Climate Change: Implications for Habitat Quality and Fish Growth Performance in the Great Lakes*

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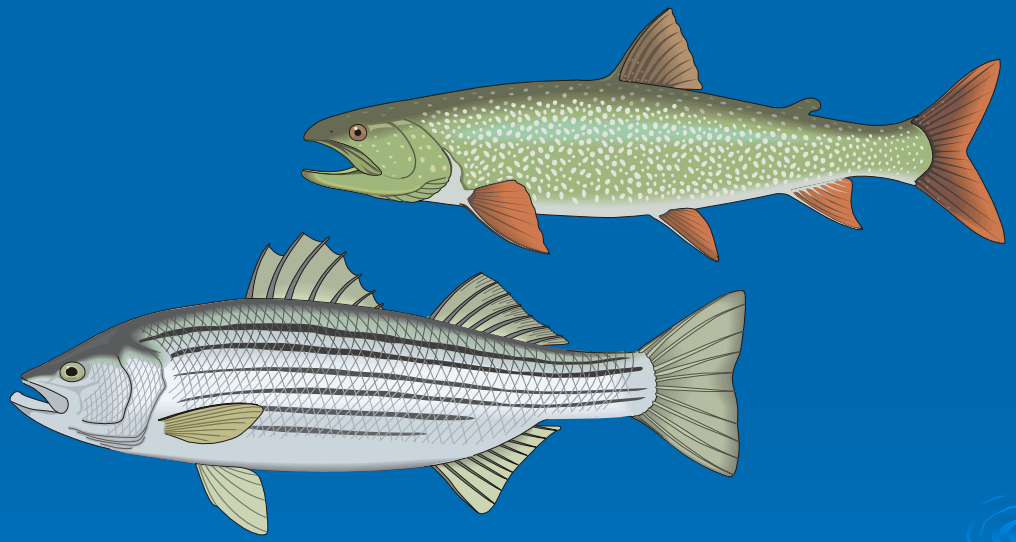
Objective

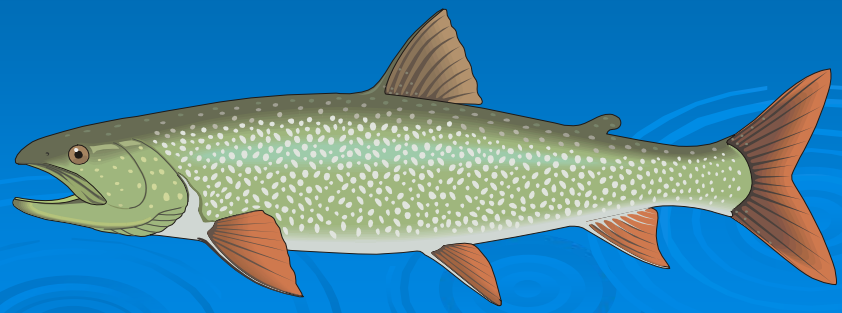
- Quantify how climate change might affect fish habitat quality as defined by Growth Rate Potential:
  - Chinook Salmon
  - Lake Trout
  - Striped Bass



- Base (1954-1995), 2030, and 2090 under predictions made by the Canadian Climate Center Climate Change Model (CGCM1).

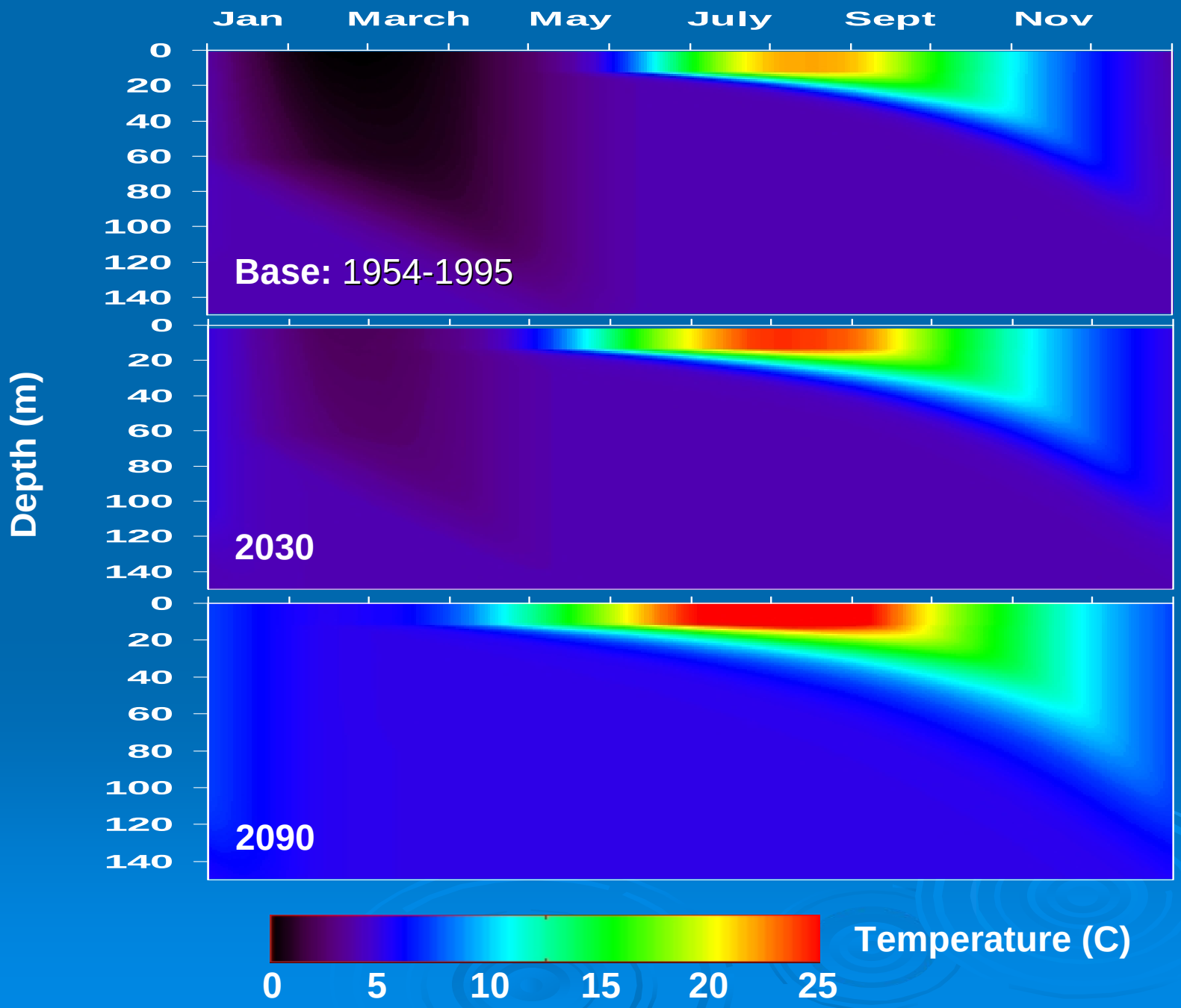
Growth Rate Potential (GRP)

- Expected daily growth rate of a fish if placed in a volume of water with known prey type, prey size, prey density, water temperature, and light
- Past research has demonstrated a positive relationship between GRP and fish growth and condition



Approach

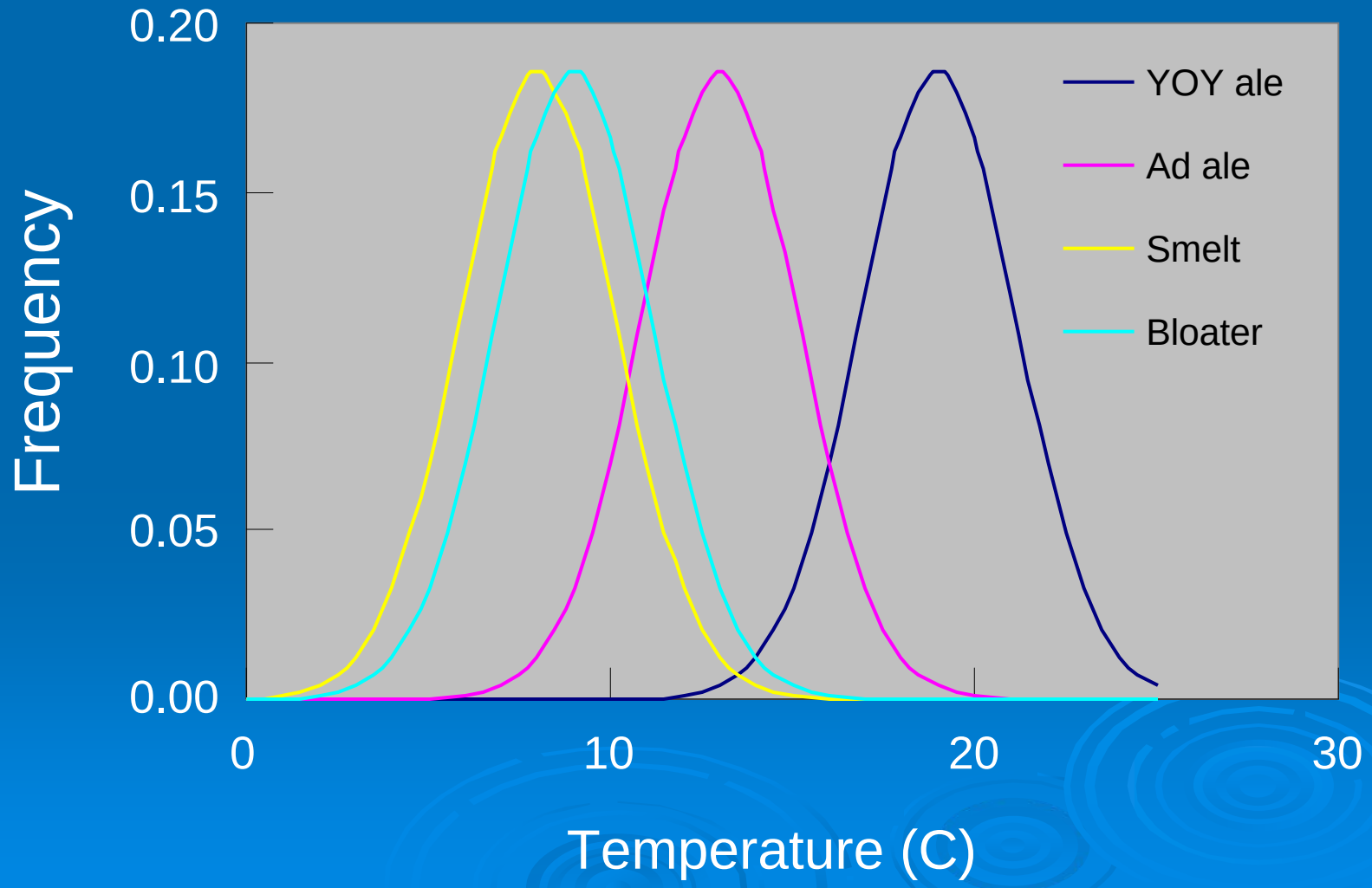
- Output from the climate change model (air temperature, precipitation, etc) used in a thermodynamics model to predict daily 1-D thermal structure for Lake Michigan.
- Fixed prey biomass was then distributed in the 1-D thermal environment based on preferred temperatures.
- Foraging model and bioenergetics model was then run using thermal input, prey type, prey density, and prey distribution.

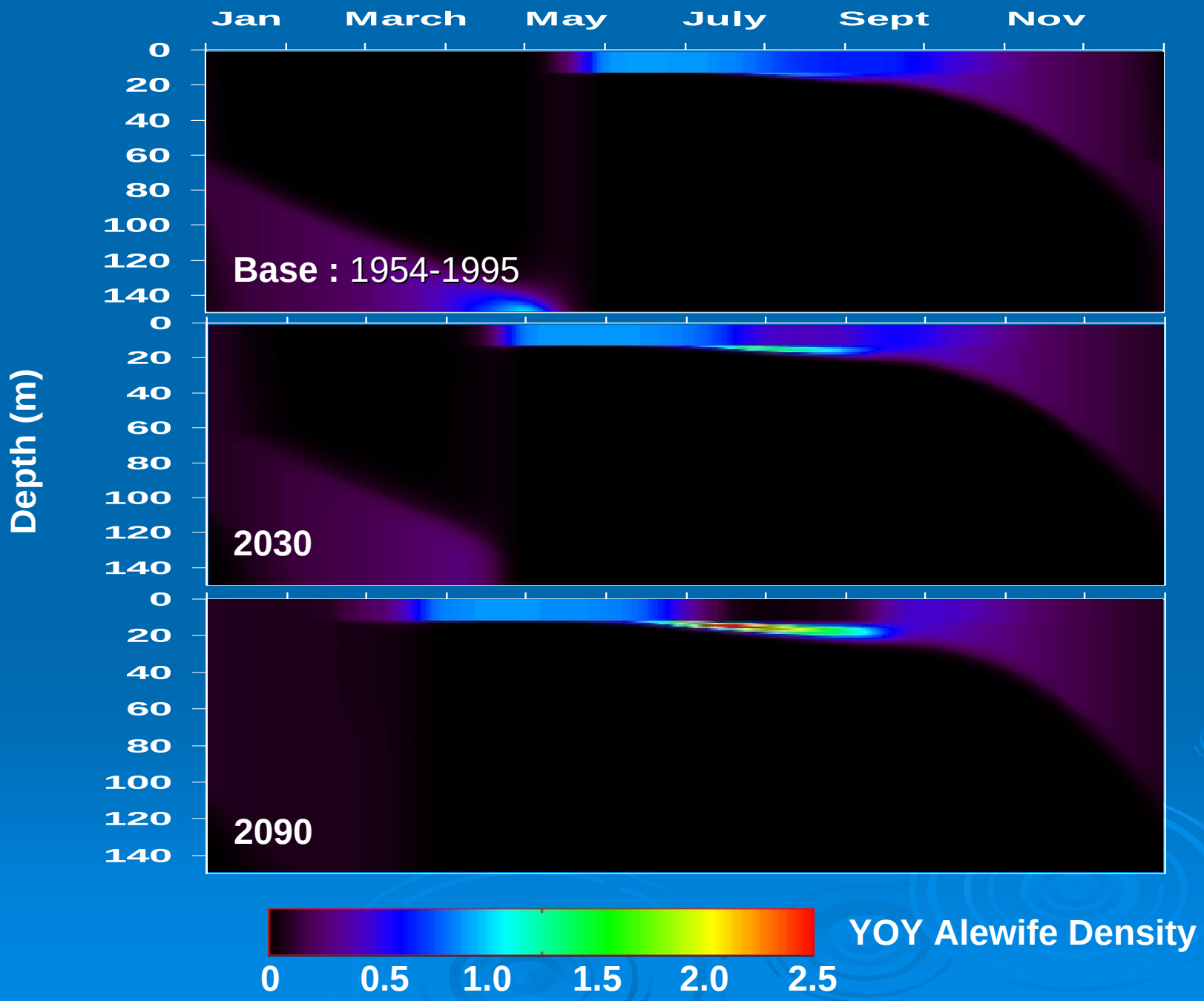

Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base: 1954-1995
2030
2090
Temperature (C)
0
5
10
15
20
25

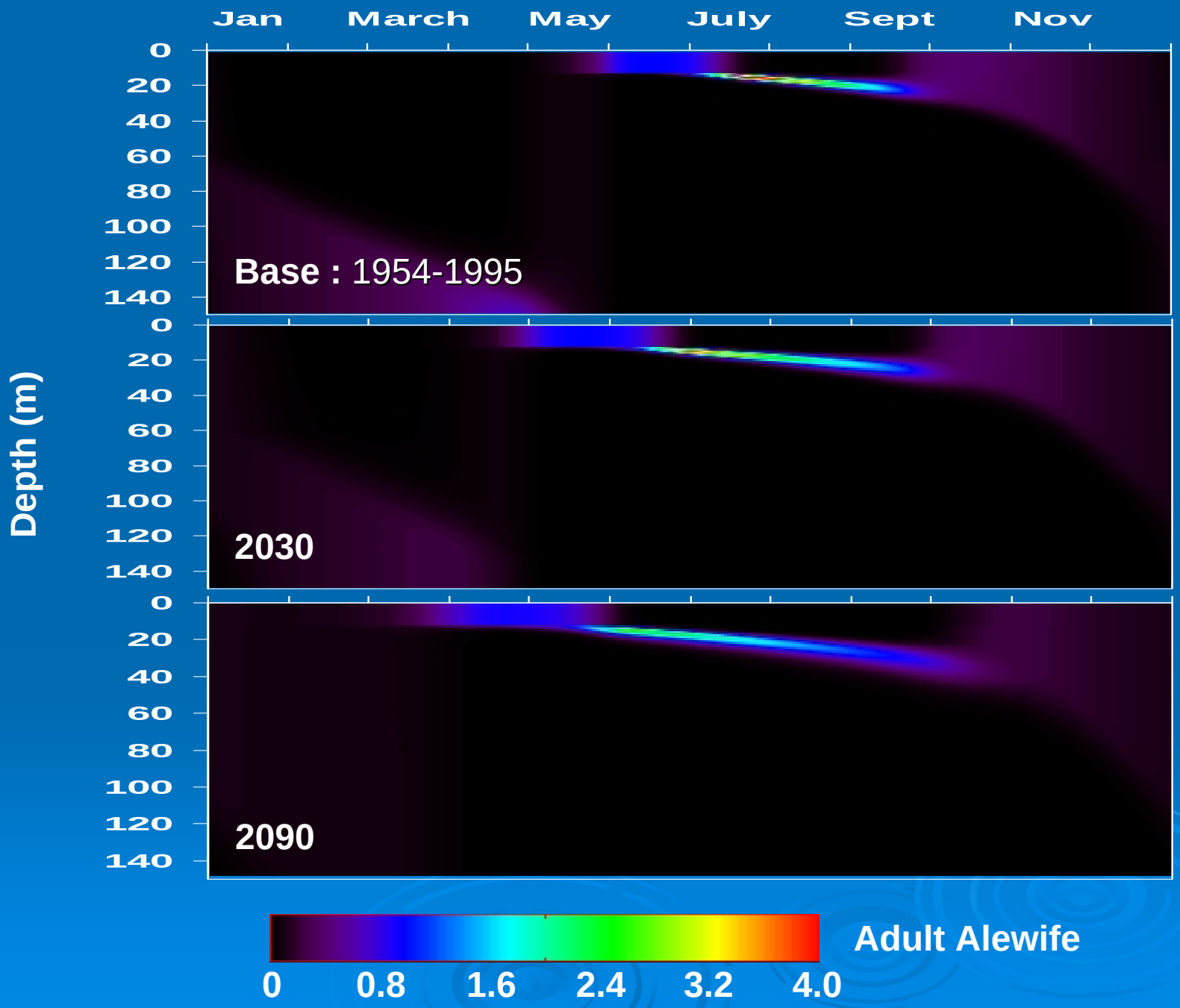
Key Assumption: Prey Fish Distributions

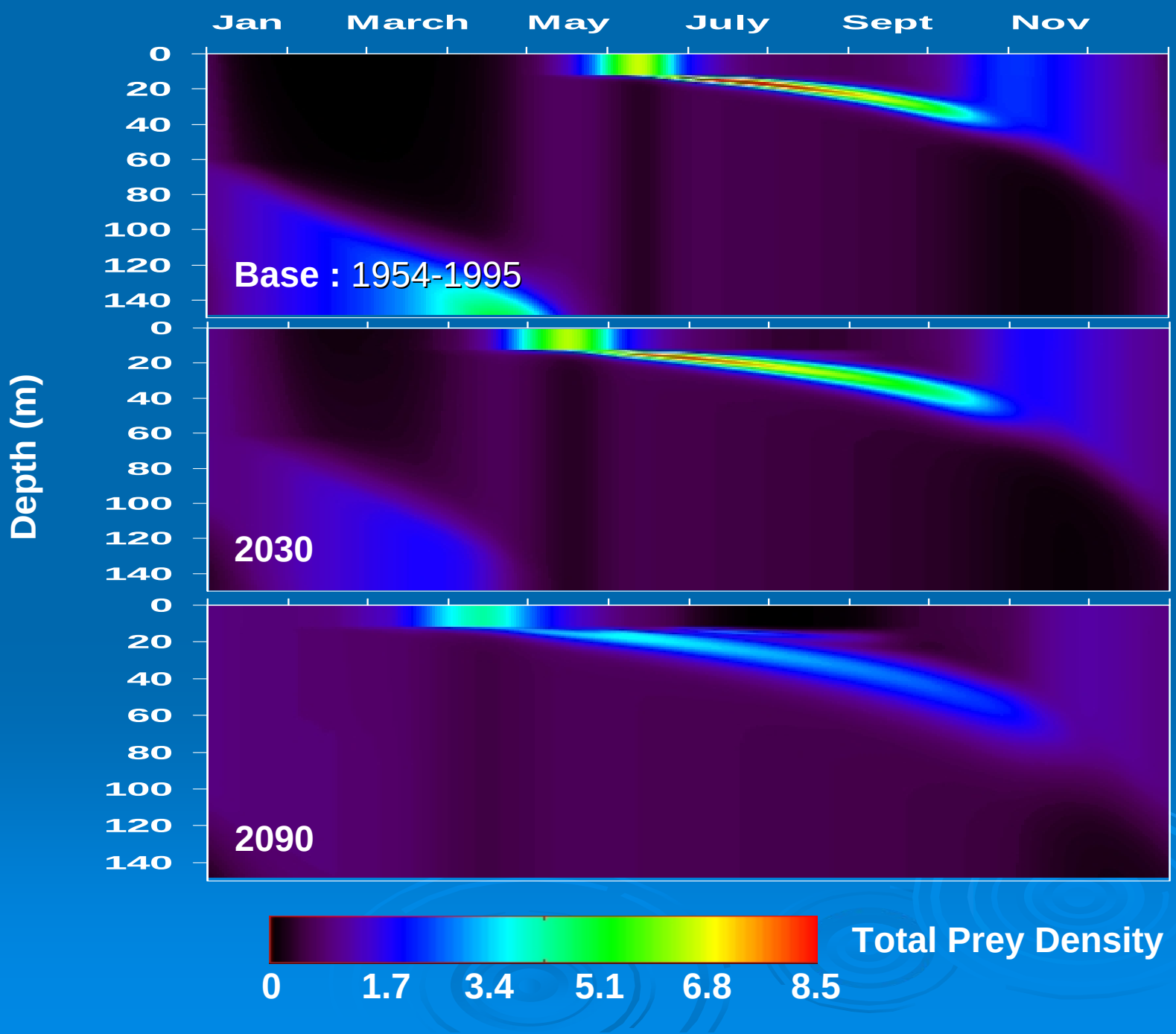
- Prey type and overall prey biomass remained constant at 1991-1996 level
- Prey were distributed across temperature according to Behavioral Thermoregulation Theory (70% within ± 2˚C of preferred and 100% within ±5˚C)
- When preferred temperature unavailable distributed in warmest water temperatures

Thermal Distribution of Prey Fish

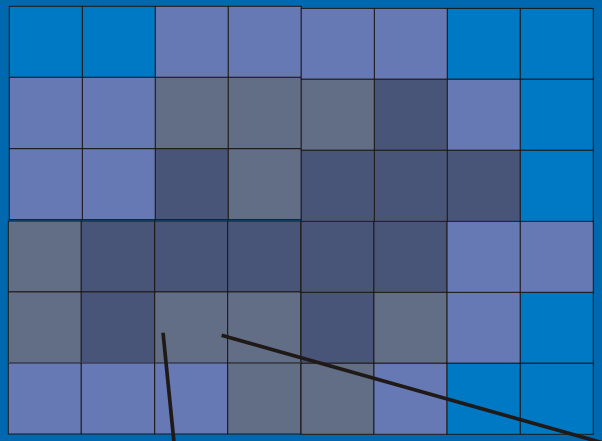


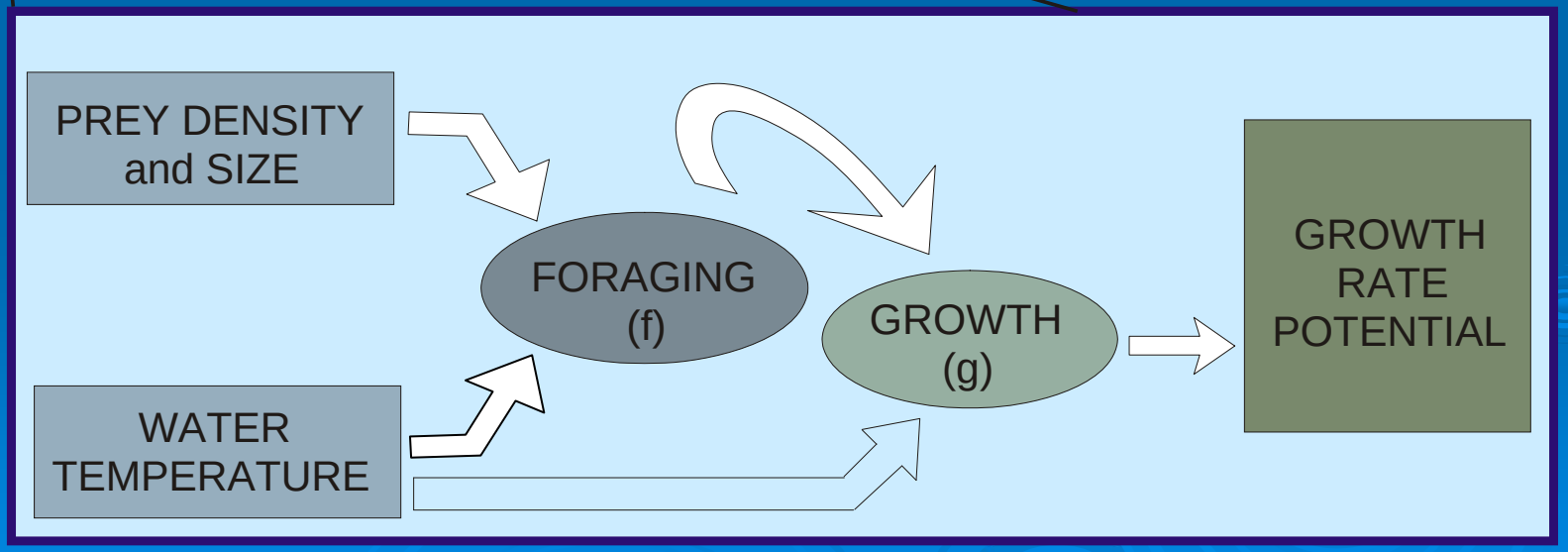

Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base : 1954-1995
2030
2090
0
0.5
1.0
1.5
2.0
2.5
YOY Alewife Density

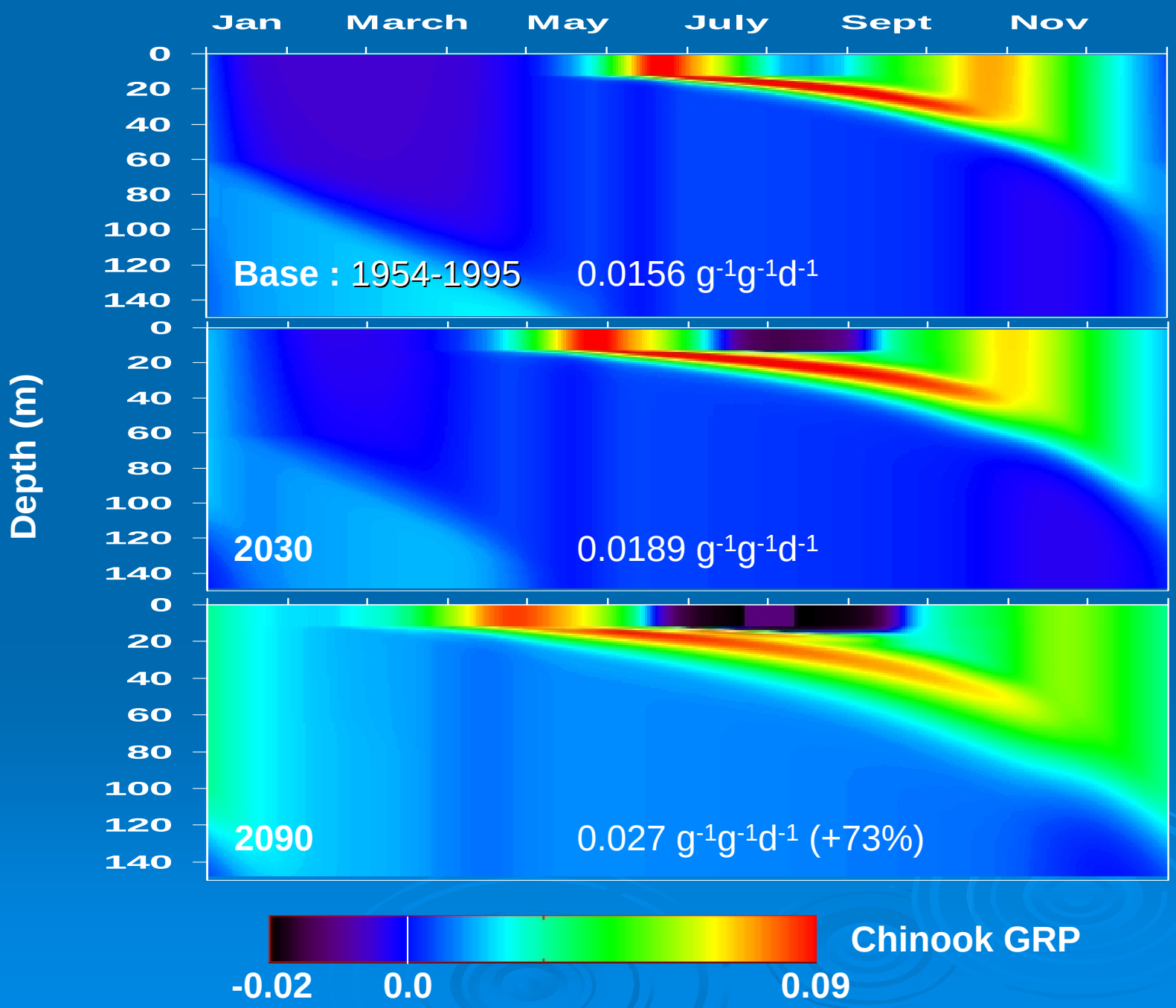

Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base : 1954-1995
2030
2090
Adult Alewife
0
0.8
1.6
2.4
3.2
4.0


Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base : 1954-1995
2030
2090
Total Prey Density
0
1.7
3.4
5.1
6.8
8.5

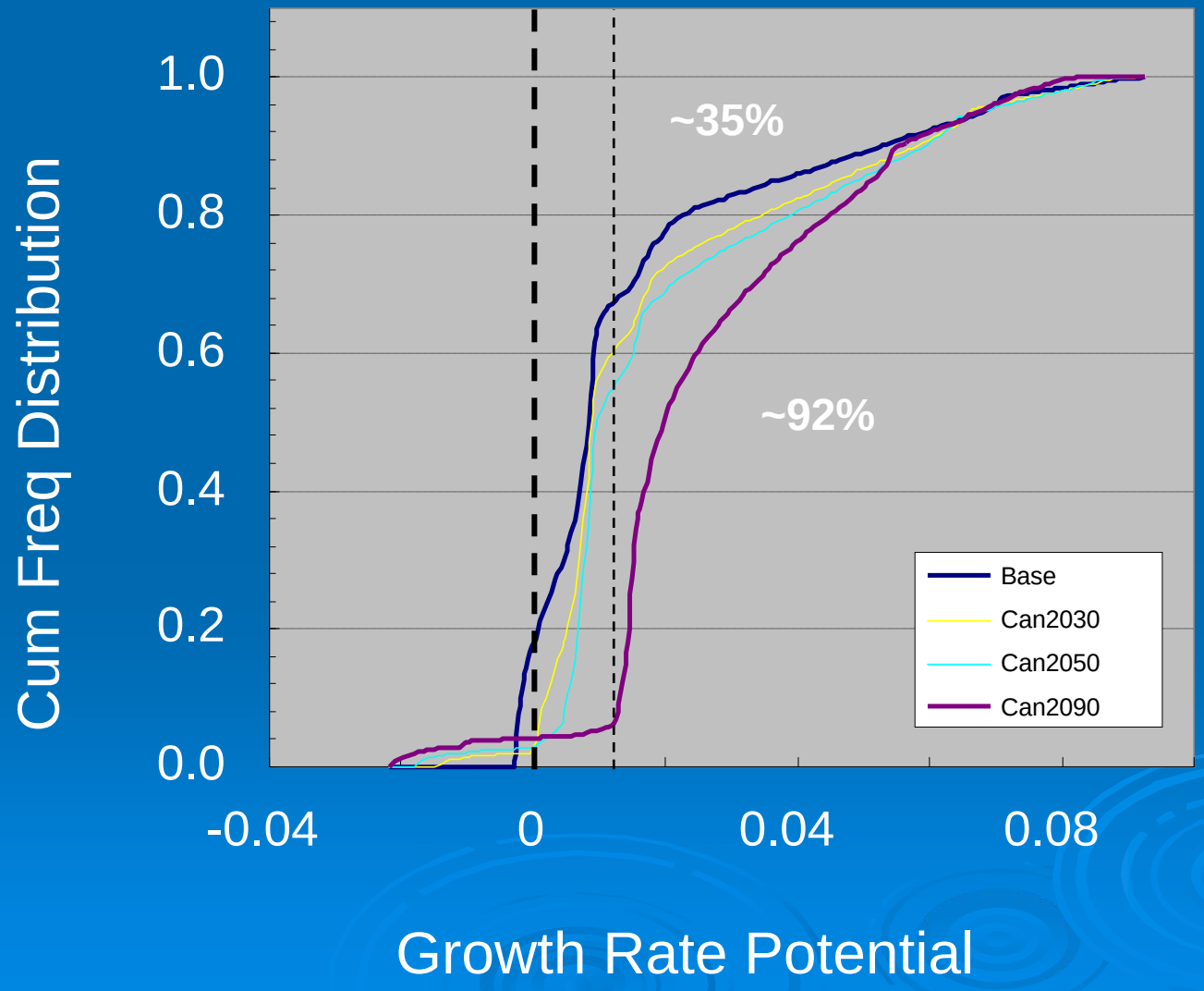
Growth Rate Potential

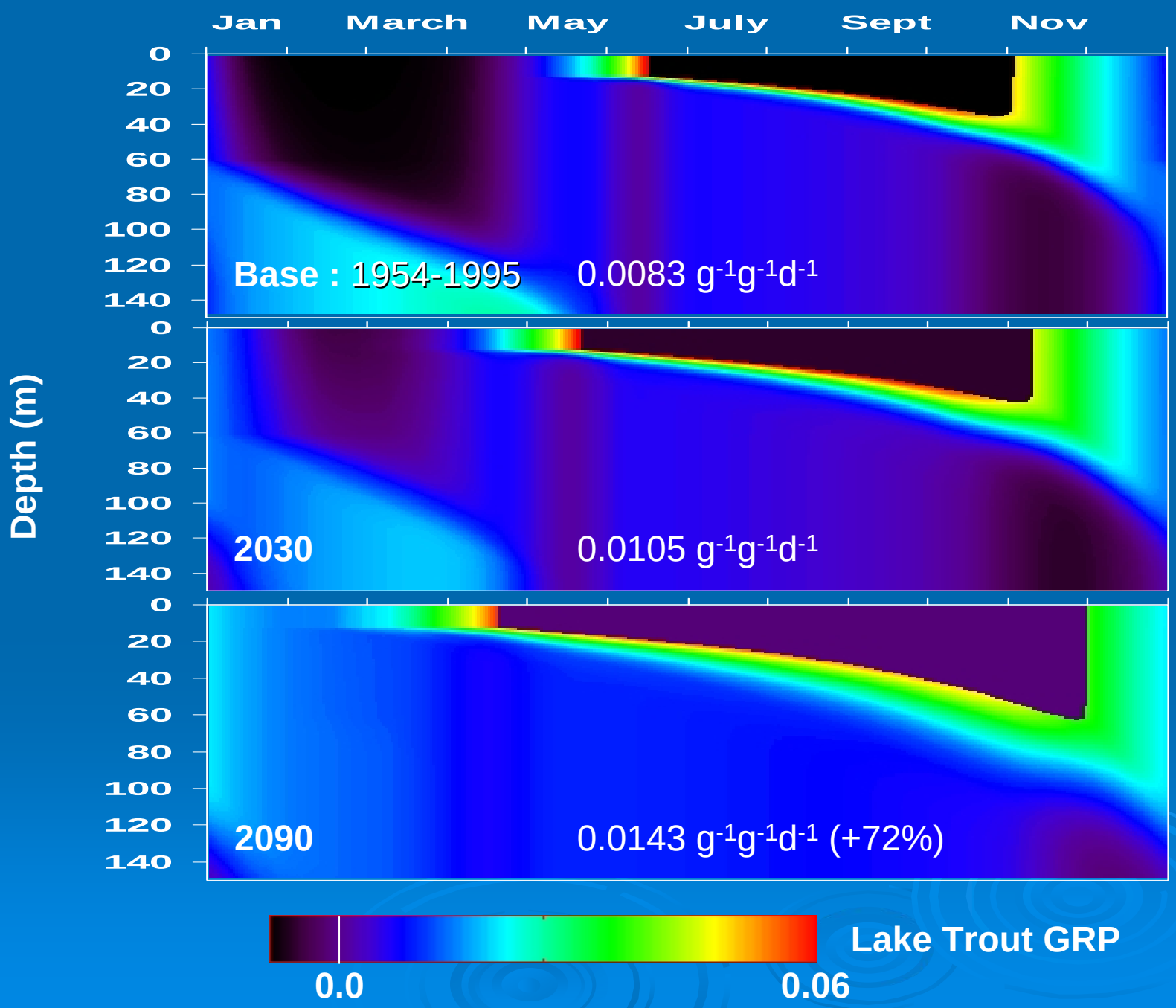


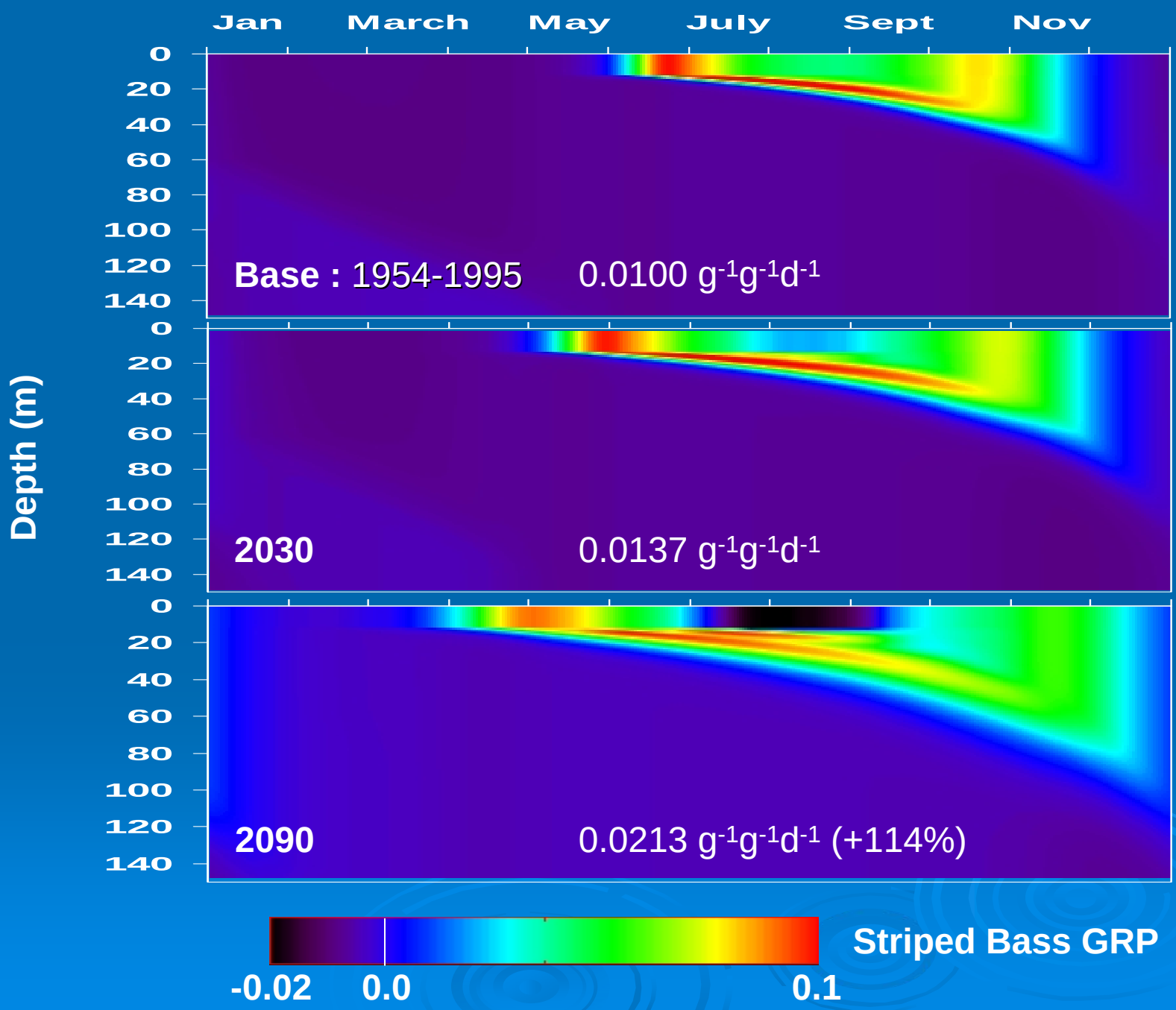



Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base : 1954-1995
0.0156 g-1g-1d-1
2030
0.0189 g-1g-1d-1
2090
0.027 g-1g-1d-1 (+73%)
Chinook GRP
-0.02
0.0
0.09

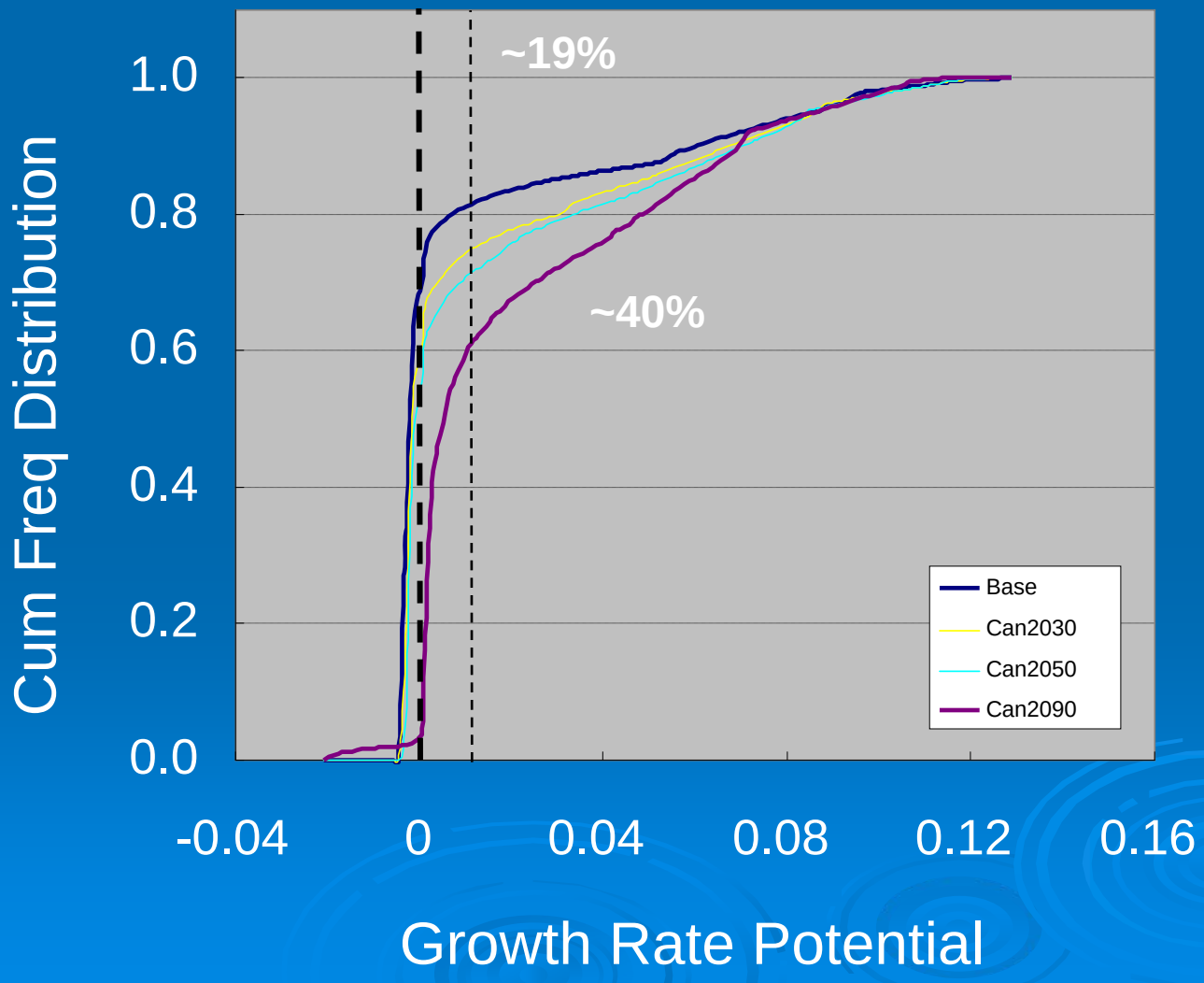
Chinook Salmon

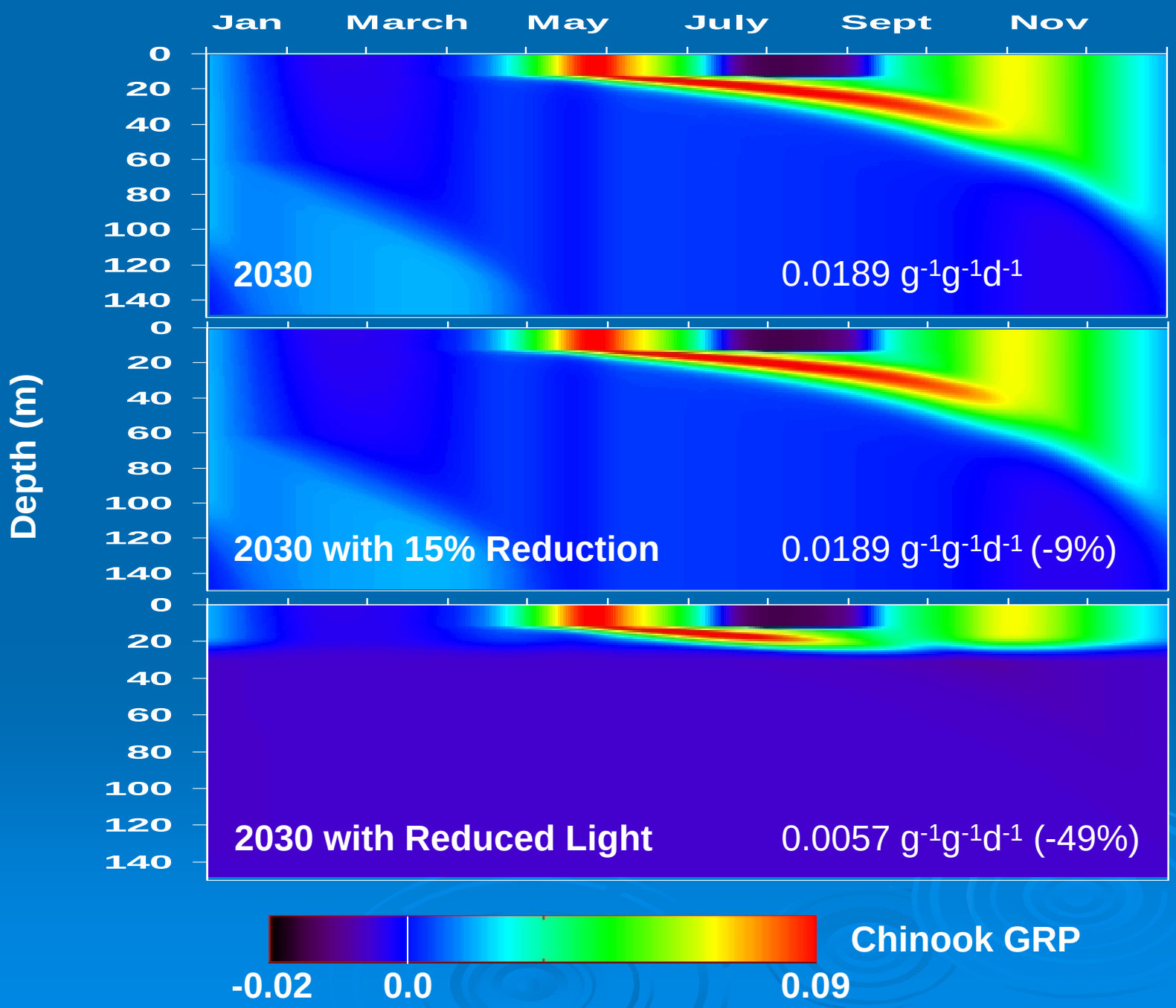


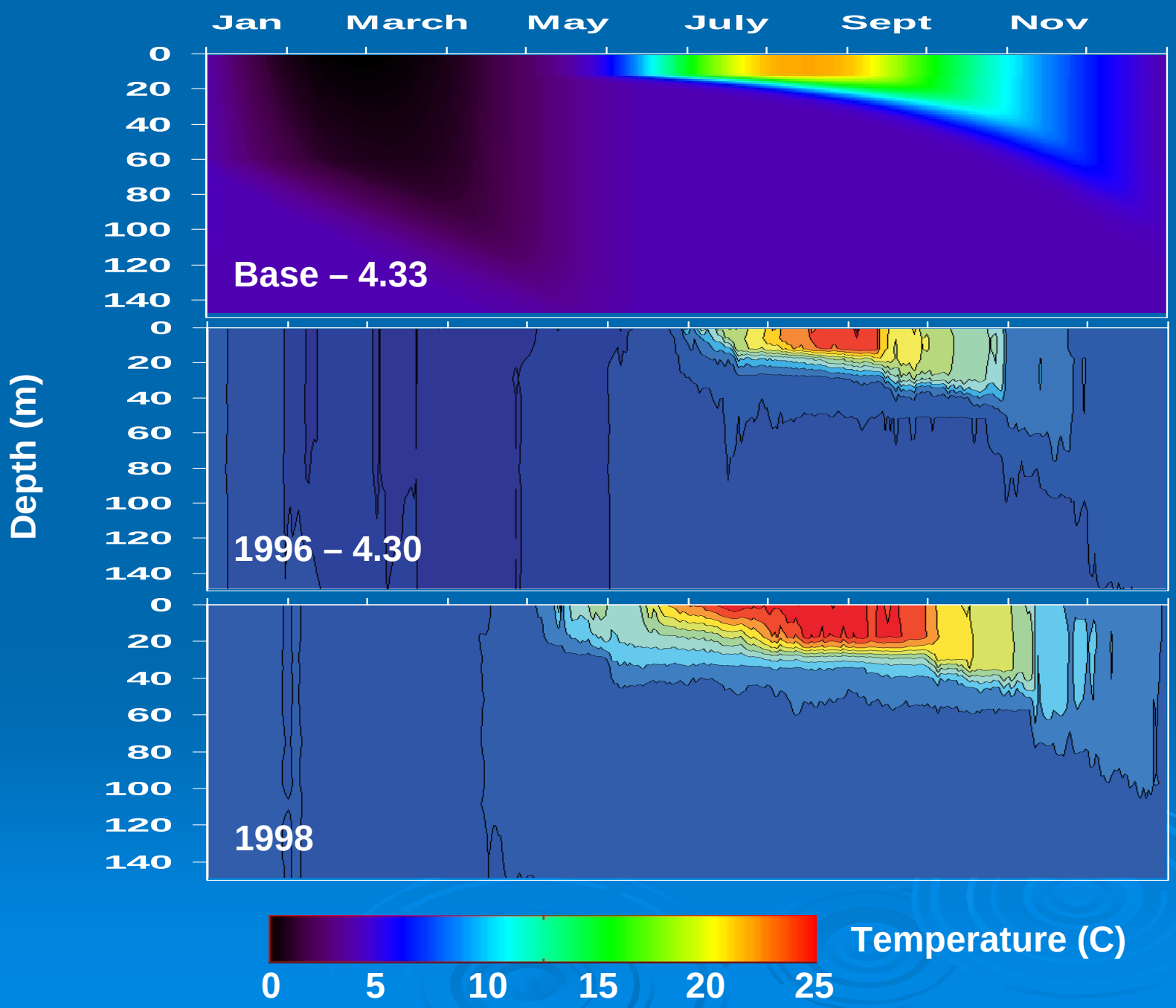

Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base : 1954-1995
0.0083 g-1g-1d-1
2030
0.0105 g-1g-1d-1
2090
0.0143 g-1g-1d-1 (+72%)
Lake Trout GRP
0.0
0.06

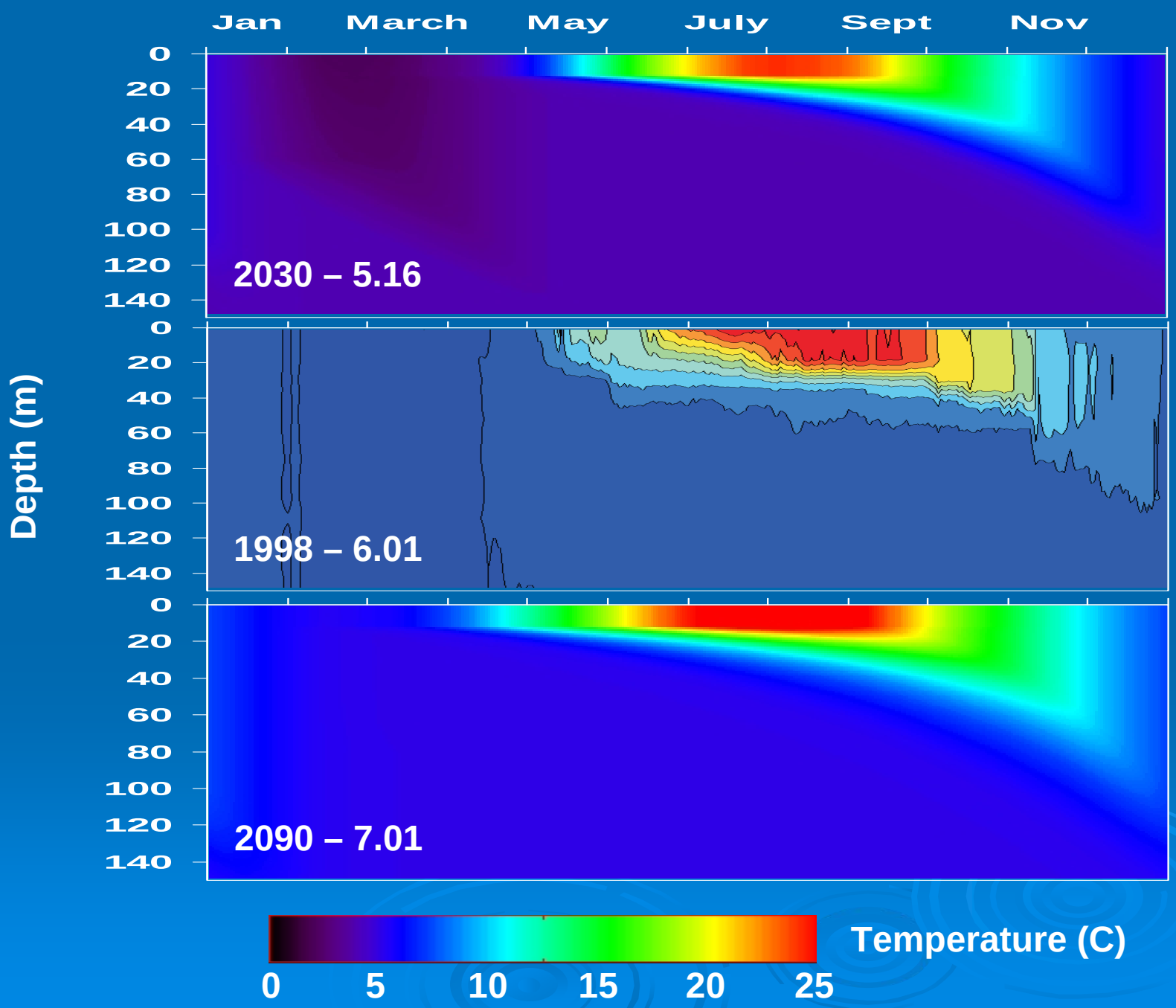

Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base : 1954-1995
0.0100 g-1g-1d-1
2030
0.0137 g-1g-1d-1
2090
0.0213 g-1g-1d-1 (+114%)
-0.02
0.0
0.1
Striped Bass GRP

Striped Bass




Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
2030
0.0189 g-1g-1d-1
2030 with 15% Reduction
0.0189 g-1g-1d-1 (-9%)
2030 with Reduced Light
0.0057 g-1g-1d-1 (-49%)
Chinook GRP
-0.02
0.0
0.09


Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
Base – 4.33
1996 – 4.30
1998
0
5
10
15
20
25
Temperature (C)


Jan
March
May
July
Sept
Nov
Depth (m)
0
20
40
60
80
100
120
140
2030 – 5.16
1998 – 6.01
2090 – 7.01
0
5
10
15
20
25
Temperature (C)

Potential affect of thermal volume

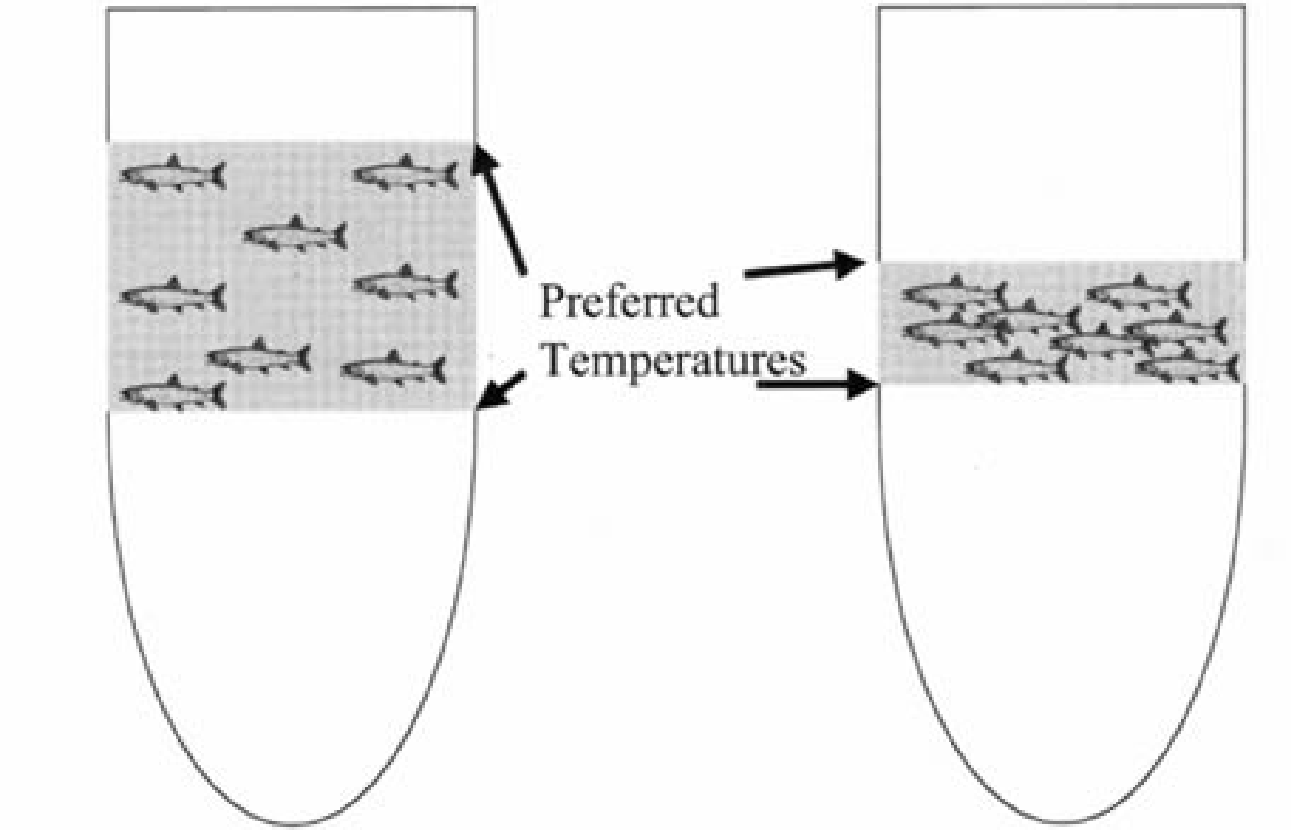


Figure 12. Conceptual demonstration of the effect of changes in the volume of thermal habitat on prey densities.

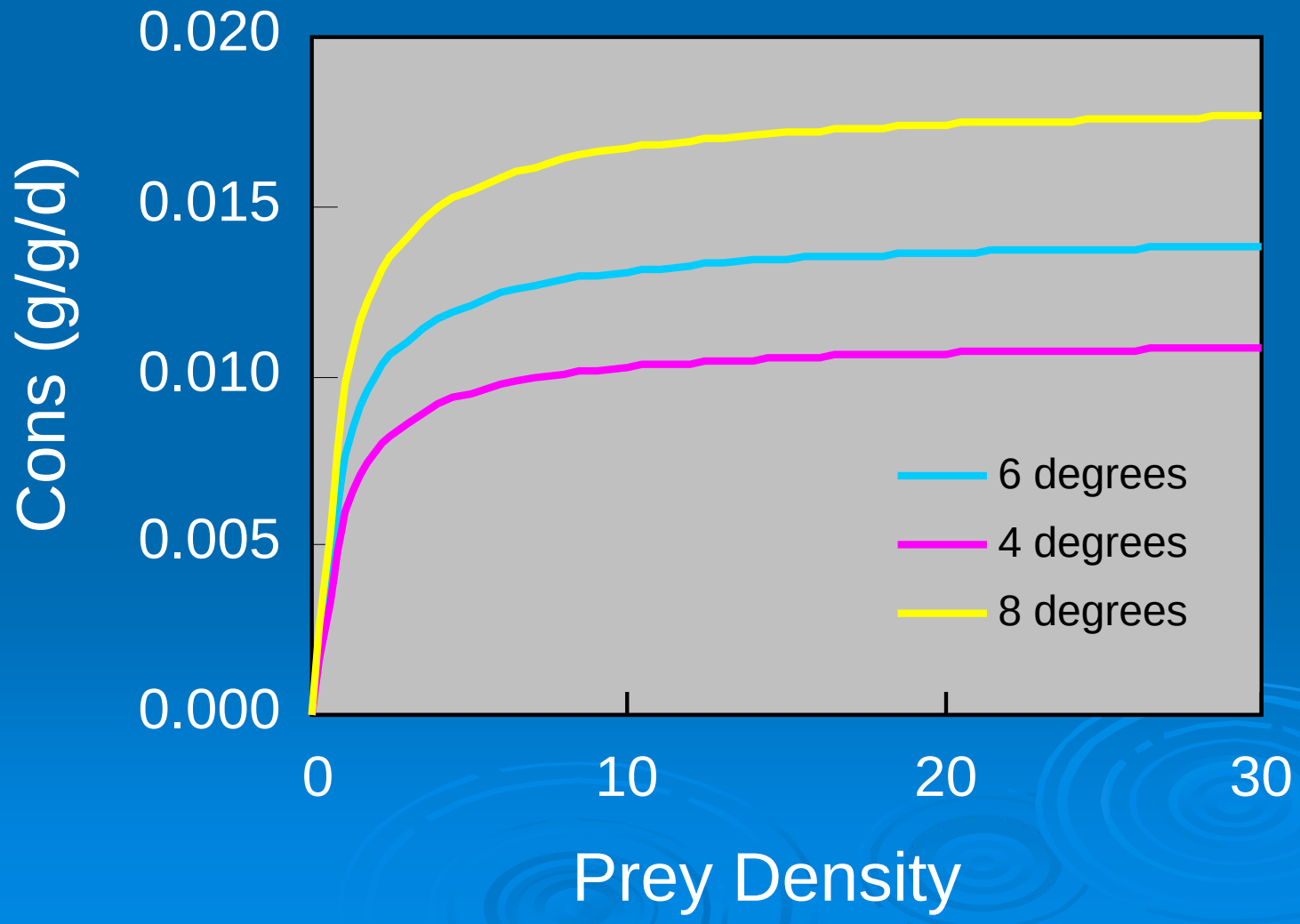
Conclusions

- Increased water temperature, increased duration of thermal stratification period, and increased depth of the thermocline.
- Fish behavior and bioenergetics potential will likely change in response to changing environmental conditions
- Potential for prey densities to decline at fixed population abundances given increase in thermal habitat (prey fish more dispersed)
- Responses will be species specific
- May result in increased habitat quality for some fishes
- Inter-annual variability may provide clues

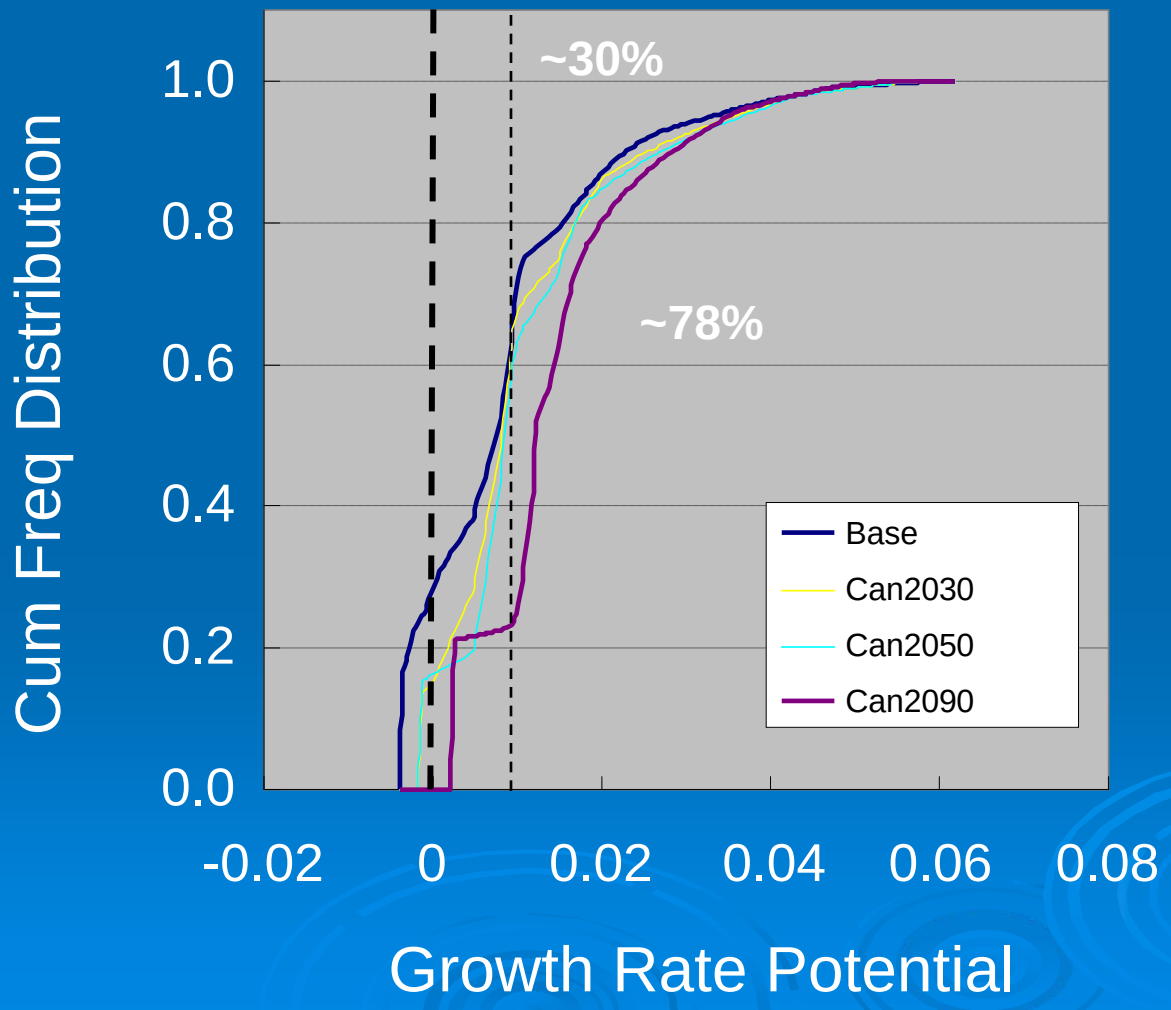
Need better understanding …

- Habitat selection
- Species-specific stage dependent responses of fishes
- Change in population and recruitment dynamics
  - Habitat requirements are stage dependent
- Response of lower trophic levels
- Response in the time and space dependence of food web interactions

Predator-Prey Functional Response (Chinook Salmon)



Lake Trout


Cum Freq Distribution
1.0
0.8
0.6
0.4
0.2
0.0
-0.02
0
0.02
0.04
0.06
0.08
Growth Rate Potential
~30%
~78%
Base
Can2030
Can2050
Can2090

Chinook Salmon (w/ Light)