declines in Both Habitat Supply and Habitat Quality on Sustainable Harvests**



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**Change in habitat supply ~ = Change in sustainable harvests**

## General Impacts of Likely Changes in Climate on Fish Ecology & Consequences for Fisheries.

| Climate Change Impacts on Fish Ecology | Consequences for Fisheries |
|---|---|
| Change in **overall fish production** in a particular aquatic ecosystem | Change in **sustainable harvests** for all fish populations in the ecosystem |
| Change in relative **productivity of individual fish populations** in a particular aquatic ecosystem | Change in **sustainable levels of exploitation** that can be directed against the fish populations of the ecosystem |
| Large-scale **shifts in geographic distribution** of species | Change in **mixture of species** that can be sustainably harvested within a specific region.<br><br>Change in **location** of profitable fishing grounds |
| Small-scale **shifts in the spatial distribution** of members of a specific population | Change in **sustainable harvest** for the population<br><br>Change in **efficiency of fishing gear**, leading to change in sustainable levels of fishing effort |

# Adapting to Climate Change

**Water conservation** increased demand for direct human uses may lead to severe reductions in habitat supply

**Refocus fishing** on populations whose productivity is improved by climate change.

**Protect** populations whose productivity is damaged by climate change

**Reduce impacts from other agents of stress**:

Eg: - mitigate impacts of contaminants
- limit competition between humans and fish for water
- control access of invasive species

**Actively accelerate** northward shift of warmwater species

AND / OR

**Actively protect** coldwater species from competition with warmwater species

## TAKE HOME MESSAGES

**1.** Climate change is underway.

**2.** Some future change is unavoidable – however, **if limited**, the impact of this change on aquatic environments can be evaluated and planned for.

**3.** Delaying control of greenhouse gases will accelerate the rate and magnitude of future change and thus render planning and mitigation difficult, and perhaps impossible.

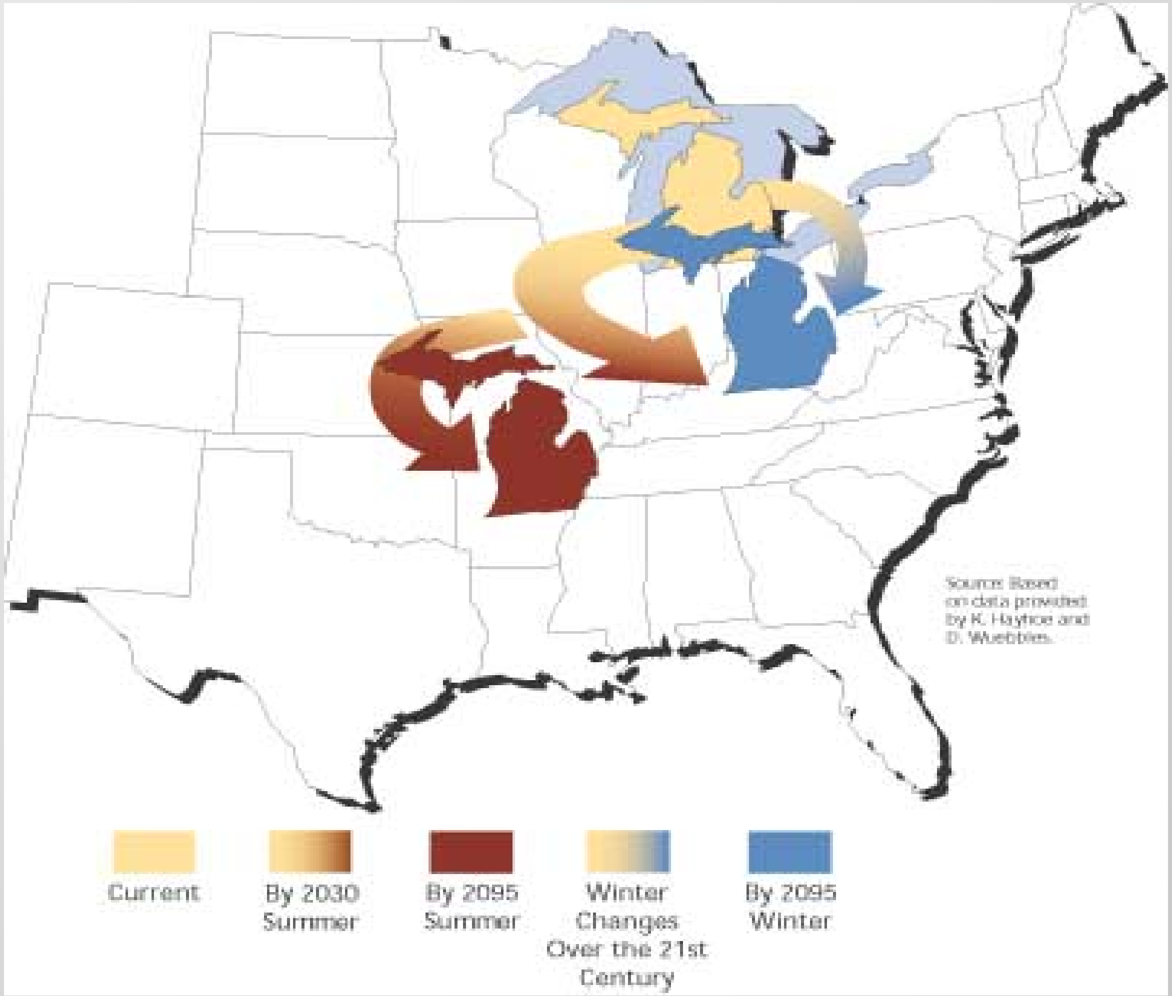
# Acknowledgements

**Ontario Ministry of Natural Resources**
**University of Toronto,**
**Fisheries and Oceans Canada,**
**Natural Sciences and Engineering Research Council of Canada,**
**Union of Concerned Scientists,**
**Ecological Society of America**

and

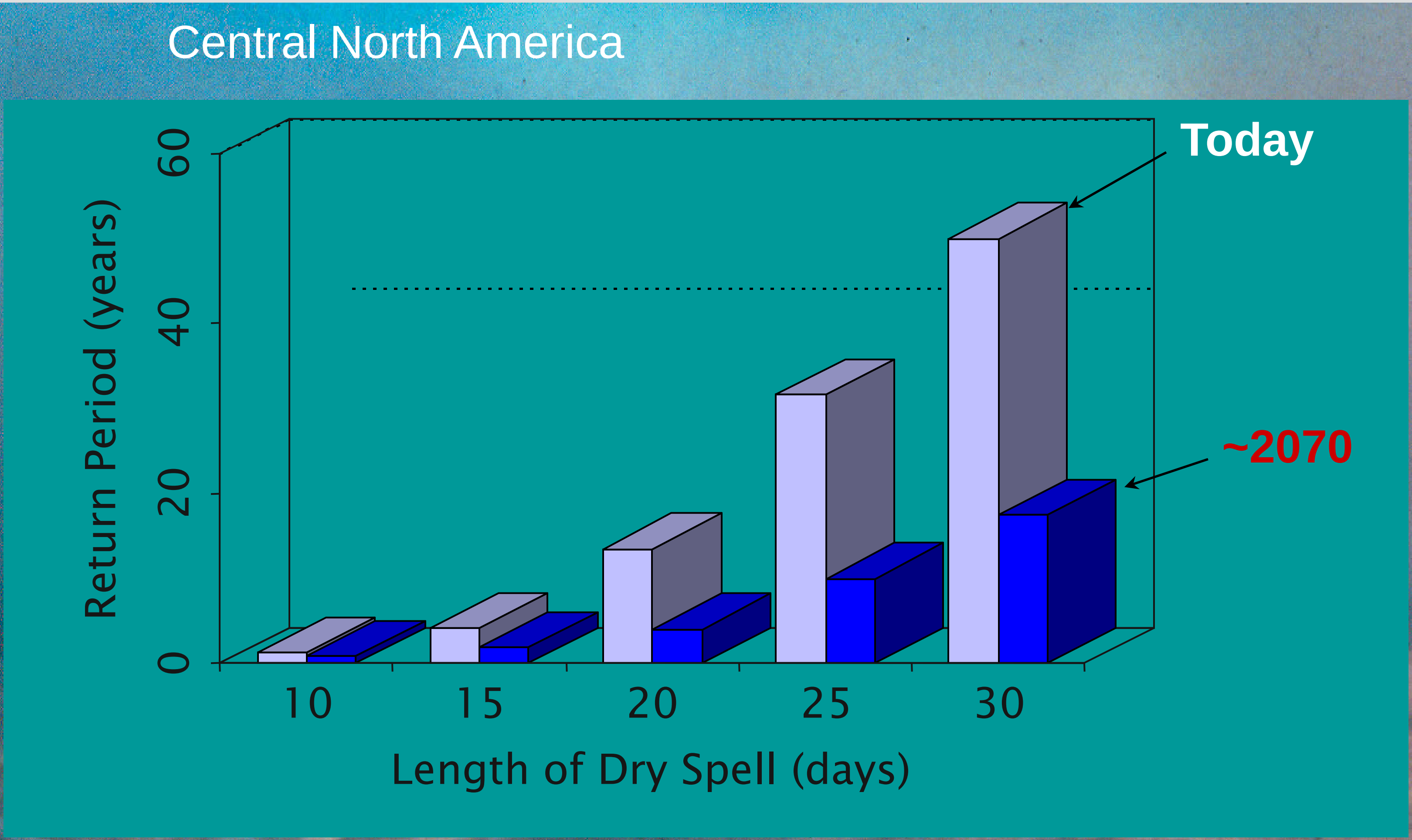
**Norene Dobiesz, Karen Ing, Mike Jones, Nigel Lester, Ken Minns, Phil Ryan, Li Wang, Yingming Zhao**

## For Michigan, summers in 2030 could be like those in Kentucky, while by the end of the century, they may feel like ones in Arkansas today.




Kling, G.W. et al. Zack. 2003. Confronting climate change in the Great Lakes Region. Union of Concerned Scientists and Ecological Society of America, Washington, D.C.

# Frequency and severity of droughts may also increase in central North America




**Longer and more often……..**

Kling, G.W. et al. Zack. 2003. Confronting climate change in the Great Lakes Region. Union of Concerned Scientists and Ecological Society of America, Washington, D.C.