

# Haliburton's Lake Trout: From the Past Into the Future

*A precious renewable resource of  
productive glacial relicts*



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# Background

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- Lake trout is a cold-water fish that occupies a broad range of thermal habitats and latitudes and supports important subsistence, commercial, and sport fisheries
- It is an important indicator species, sensitive to water quality and environmental change, and in Ontario, they are at the southern part of their range
- A research study was initiated in the Haliburton Highlands of Ontario in the late 1970s on a set of lake trout lakes to determine the effects of acid precipitation on lake trout populations

*Let's look at some of the insights gained from this study !*

# Objectives

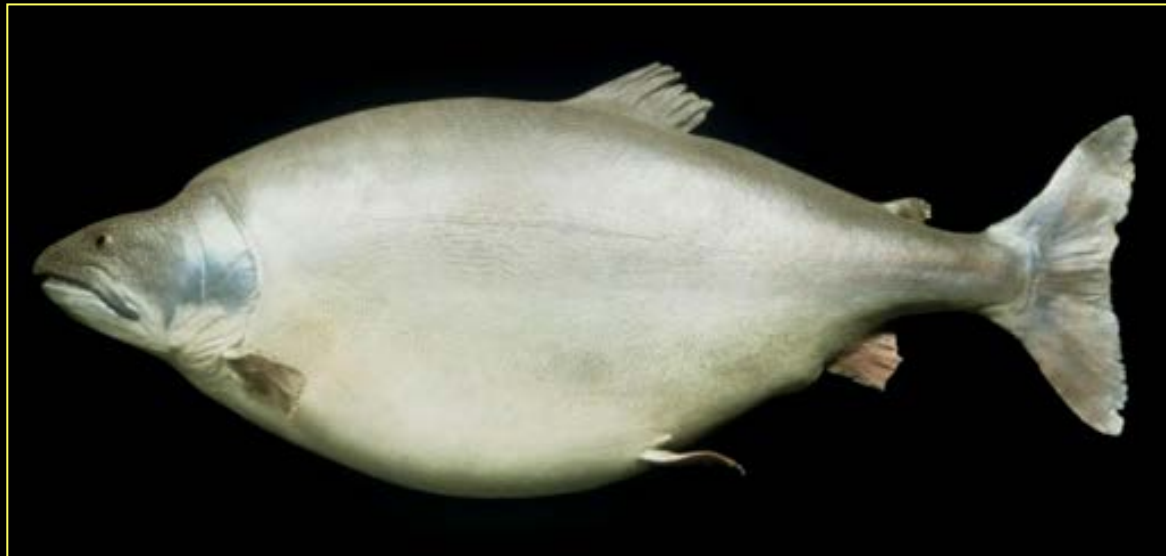
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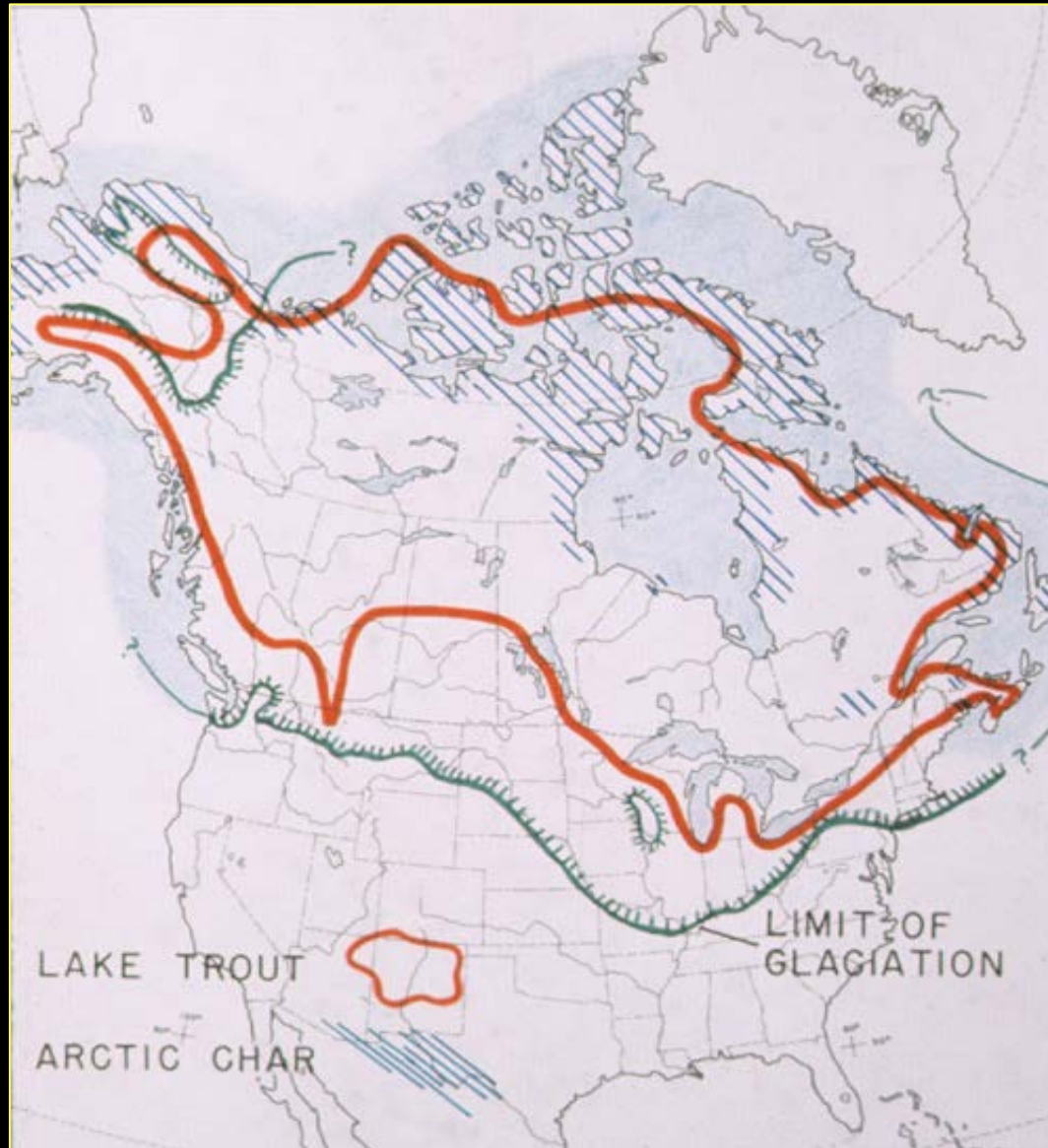
- Environmental conditions were monitored – temperature, oxygen, and water quality
- Fish communities were sampled – quantitative electrofishing, fine-mesh gill netting, and intensive creel sampling
- Newly refined research techniques were applied – age and growth determination, genetics, and isotopic analyses
- Other stressors were considered – angling pressure, climate change, and exotic invasions; results were compared with other ongoing studies

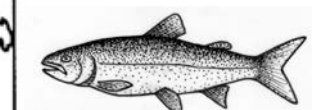
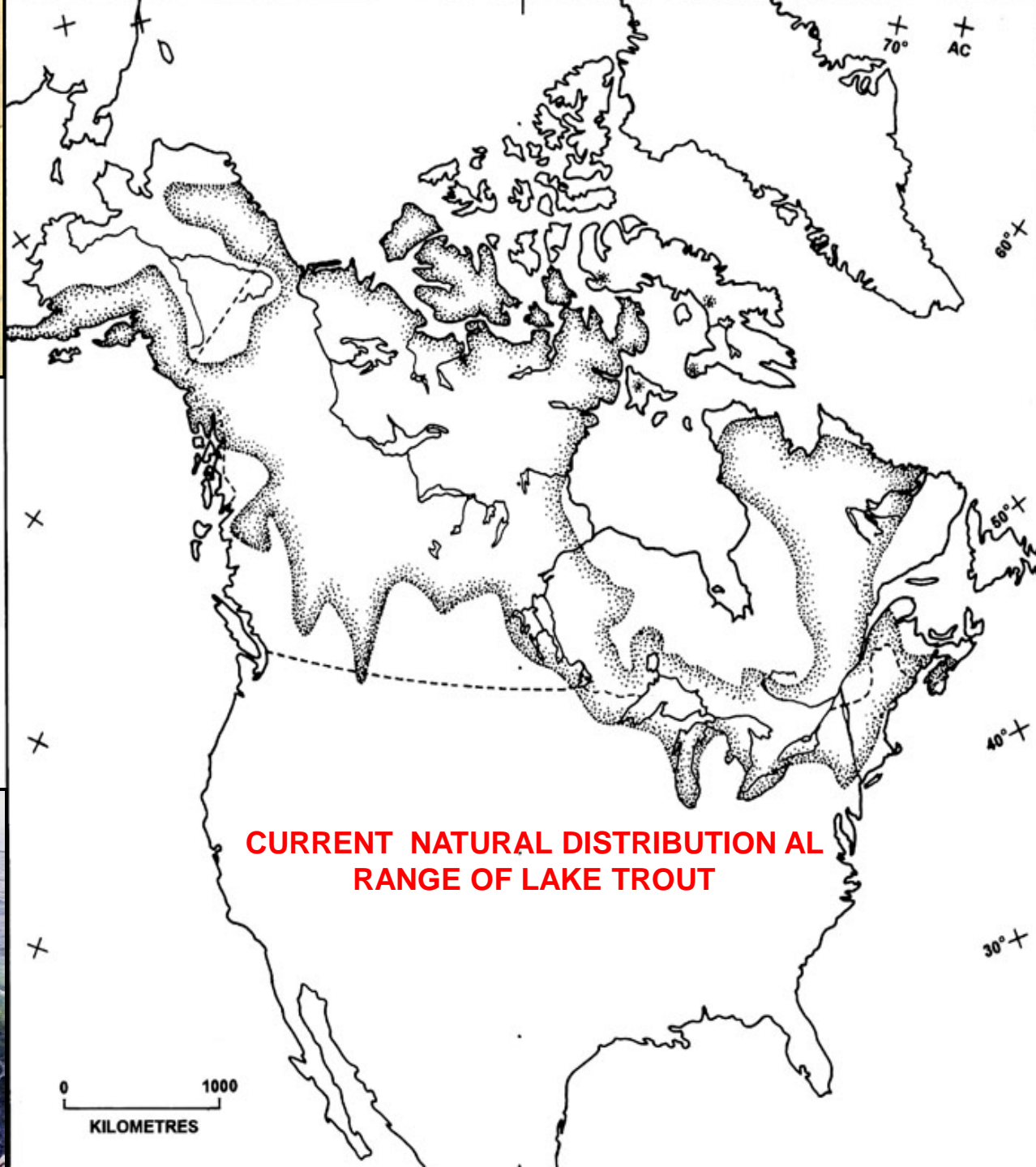
*Provides a two-decade lake trout case-history study !*

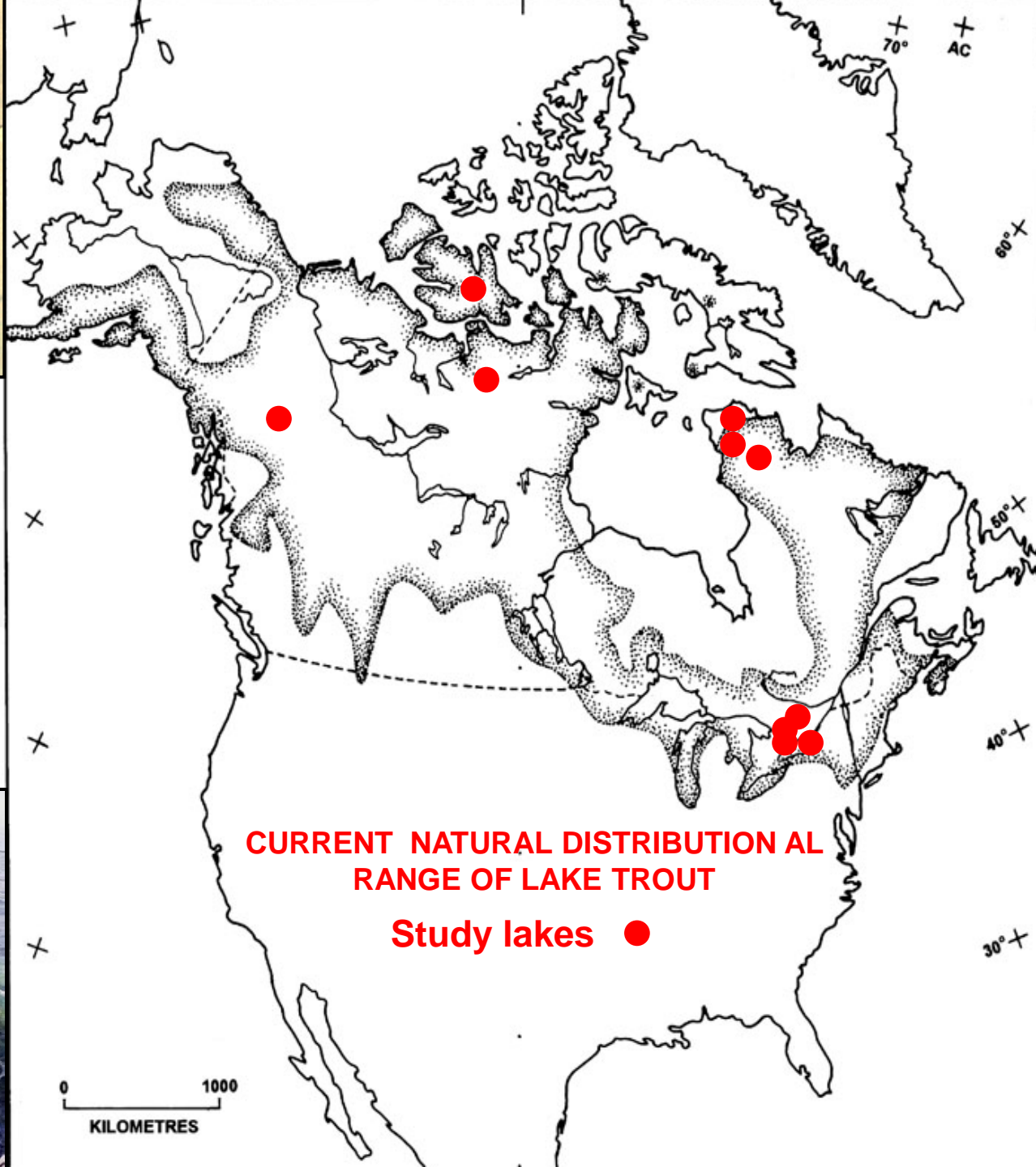
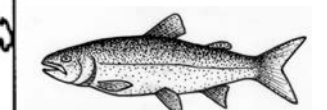
***Lake trout (Salvelinus namaycush) is a cold-water fish preferring well-oxygenated waters in oligotrophic lakes***



***Lake trout are found from 43° to 73° N latitude, generally following the limits of previous glacial periods***







# Thermal Requirements and Optimum Temperature for Spawning and Growth

*Cold-water, cool-water,  
warm-water fish*



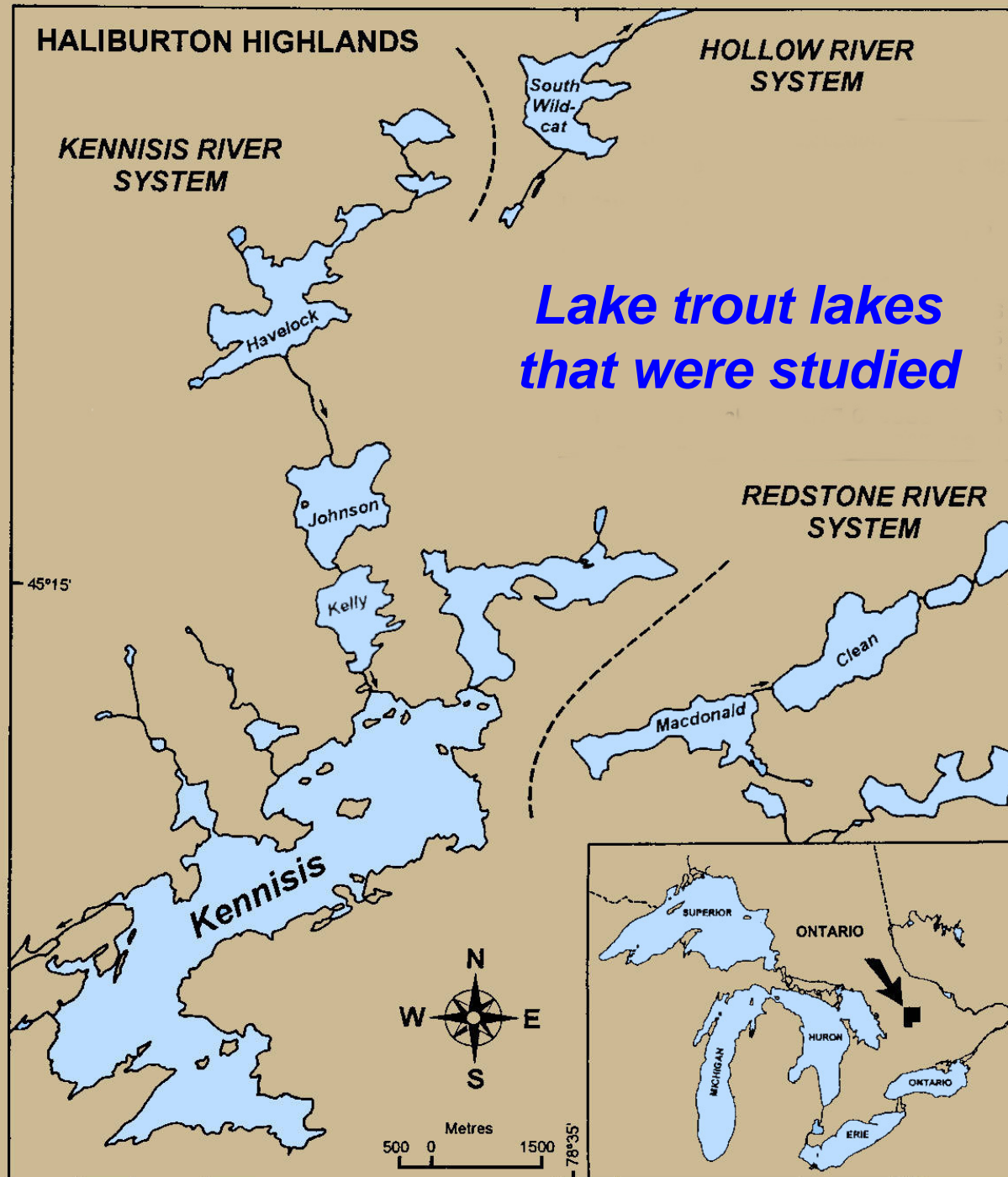
# Temperature requirements of typical temperate-region Great Lakes fish of the three major thermal groupings.

Thermal grouping	Species	Thermal requirement			
		Spawning	Optimum	Preferred	Mean
<b>coldwater</b> 	brook trout	8.7	15.0	13.0	14.0
	lake whitefish	5.7	15.2	11.1	13.2
	lake trout	10.6	11.7	11.2	11.5
	Mean	8.3	14.0	11.8	12.9
<b>coolwater</b> 	yellow perch	9.3	22.5	23.3	22.9
	walleye	8.0	22.6	21.7	22.2
	northern pike	6.9	20.0	23.5	21.8
	Mean	8.1	21.7	22.8	22.3
<b>warmwater</b> 	bluegill	23.7	30.2	31.3	30.8
	white perch	20.1	28.8	29.8	29.0
	smallmouth bass	18.0	27.0	27.4	27.2
	Mean	20.6	28.7	29.5	29.0

# **A Study of Acid Precipitation, Fish, and Fisheries Was Initiated in the Haliburton Highlands in the Late 1970s**

***A set of lake trout lakes was chosen  
in the Haliburton Forest and Wild  
Life Reserve***

***Lake trout are a sensitive indicator species !***



***In the Kennisis River system, four major headwater lakes were studied, primarily Havelock, Johnson, and Kelly***



***In the Redstone River system, four major headwater lakes were studied, primarily Macdonald and Clean***



# Intensive Water Sampling Was Conducted Throughout the Watersheds

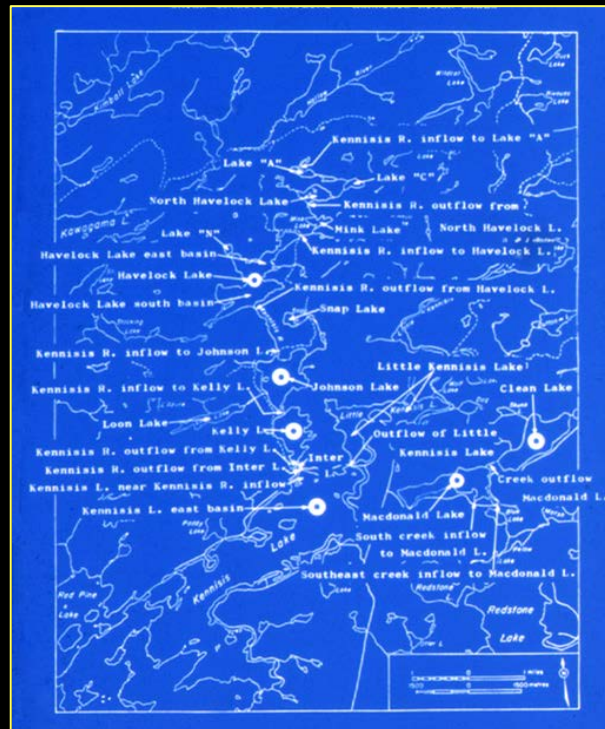
*pH, alkalinity, and total dissolved  
solids were measured throughout  
the year*

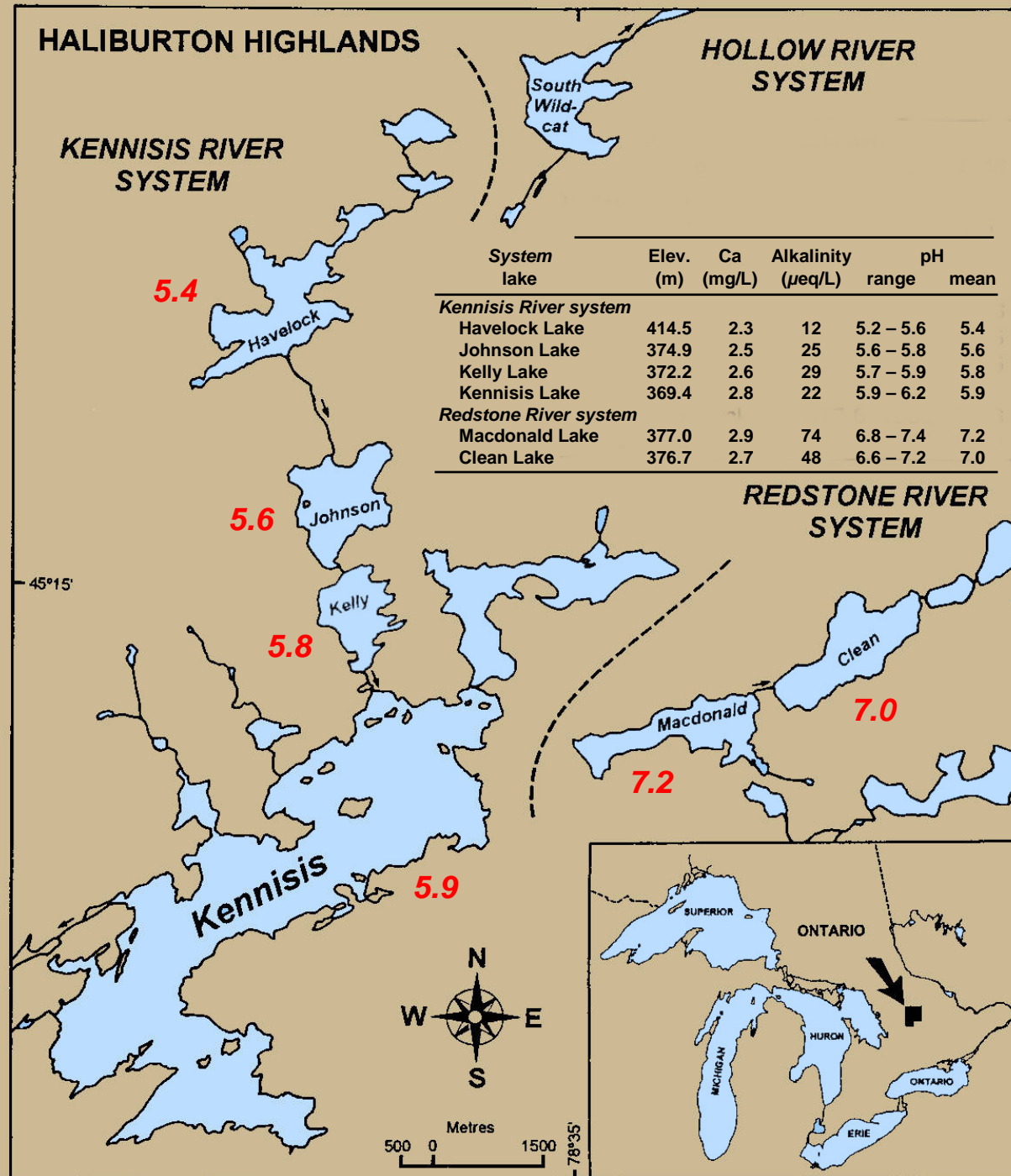
*New insights were acquired !*

***Multi-year water sampling indicated very consistent spatial and seasonal trends across the watersheds***

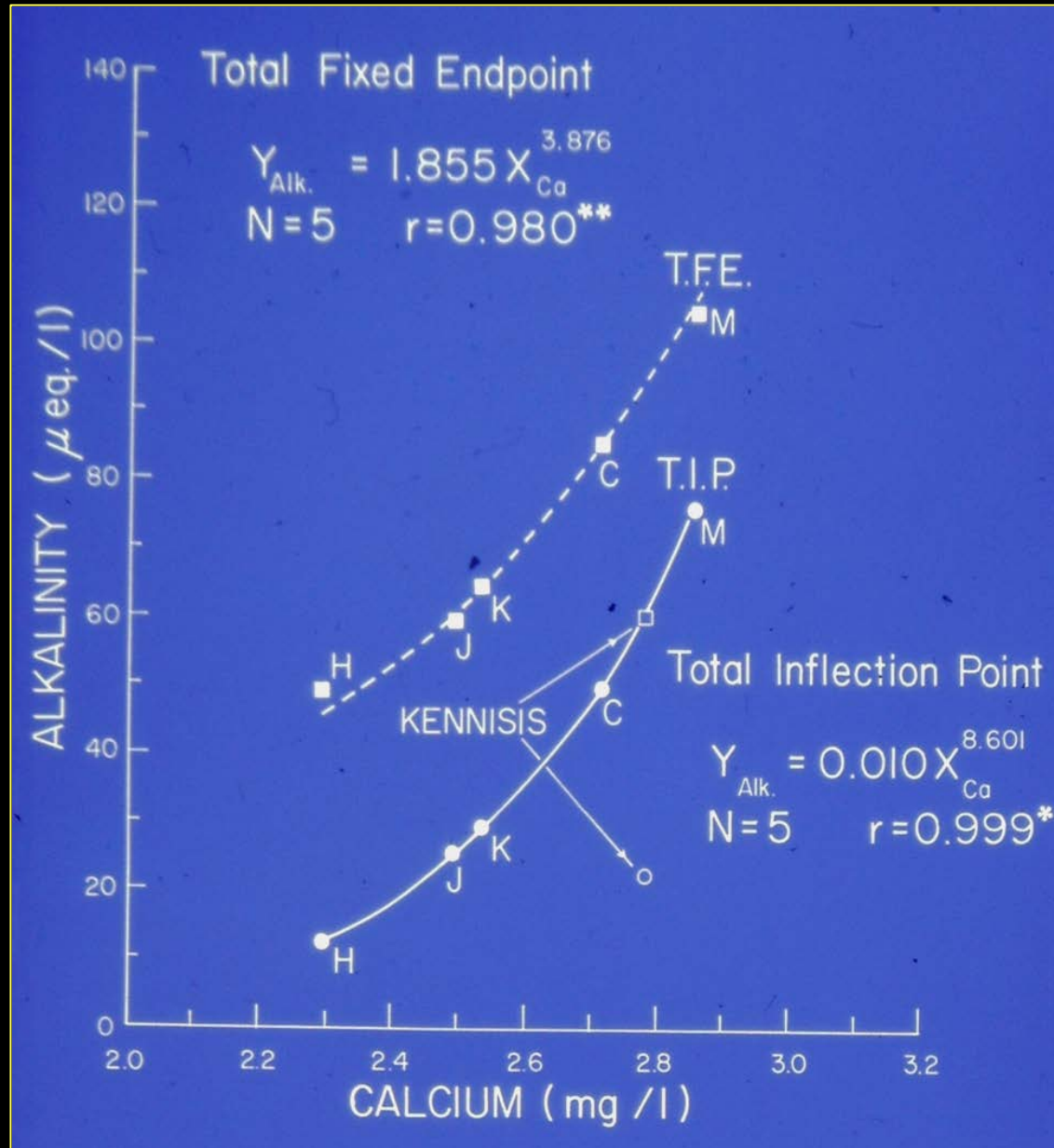
***A strong pH gradient existed across lakes, significantly higher in the Redstone River lakes, Macdonald and Clean***

***These provided a good comparative study of the effects of acid precipitation on fish and fisheries***

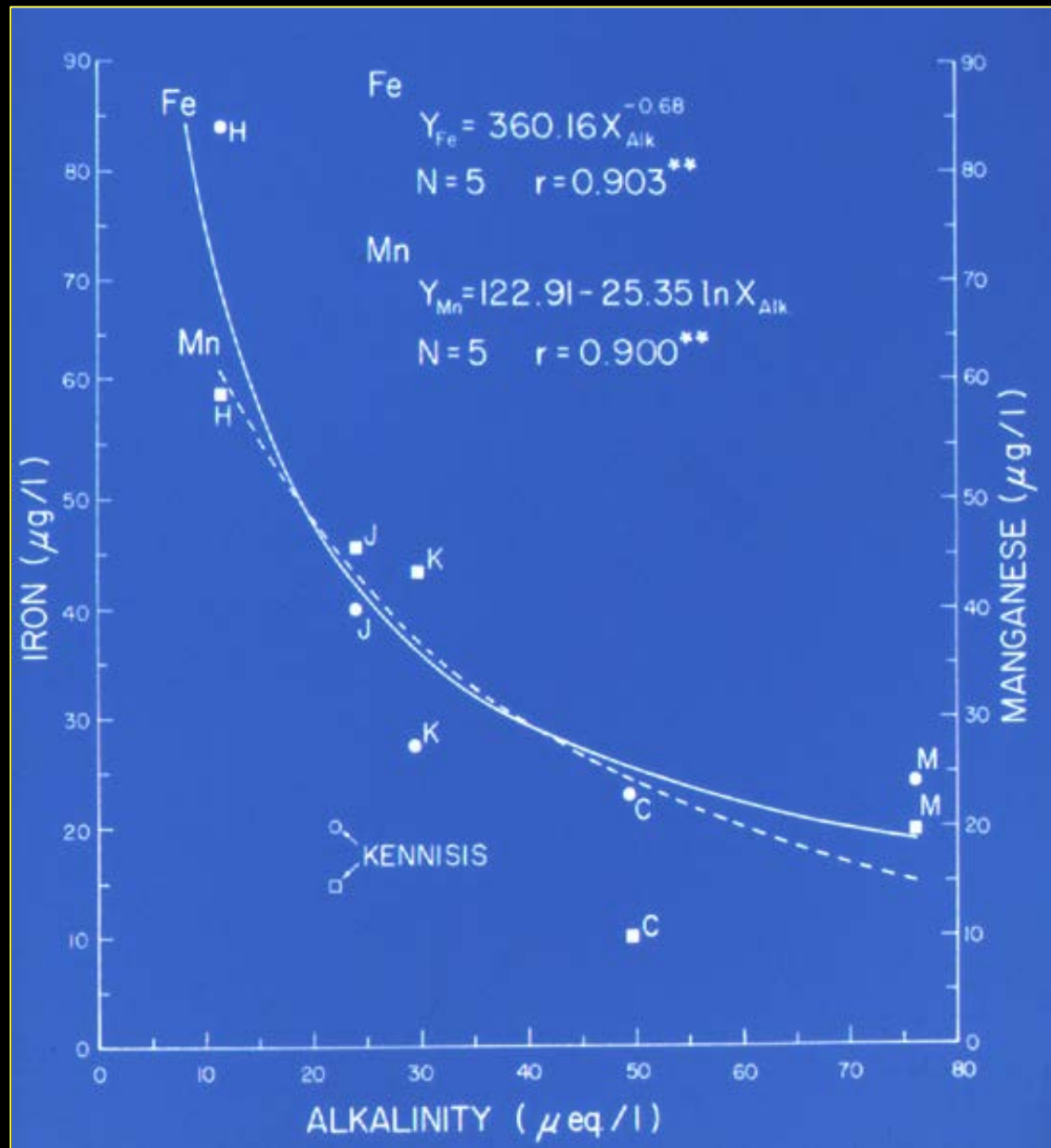




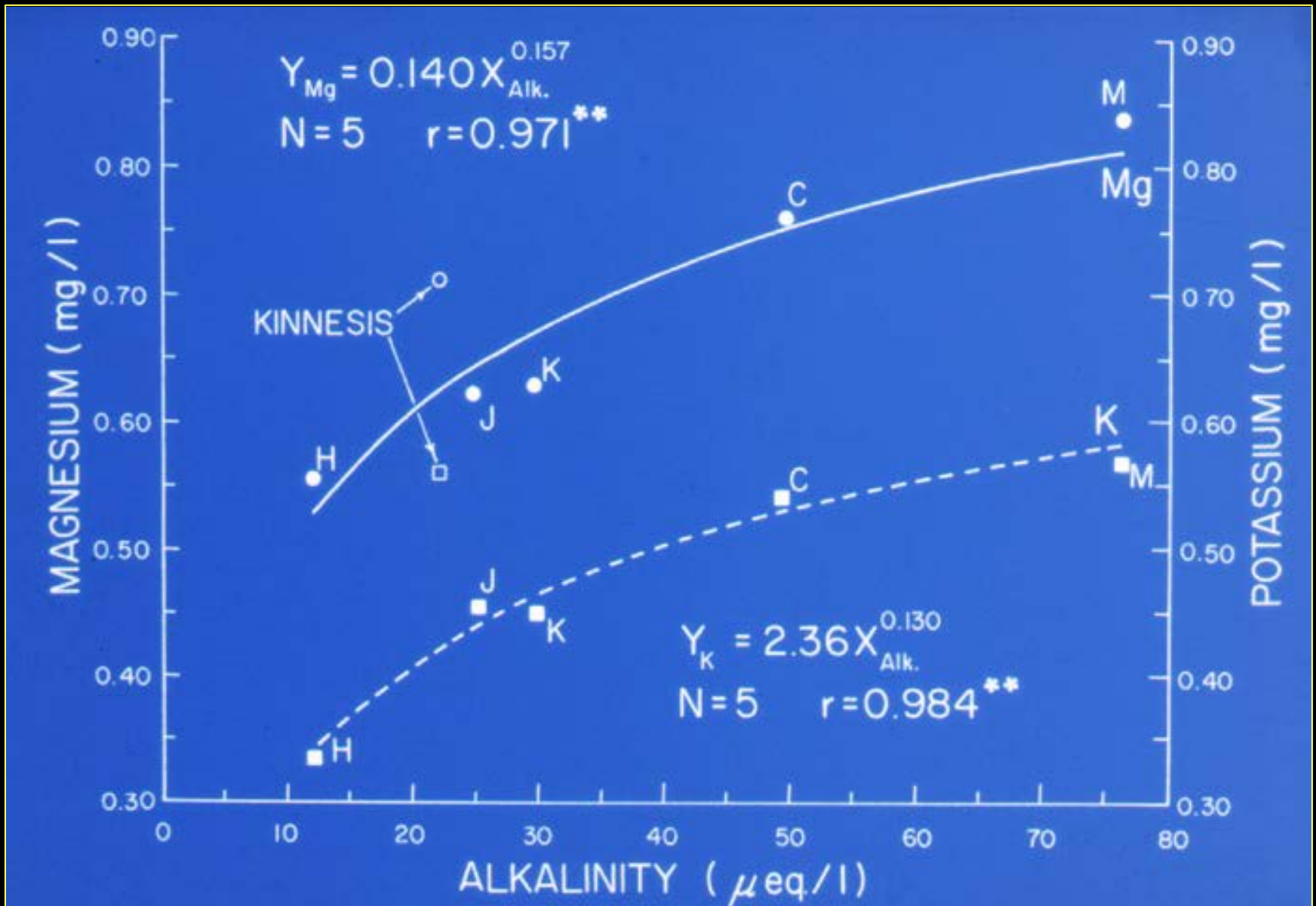
## Calcium and alkalinity increased downstream



## *Iron and manganese decreased downstream*



## ***Magnesium and potassium increased downstream***

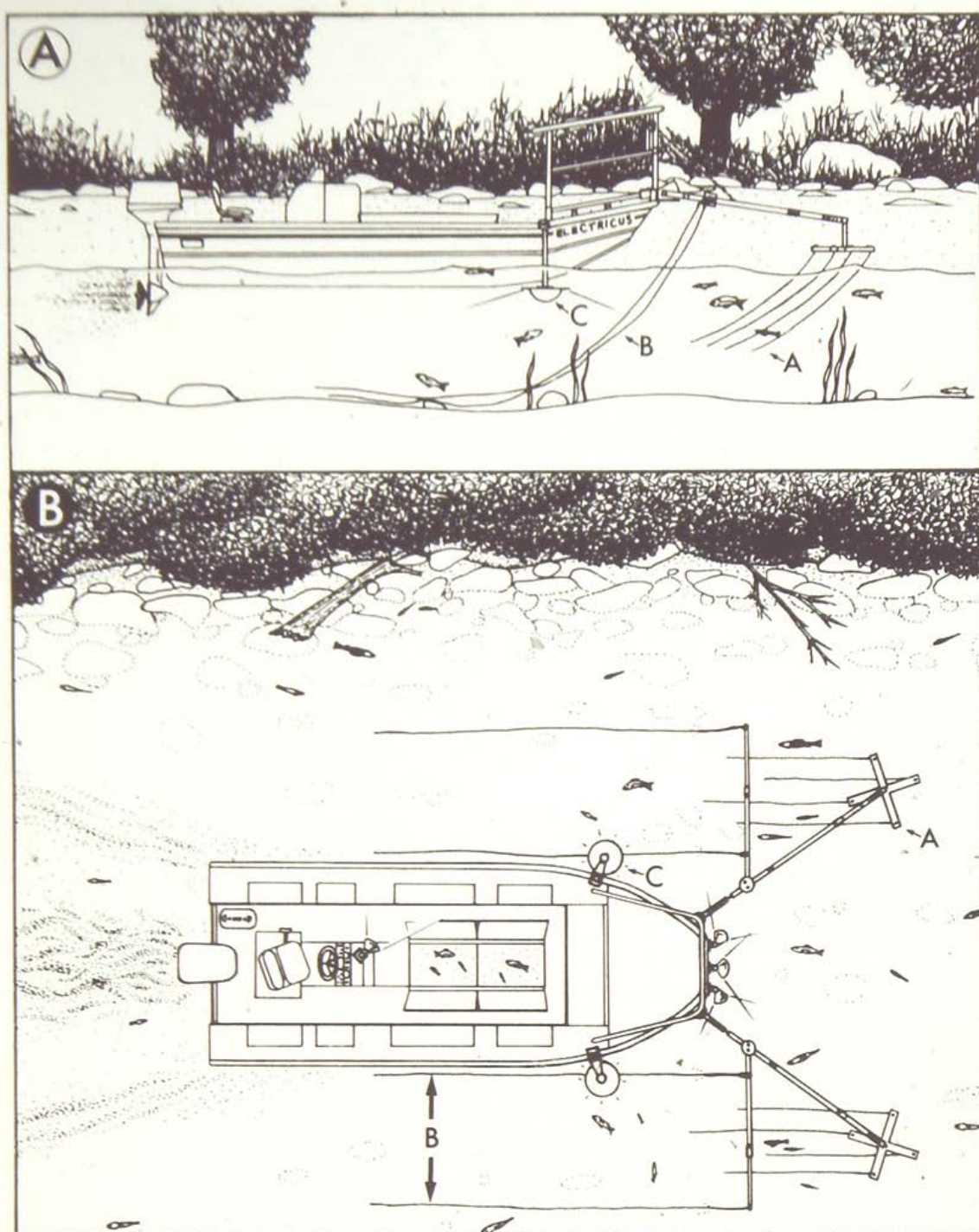


# **Intensive Fish Sampling Was Conducted, Using Various Techniques:**

***Quantitative electrofishing, fine-  
mesh netting, and angler creels***

***Extensive information was obtained  
from the late 1970s until the late 1990s***

**Quantitative open-water boat electrofishing was used to determine fish density on a unit area basis**



# FINE-MESH GILL NETTING WAS CONDUCTED at various depths on a seasonal and annual basis

*Employed as a live  
capture-release  
method*



# CREEL SAMPLING WAS INTENSIVE

Some lakes were heavily fished

*Anglers provided  
many samples*

*A very beneficial  
relationship*



***Complete creels were run on five of the lakes for over two years; virtually all of the angled fish caught were processed for samples; anglers were extremely supportive and their assistance was critically important !***





***Most of the angled lake trout from some lakes were relatively small, but the occasional large fish was caught; this was the largest lake trout caught in Macdonald Lake during the study***

**LAKE TROUT FROM SOME LAKES APPEARED DIFFERENT**  
**Anglers said this was especially true for Macdonald and Clean**

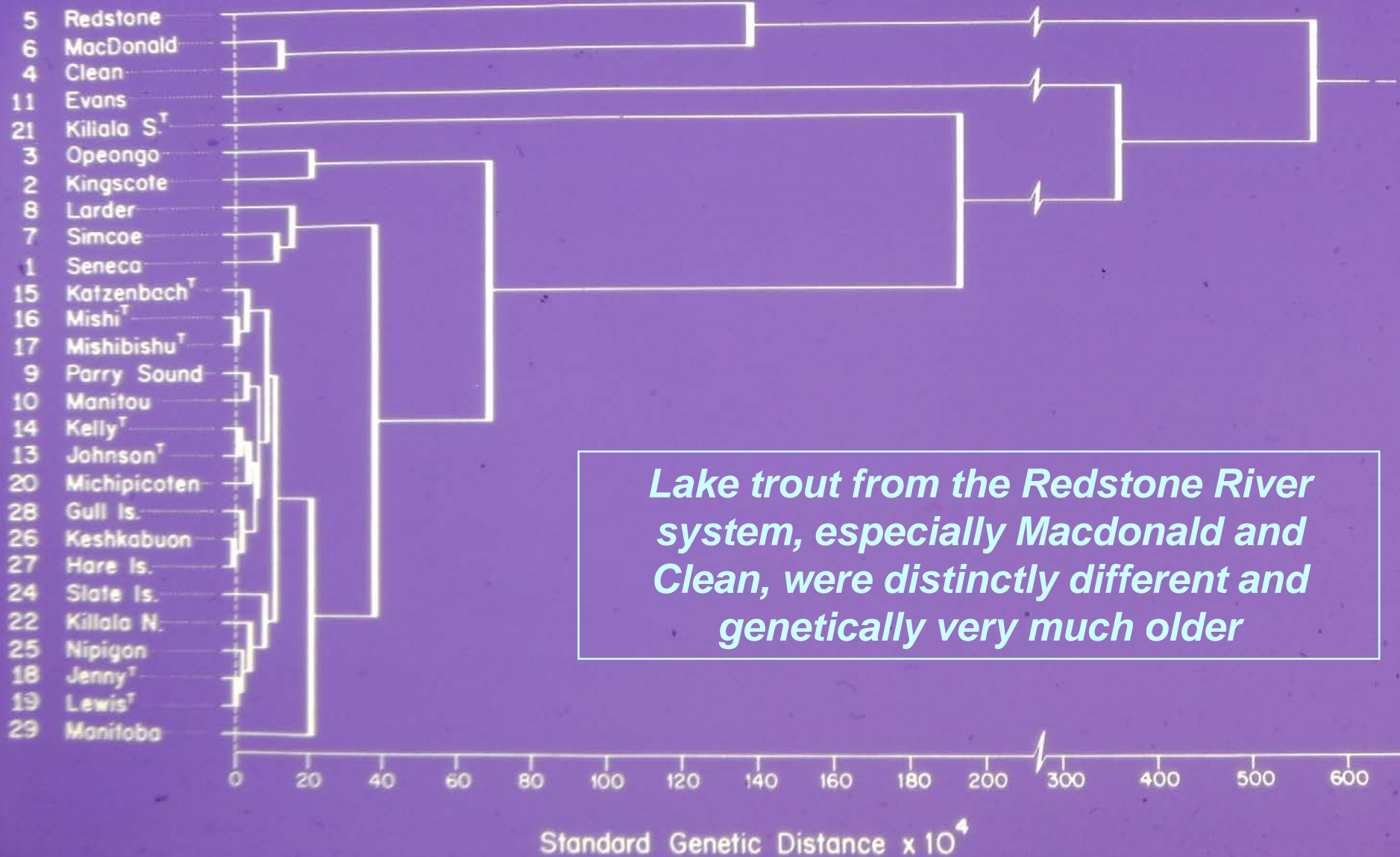


# **Genetic Analysis Was Conducted on a Large Number of Angled Lake Trout**

***Electrophoresis showed significant  
differences among lakes***

***New insights were acquired !***

# ***Genetic testing was done on lake trout from all lakes***



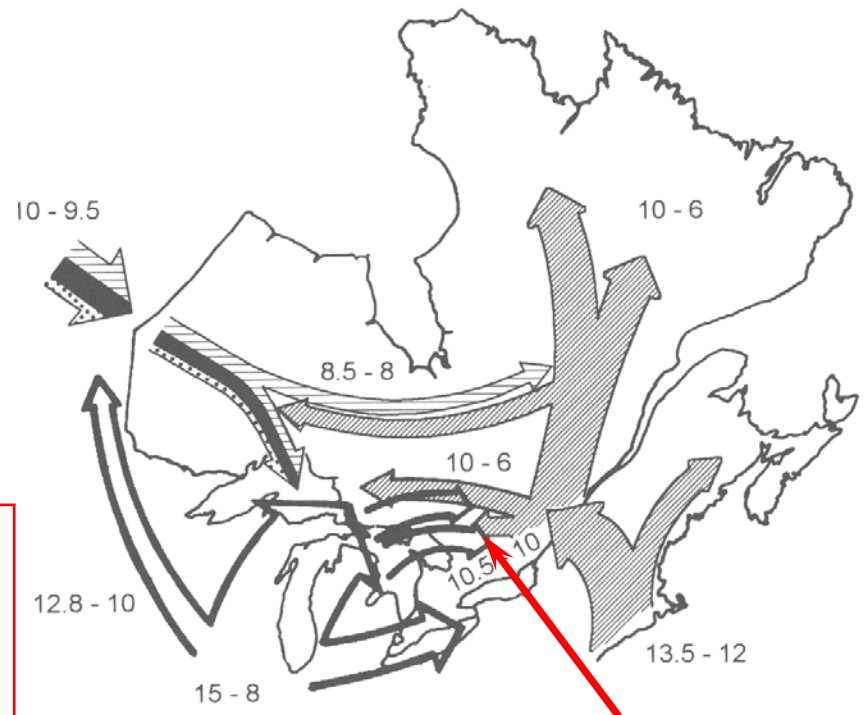
# GENETIC DIFFERENCES IN LAKE TROUT

depend upon their refugium and post-glacial history



*These Haliburton lake trout are a very pure form of Mississippi Refugium fish*

*Have been separated from all other lake trout for more than one glaciation*

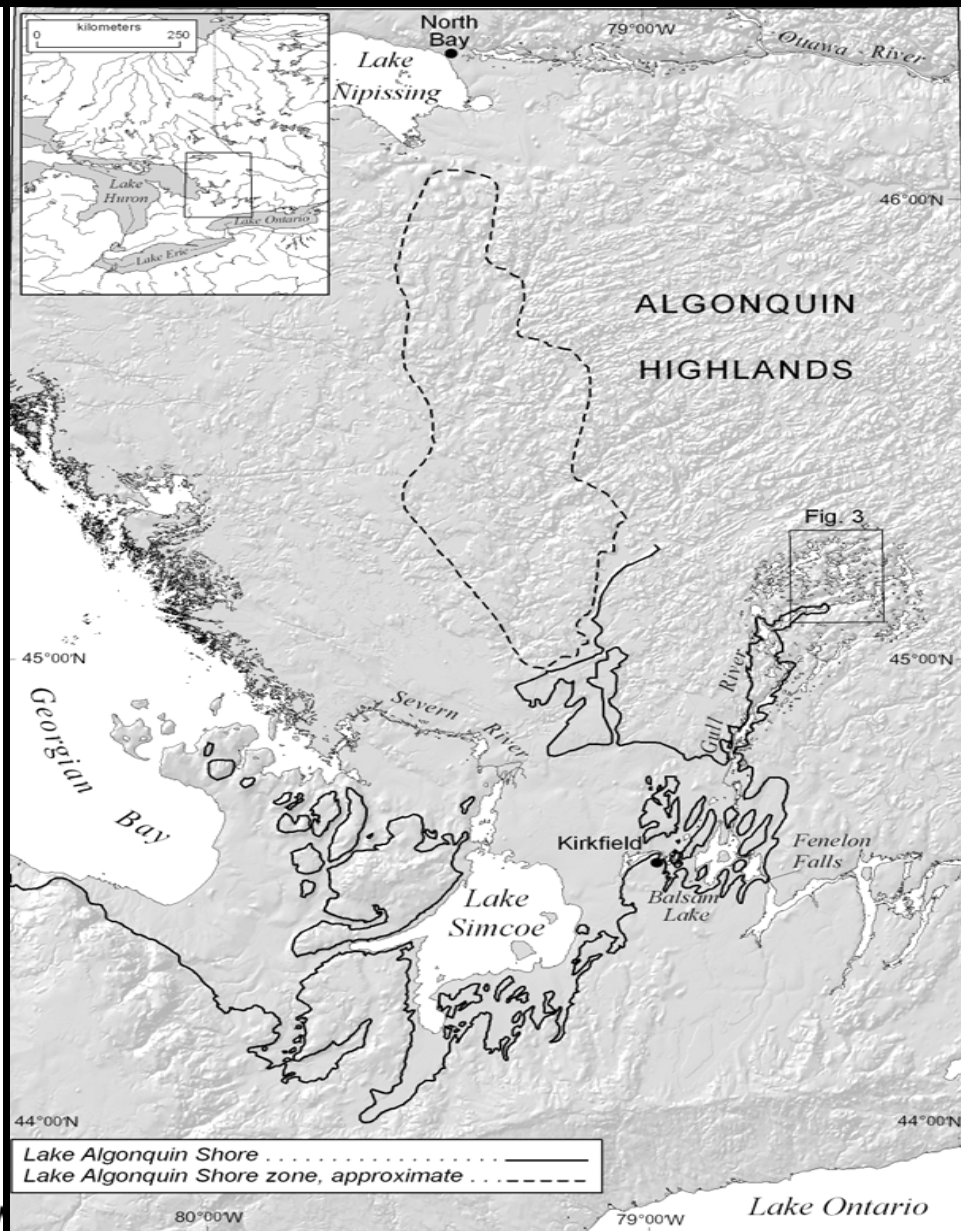
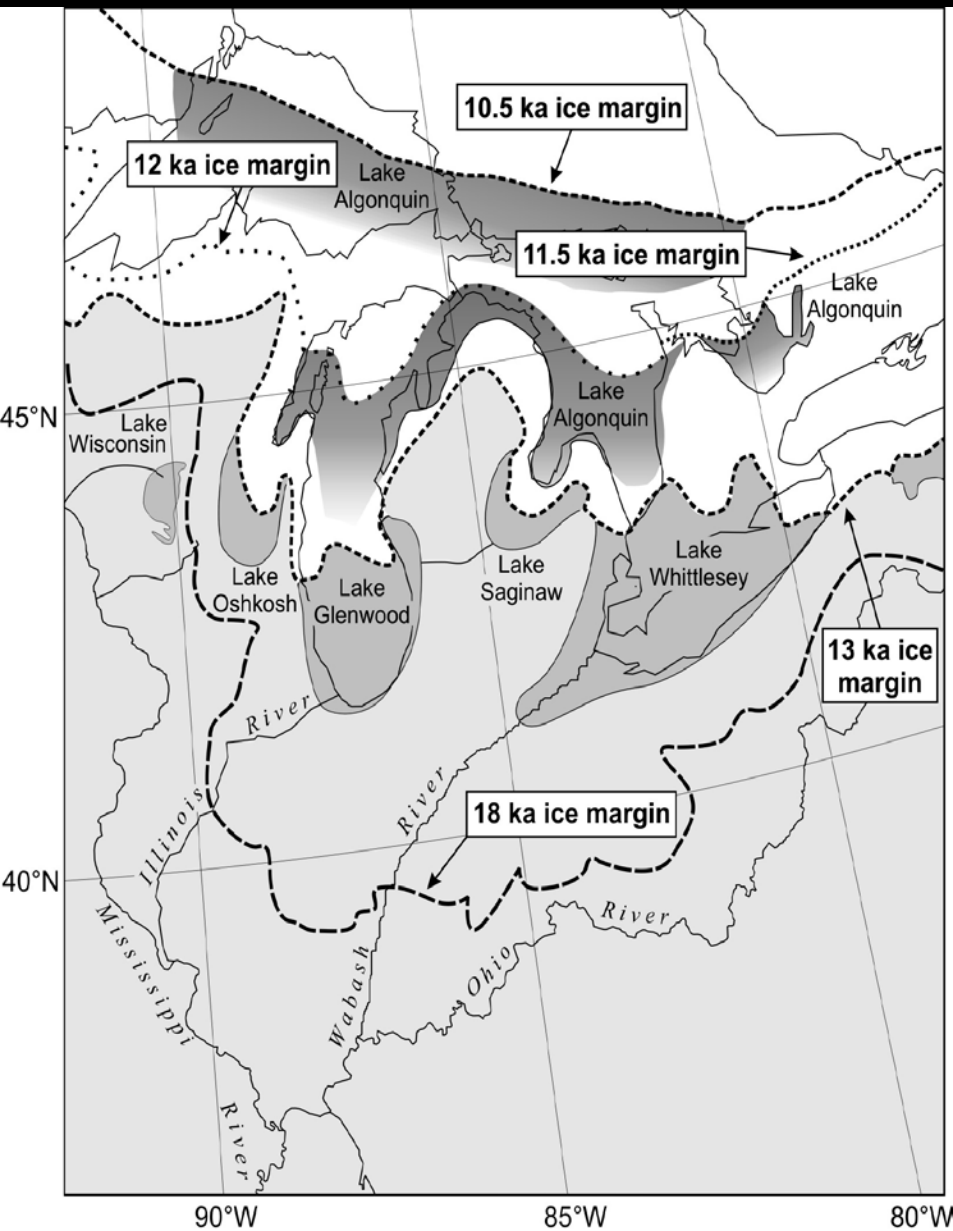


# Dispersal of Haliburton Lake Trout From the Mississippi Refugium

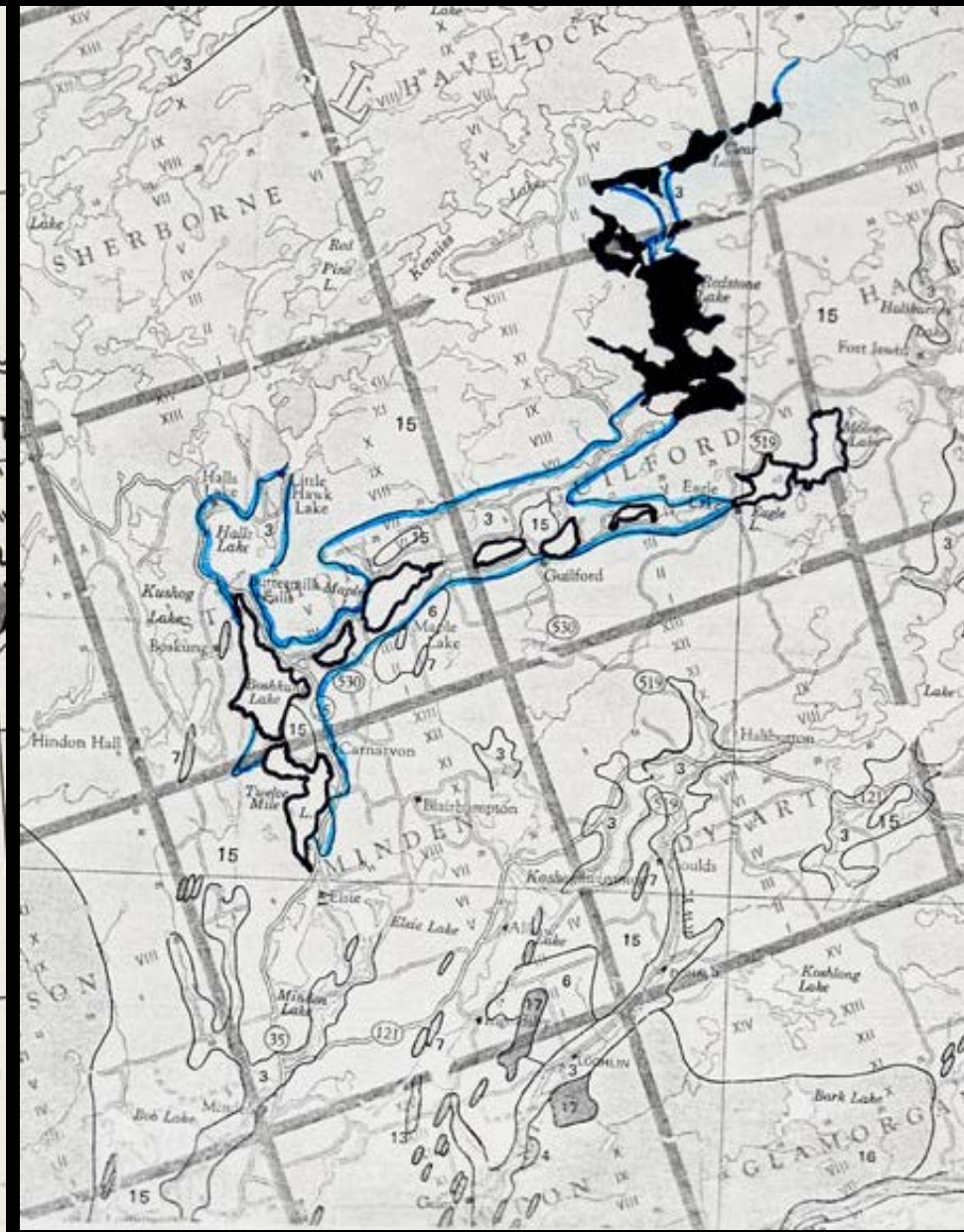
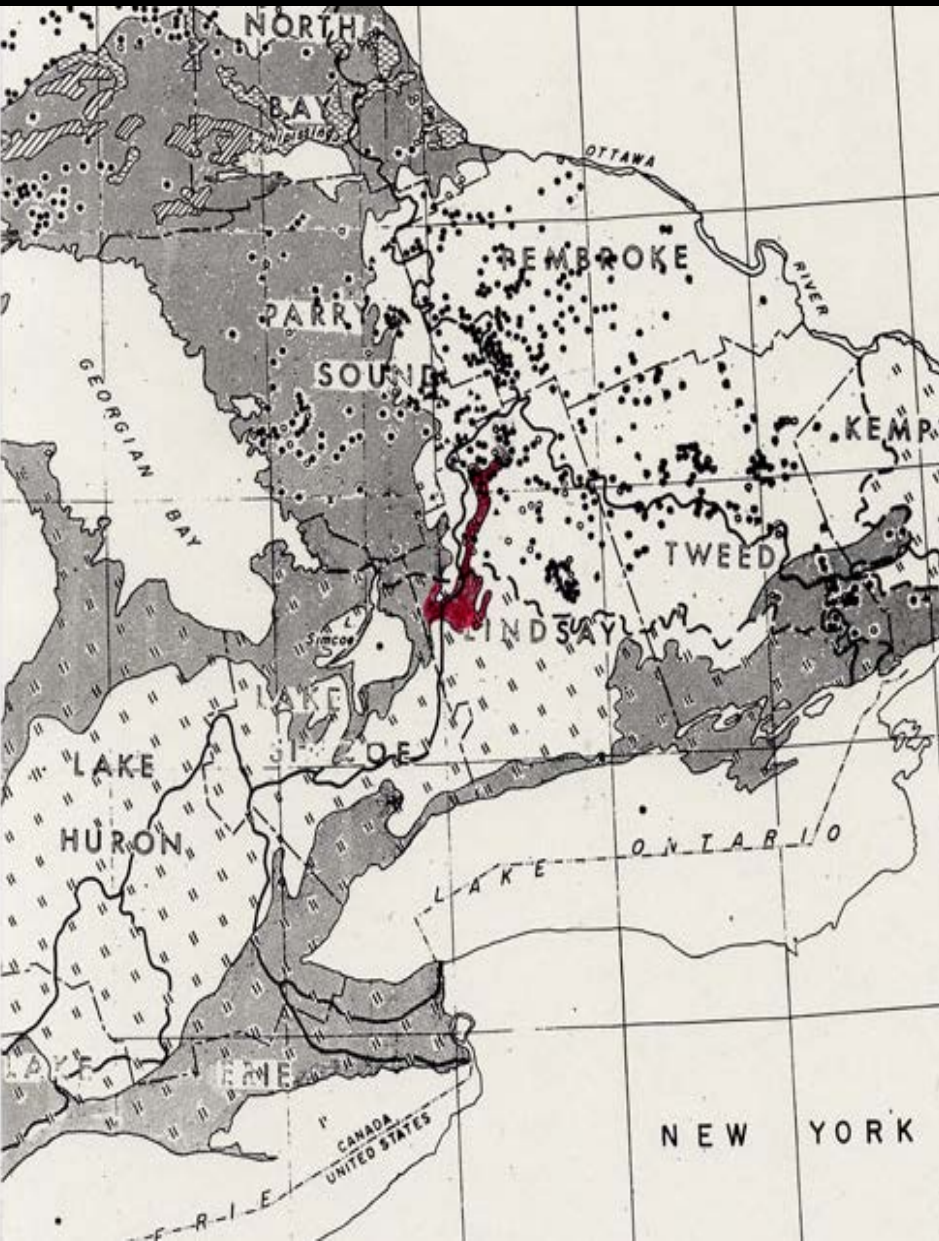
*The retreat of the Wisconsin  
glaciation and Lake Algonquin  
provides the insights*

*New insights were acquired !*

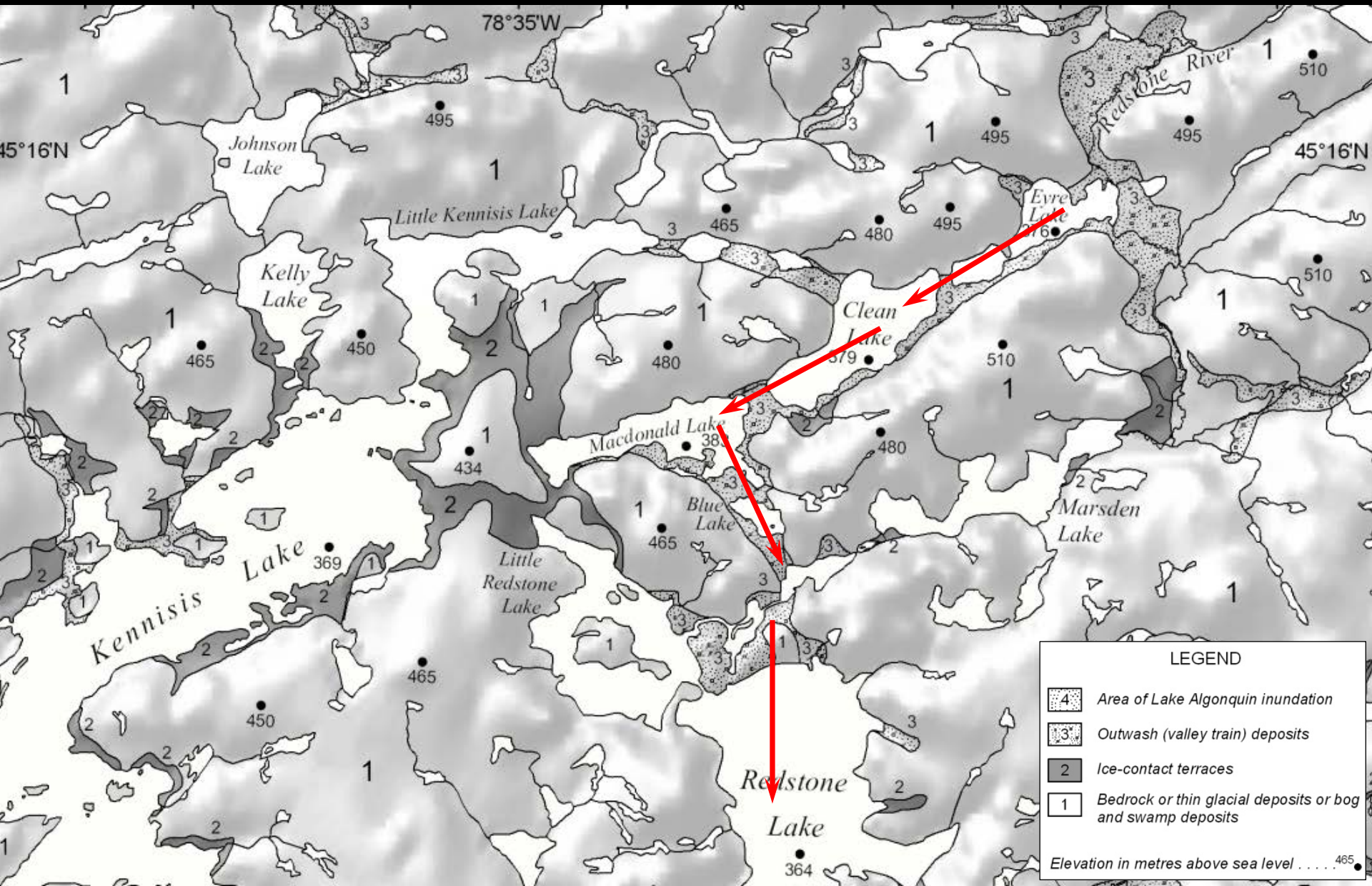
# Glacial retreat and the glacial Lake Algonquin shoreline



## ***Gull and Beech R. systems and Lake Algonquin shoreline***



## ***Surficial geology and the ancient glacial Redstone R. system***



# ***The Haliburton Lake Trout***



***Was originally probably a riverine lake trout  
and was first discovered in  
the Haliburton Forest and Wild Life Reserve***

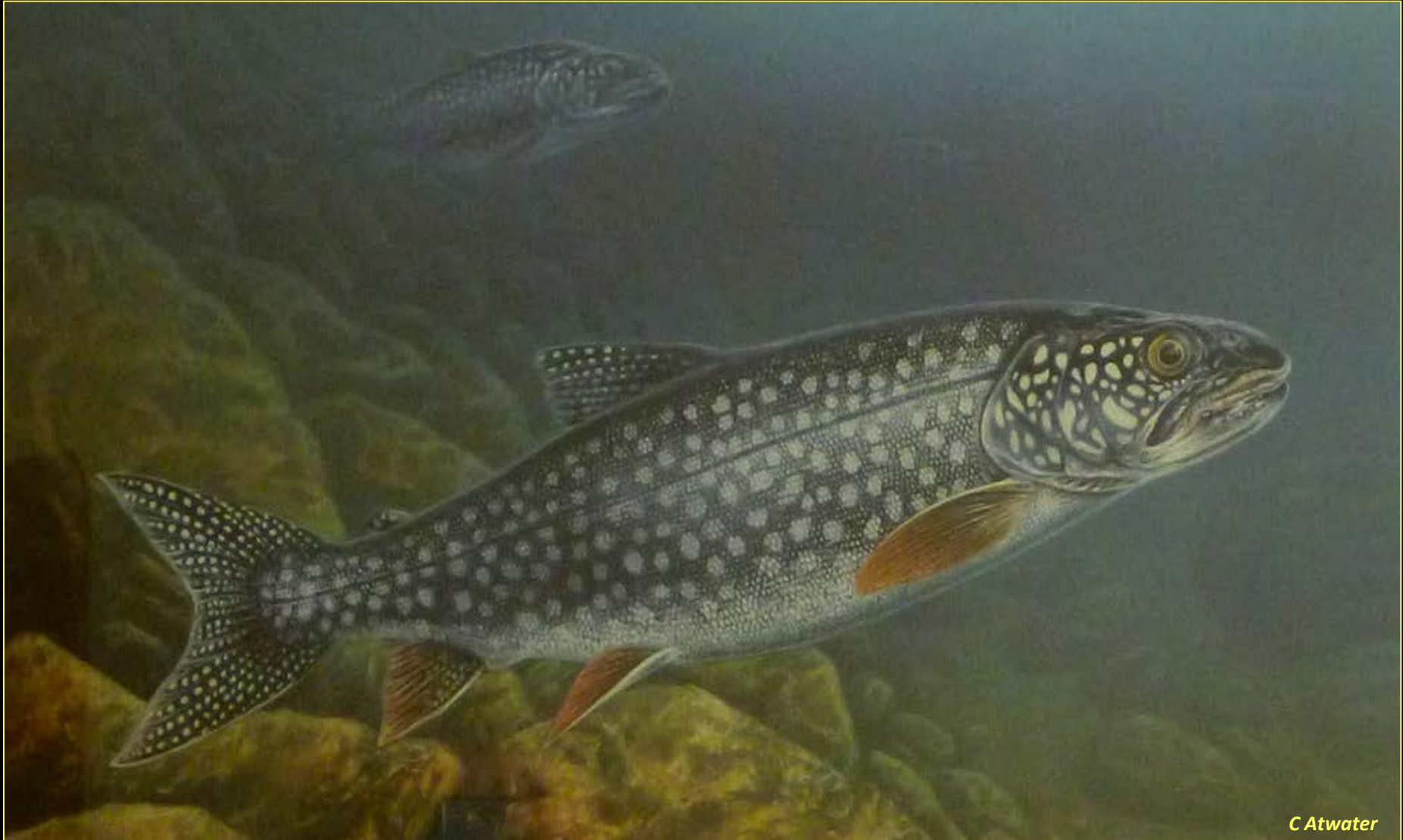
# Glacial Relict Lake Trout of the Haliburton Highlands

*Genetically unique and highly  
productive native stock*

*A precious renewable resource !*



# *The Haliburton Gold*



*As good custodians . . .*

*we should ensure that our association with these ancient fish persists, an association best perpetuated through sustainable use*

*Human-induced stressors can seriously jeopardize this association*

*Let's look at the case history of the Haliburton lake trout – **the Haliburton Gold***

*What have we learned ?*

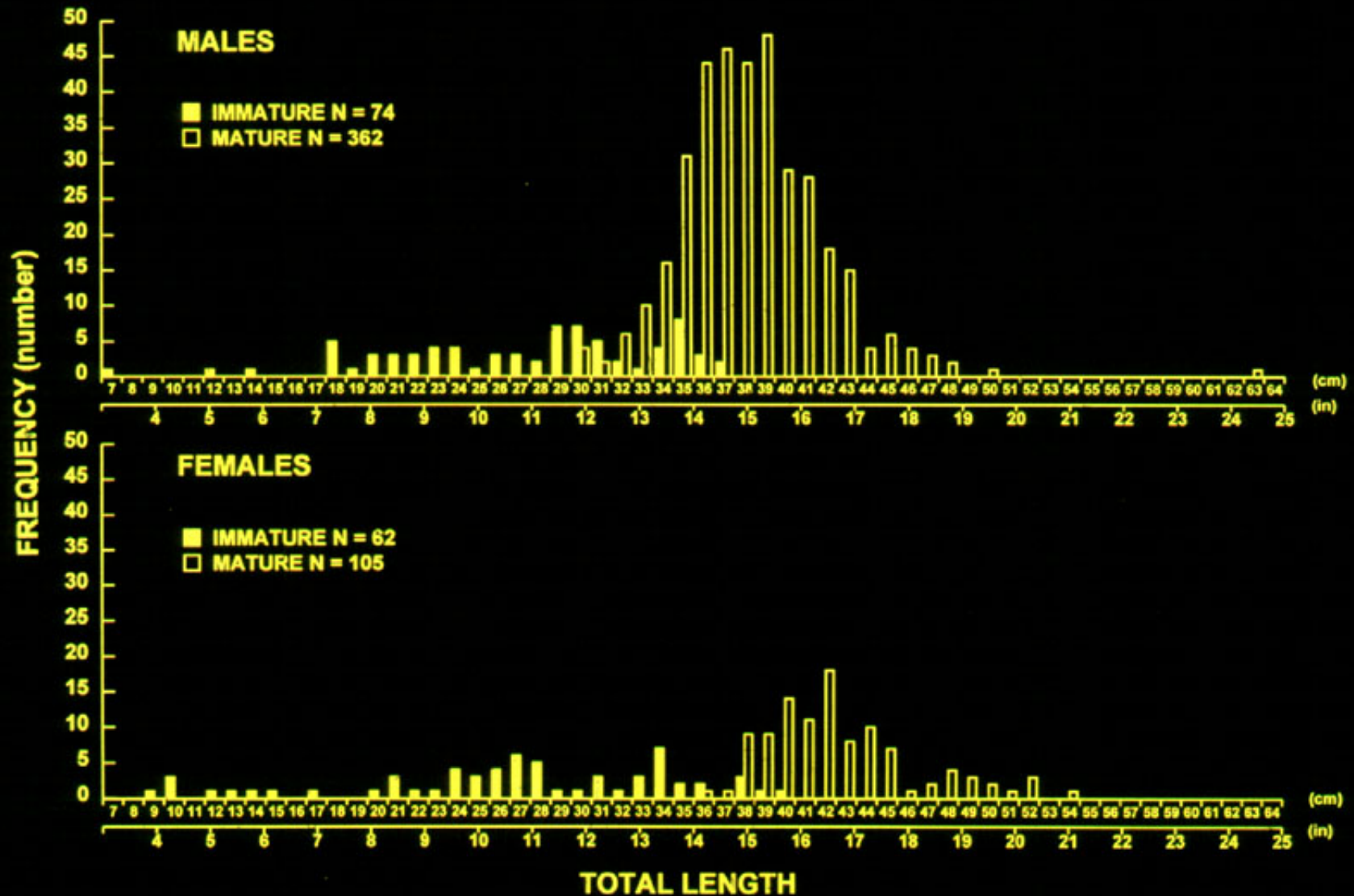
# Lake Trout Creels Provided a Very Large Sample of Fish

*It is rare to have so much  
information on lake trout  
populations*

*New insights were acquired !*

# SMALL FISH DOMINATED IN MACDONALD AND CLEAN

There were very fewer mature females, 1983 and 1984

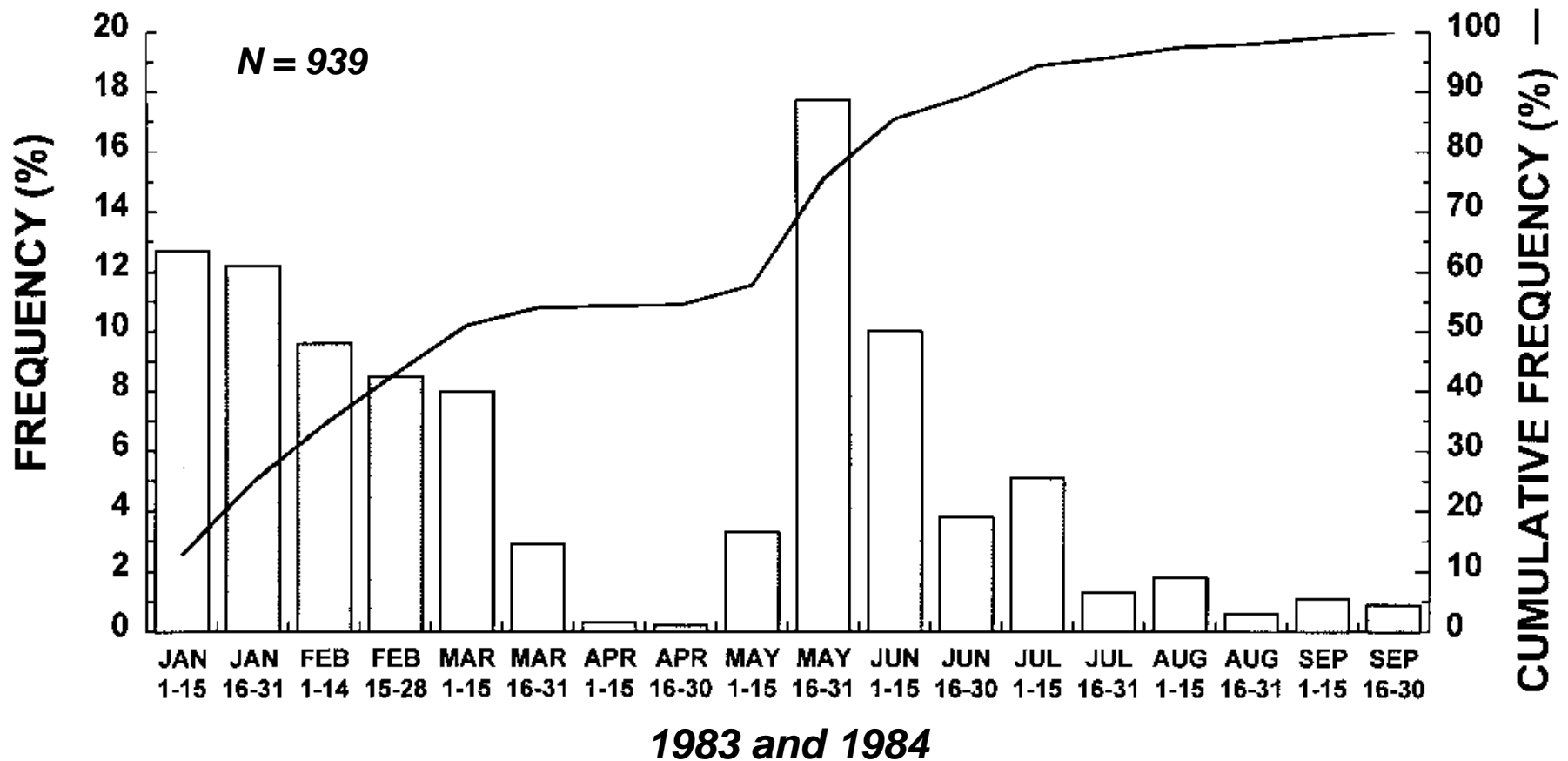


# SEASONAL CATCH OF LAKE TROUT

## For 18 bimonthly periods, 1983 and 1984

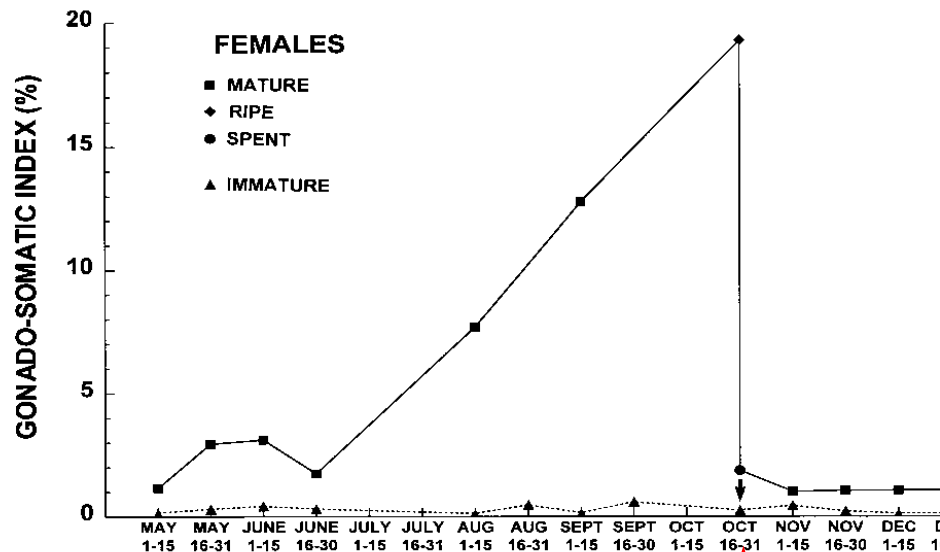


### *Macdonald Lake*

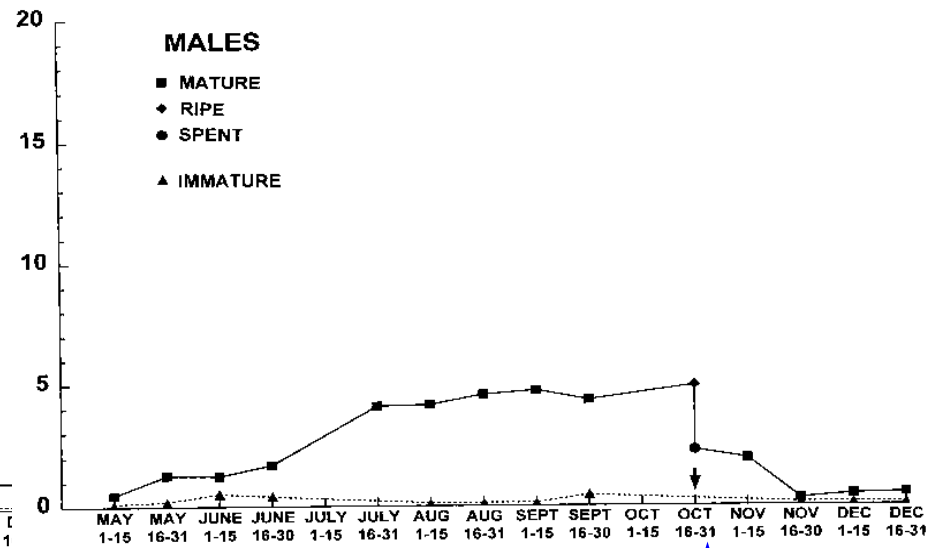


# GONADAL DEVELOPMENT AND SPAWNING

## Development commences midsummer, solstice



*Females*



*Males*

# SEASONAL CATCH OF MATURING FEMALES

## Selective harvest commences at summer solstice

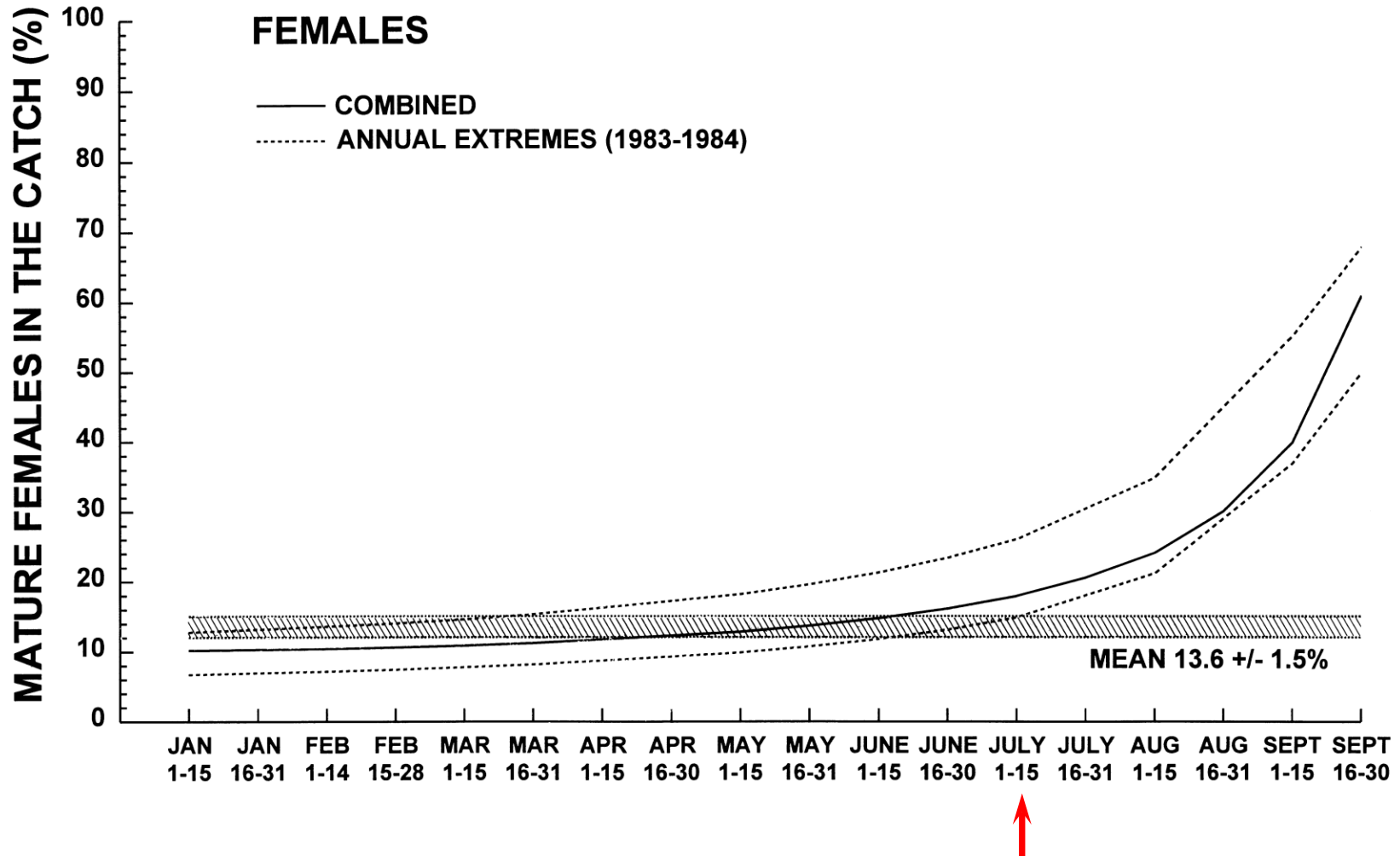


Table 1. Seasonality of catch of lake trout angled in Macdonald Lake in 18 bimonthly periods in 1983 and 1984 (N = 939). Cumulative percent of the catch is provided, along with percent remaining for the nine monthly periods. The occurrence of mature lake trout is also indicated. Means and 95% confidence intervals (C.I.) are provided.



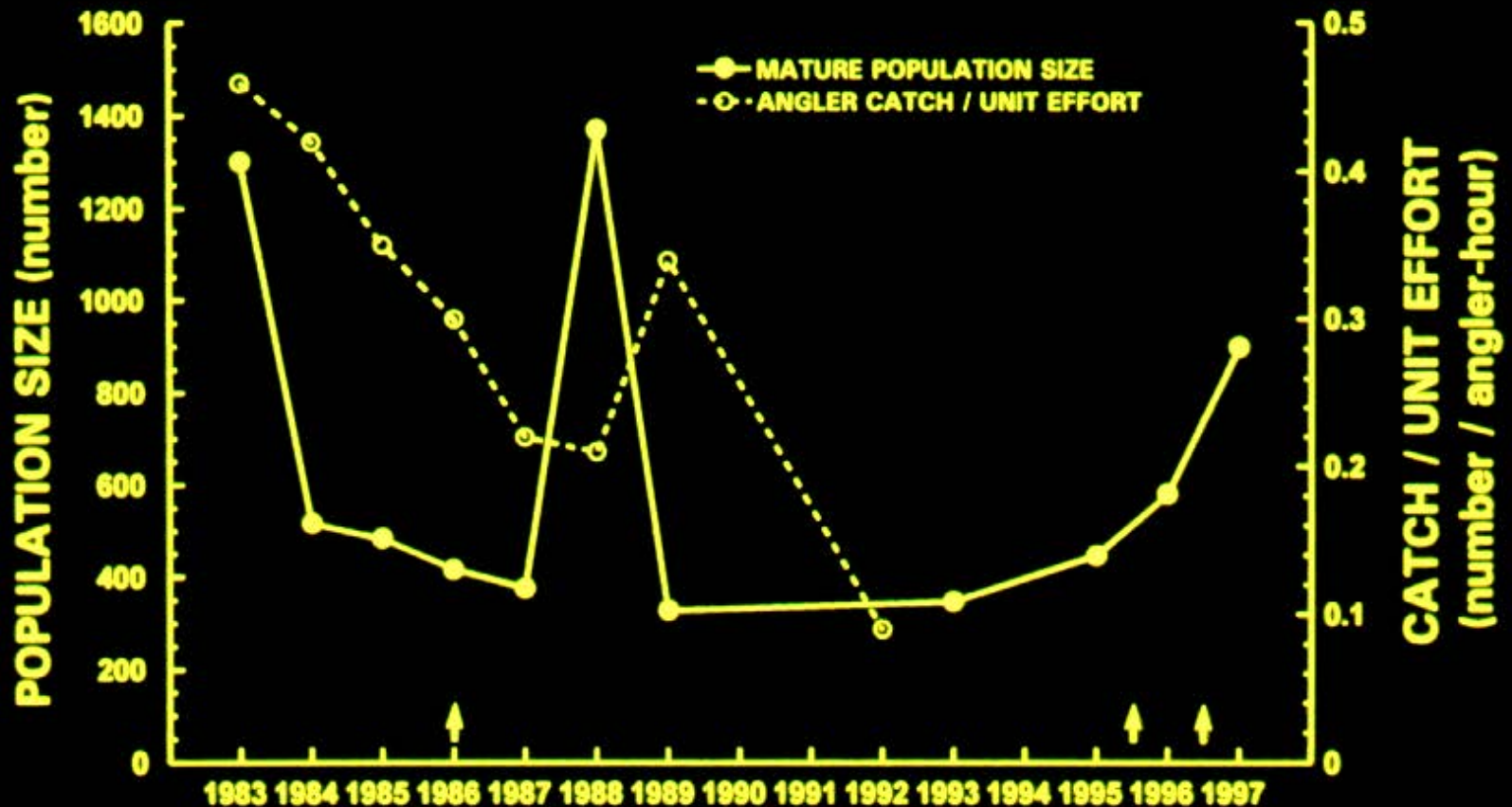
Bimonthly Period	Julian days	Total catch (N)	Annual total catch (%)	Total annual catch		Frequency in the catch	
				Cumulative total annual catch (%)	Annual total catch remaining (%)	Mature females	Mature males
Jan. 1-15	1-15	119	12.7	12.7	87.3	12.6	26.1
Jan. 16-31	16-31	115	12.2	24.9	75.1	11.3	22.6
Feb. 1-14	32-45	90	9.6	34.5	65.5	7.8	32.2
Feb. 15-28	46-59	80	8.5	43.0	57.0	12.5	30.0
Mar. 1-15	60-74	75	8.0	51.0	49.0	13.3	30.7
Mar. 16-31	75-90	27	2.9	53.9	46.1	7.4	22.2
Apr. 1-15	91-105	3	0.3	54.2	45.8	33.3 <sup>a</sup>	0.0 <sup>a</sup>
Apr. 16-30	106-120	2	0.2	54.4	45.6	50.0 <sup>a</sup>	0.0 <sup>a</sup>
May 1-15	121-135	31	3.3	57.7	42.3	16.1	45.2
May 16-31	136-151	166	17.7	75.4	24.6	12.7	28.9
Jun. 1-15	152-166	94	10.0	85.4	14.6	9.6	43.6
Jun. 16-30	167-181	36	3.8	89.2	10.8	36.1	33.3
Jul. 1-15	182-196	48	5.1	94.3	5.7	27.1	47.9
Jul. 16-31	197-212	12	1.3	95.6	4.4	36.7	33.3
Aug. 1-15	213-227	17	1.8	97.4	2.6	41.2	23.5
Aug. 16-31	228-243	6	0.6	98.0	2.0	83.3	16.7
Sep. 1-15	244-258	10	1.1	99.1	0.9	60.0	30.0
Sep. 16-30	259-273	8	0.8	100.0	0.0	75.0	12.5
Mean ± 95% C.I.		52.2 ± 24.4	5.6 ± 2.6			28.9 ± 13.1	29.9 ± 5.2

<sup>a</sup> Extremely small samples, not used in analysis.

# POPULATION SIZE AND CATCH VARIED WIDELY

Over 15 years, dynamics were extreme

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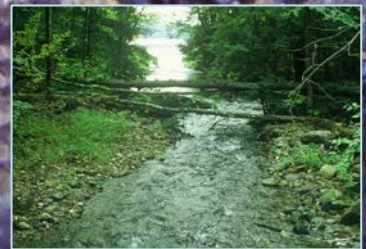
*Macdonald Lake*

# **White Sucker Populations Were Also Studied**

***Dwarf precociously mature  
suckers were detected in  
several lakes***

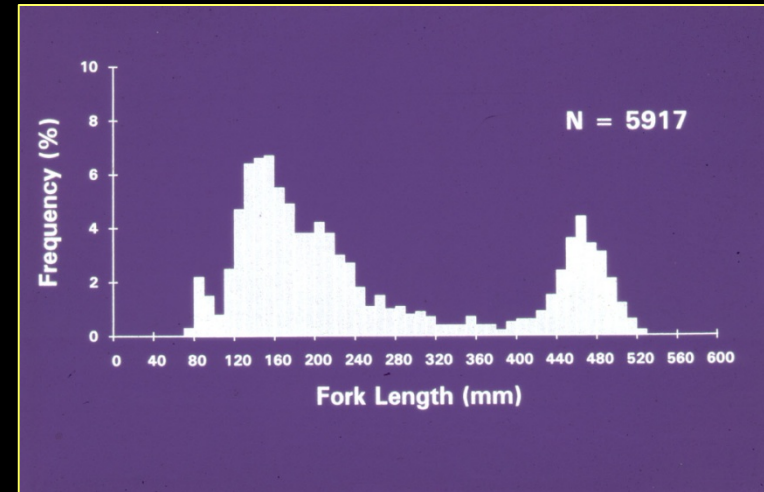
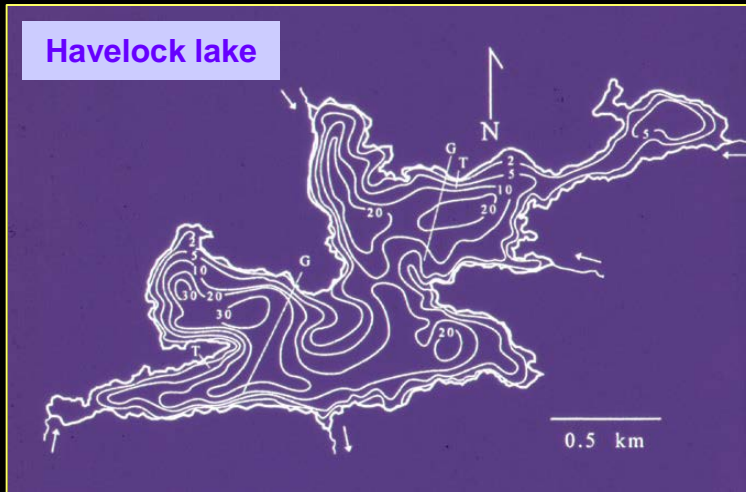
***New insights were acquired !***

***White suckers were very abundant and studied throughout the Kennisis River system***



# DIMORPHISM IN WHITE SUCKERS

Resulted from size selective predation by trout

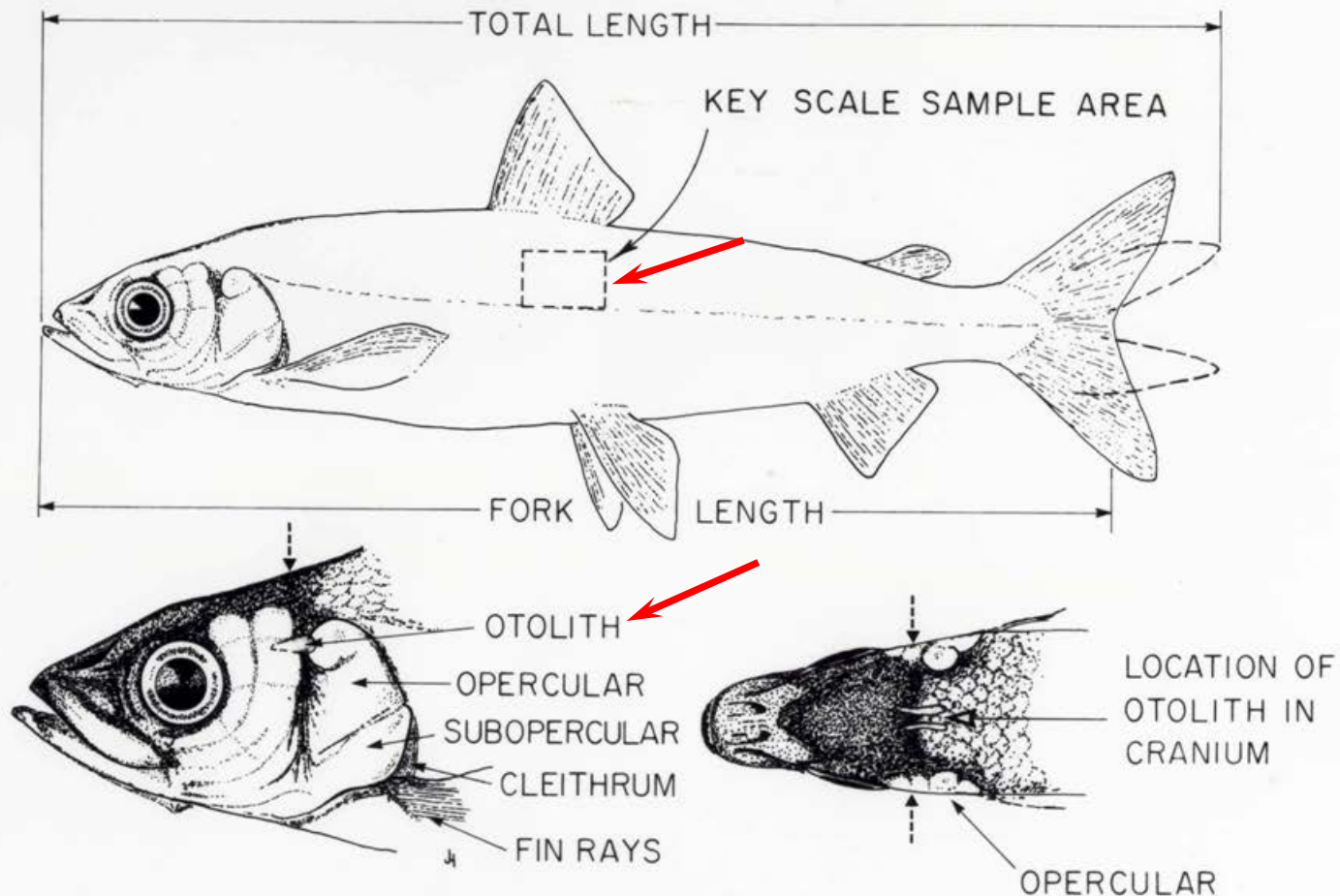


# **Age and Growth Determination of Lake Trout Is Very Difficult but Important**

***Refining and improving  
procedures using known-age  
lake trout***

***New insights were acquired !***

# Calcified Structures Used to Determine Age and Growth of Fish

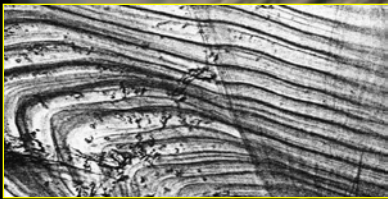


LAKE HERRING *Coregonus artedii* Lesueur



# CALCIFIED STRUCTURE AGE

*Accurate age can teach many  
things, including  
conservation ethics !*

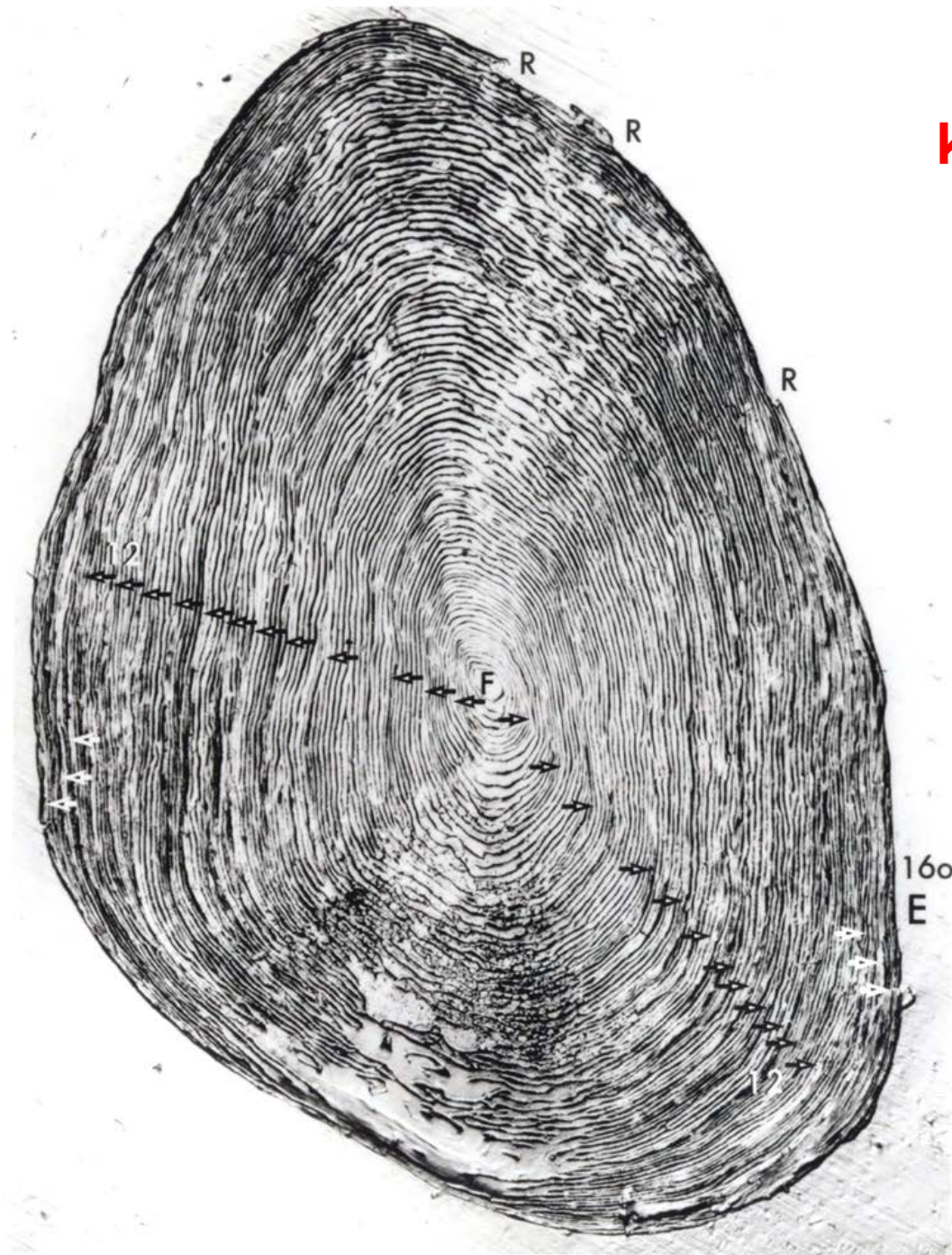


*This lake trout is 4 times  
the age of the boy !*

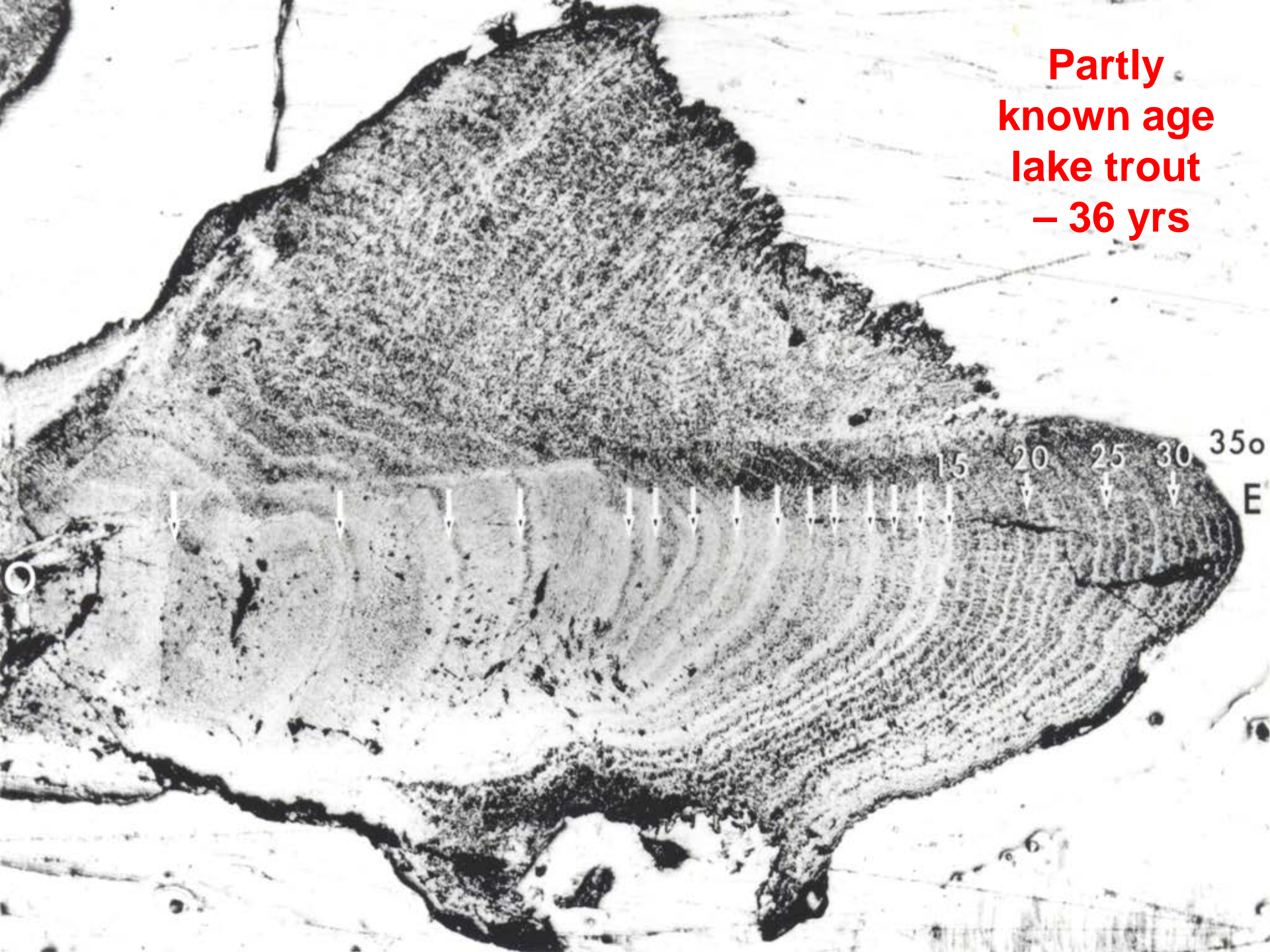
*Partly known age  
lake trout – 36 yrs*



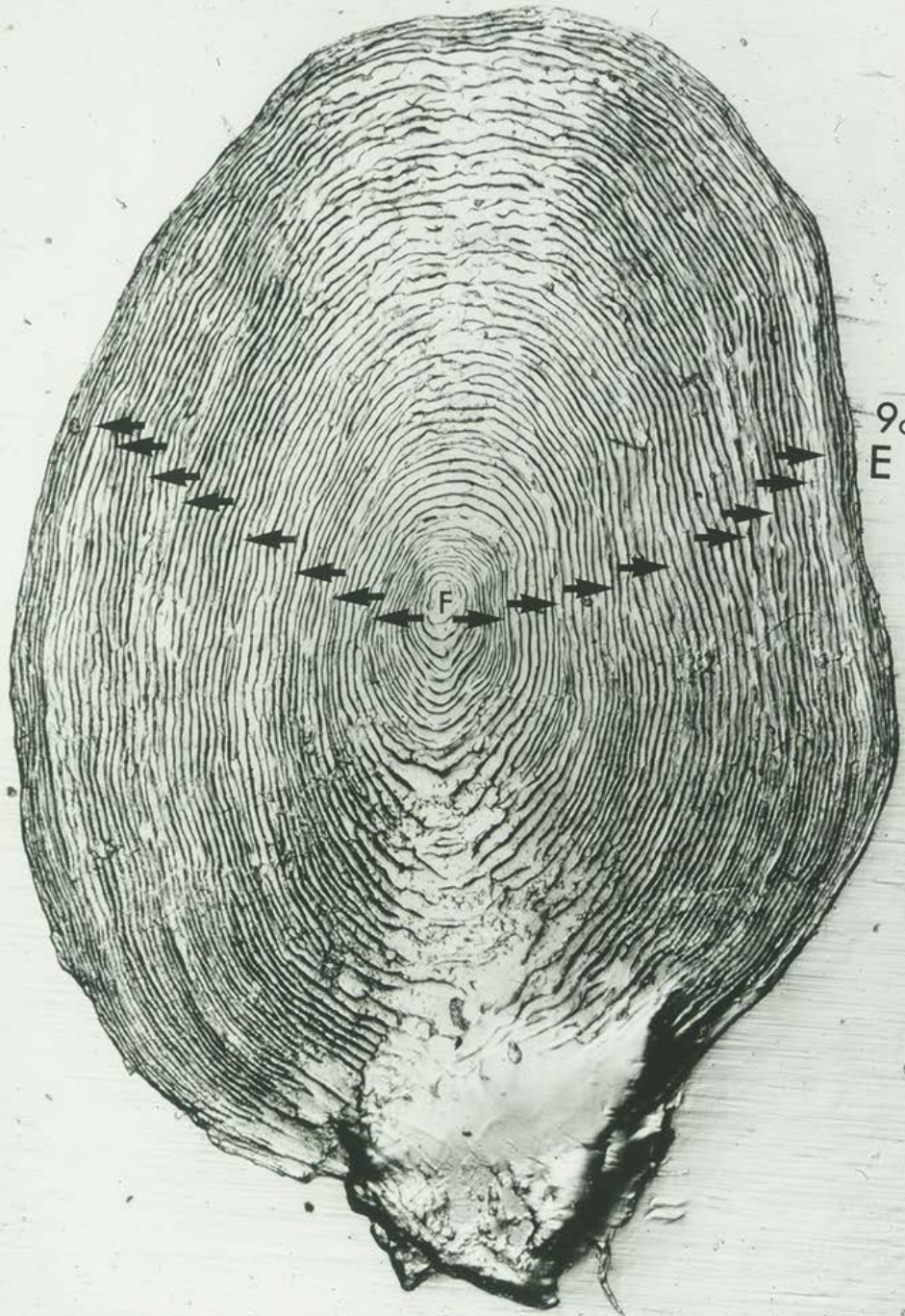
**Partly  
known age  
lake trout  
– 36 yrs**

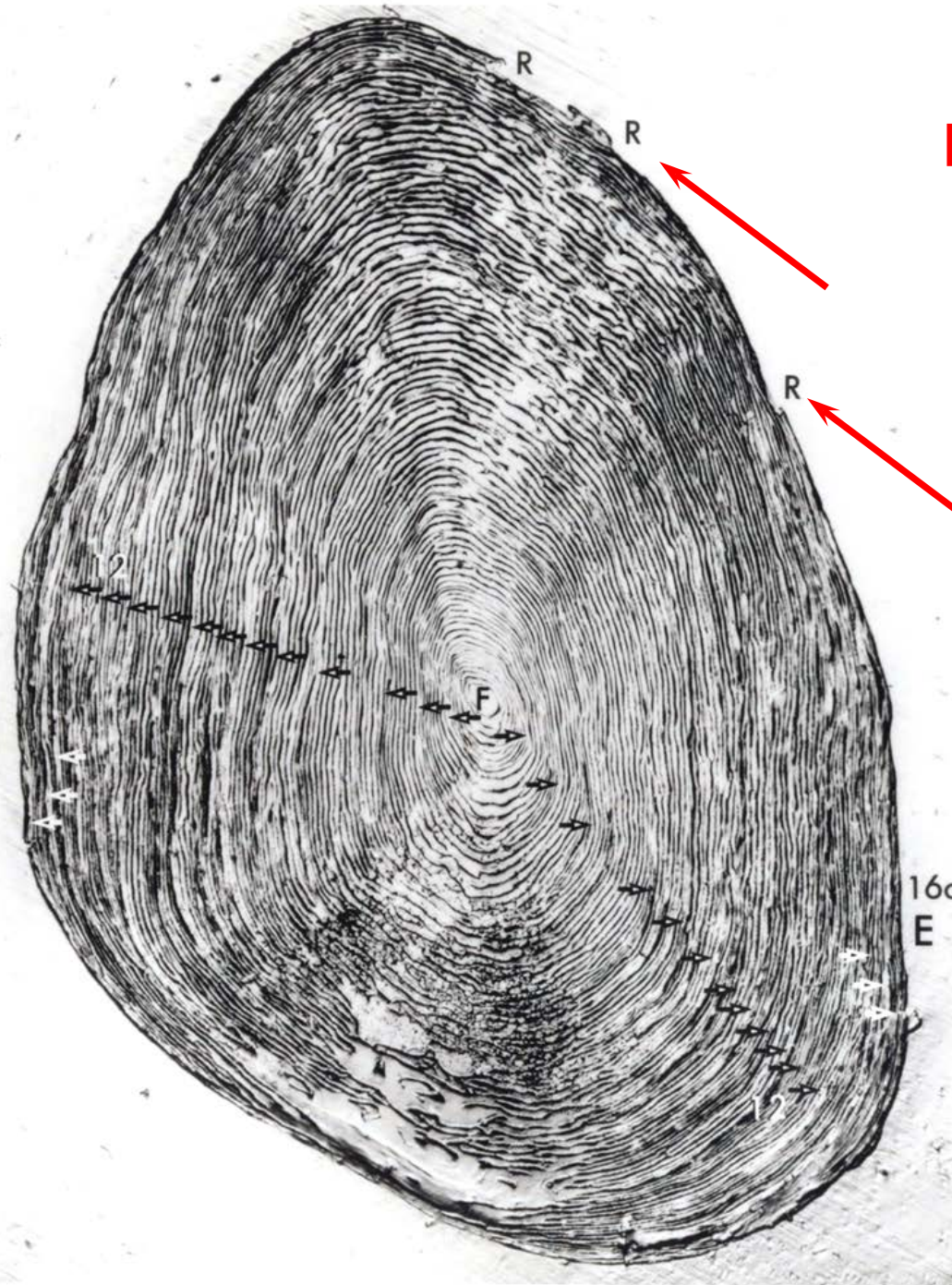


**Partly  
known age  
lake trout  
– 36 yrs**



**Known age  
lake trout  
– 16 yr**

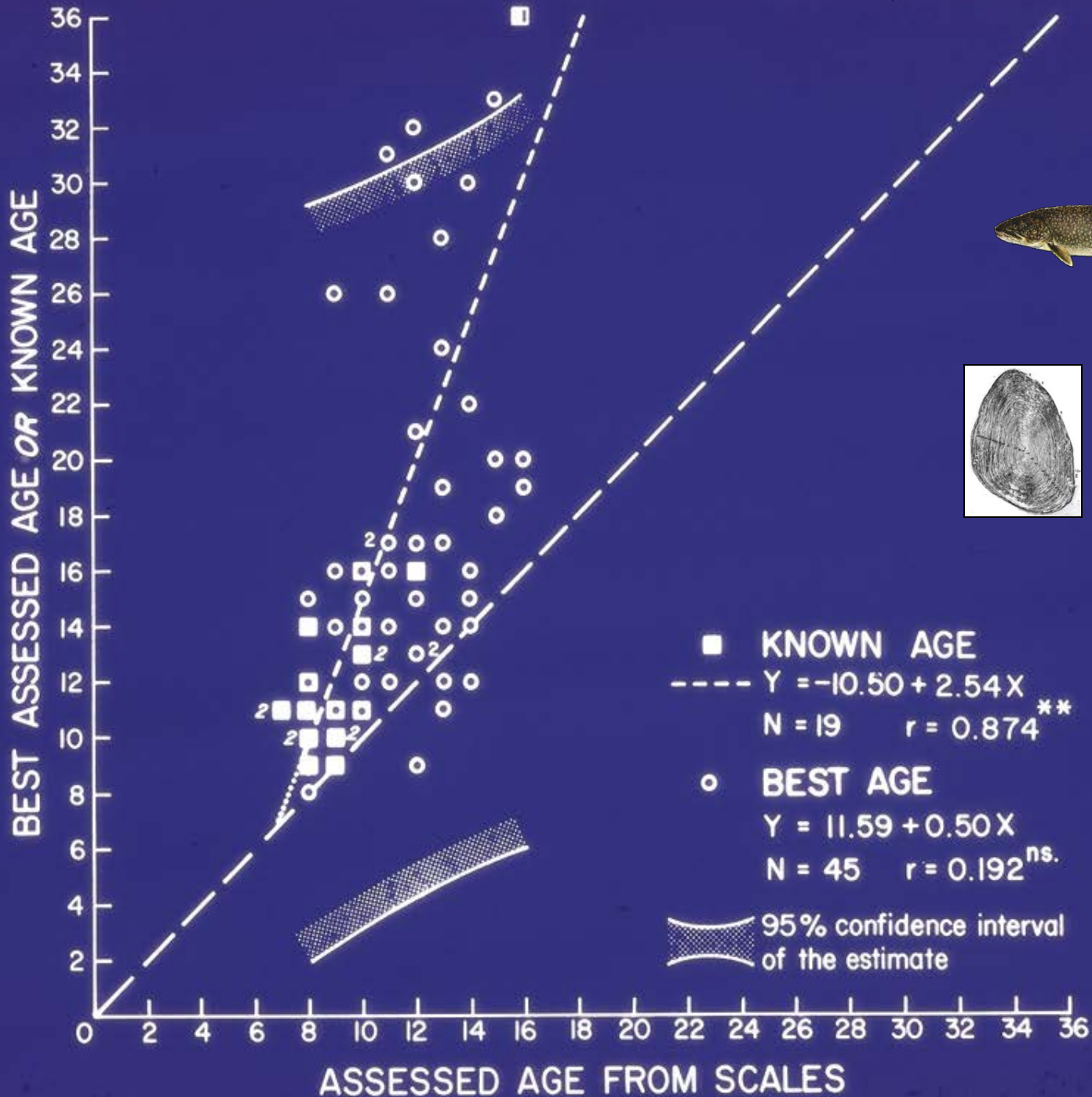


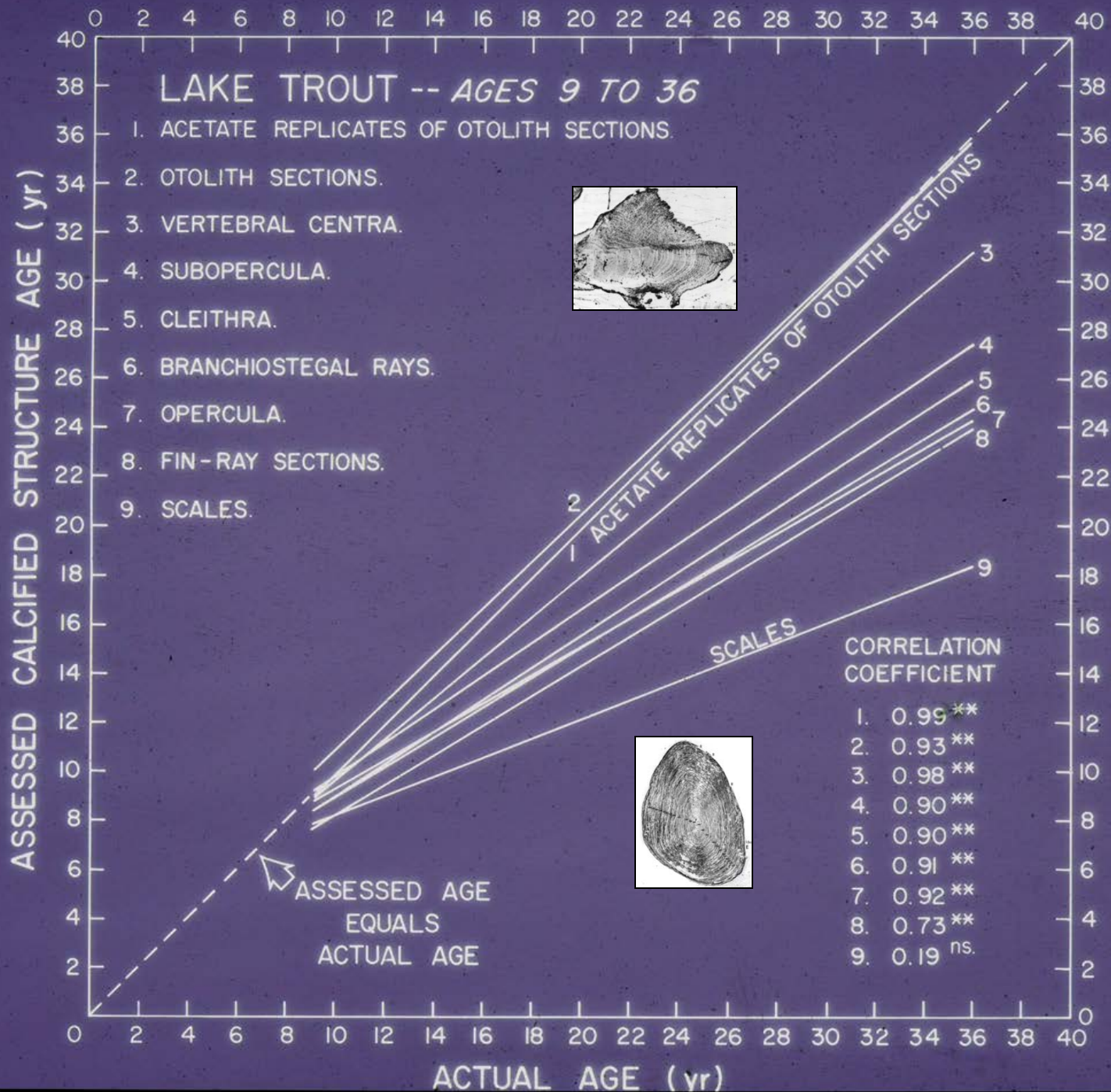


**Partly  
known age  
lake trout  
– 36 yr**

***Resorption  
and  
erosion***





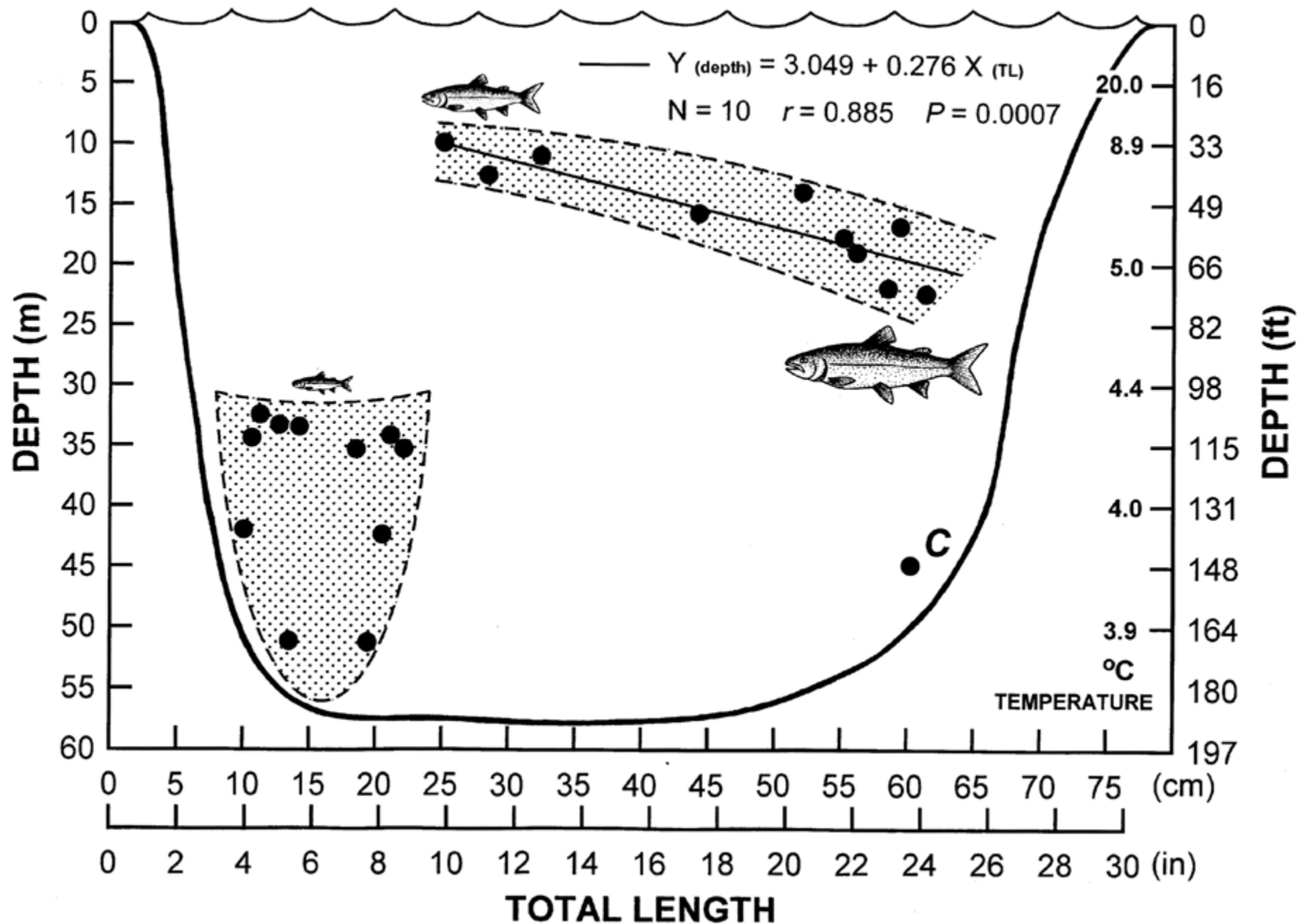


# Midsummer Depth Distribution and Behaviour of Juvenile and Adult Lake Trout

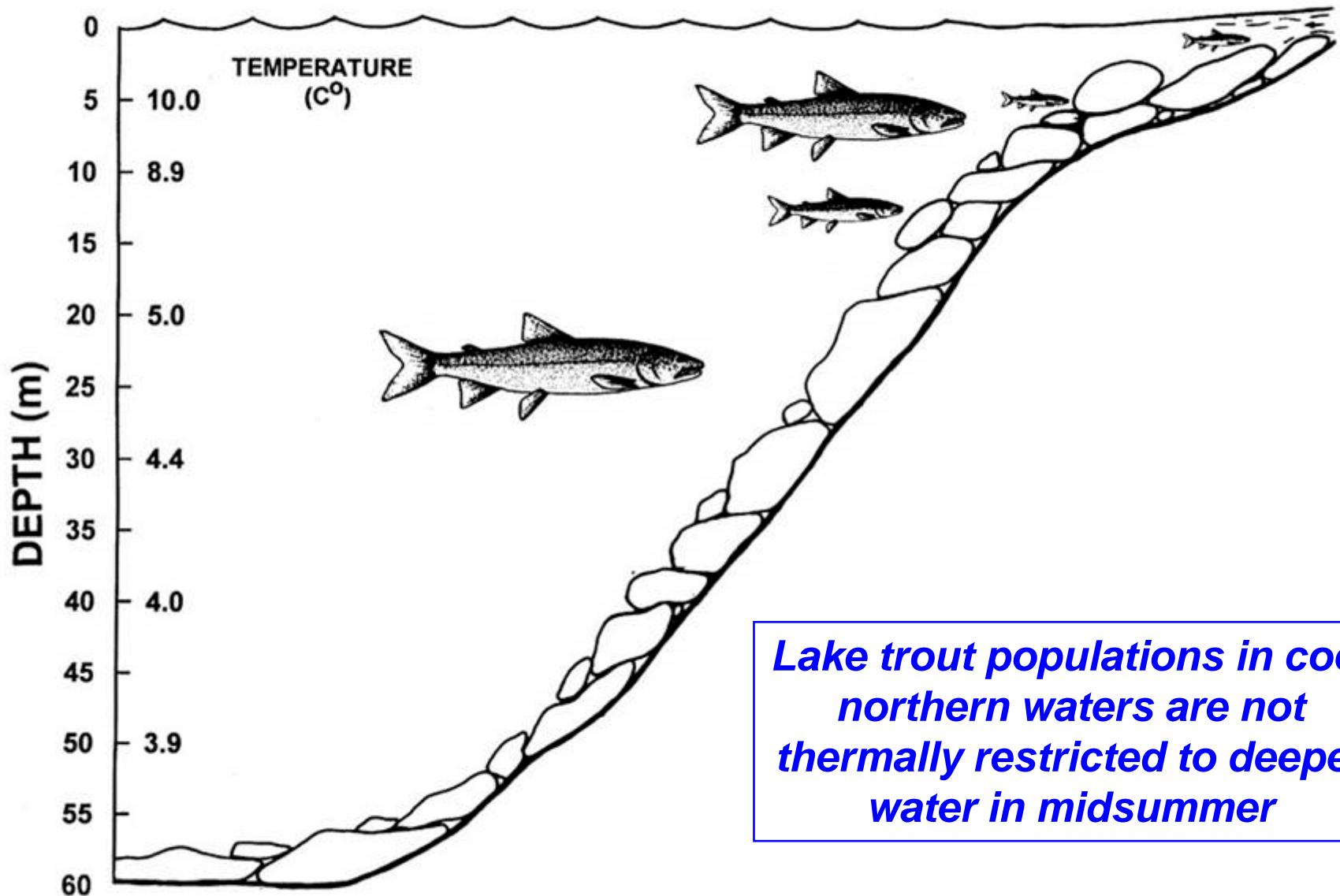
*Thermal requirements and  
cannibalism require unique  
behaviour in warm temperate waters*

*New insights were acquired !*

# DEPTH DISTRIBUTION — TEMPERATE

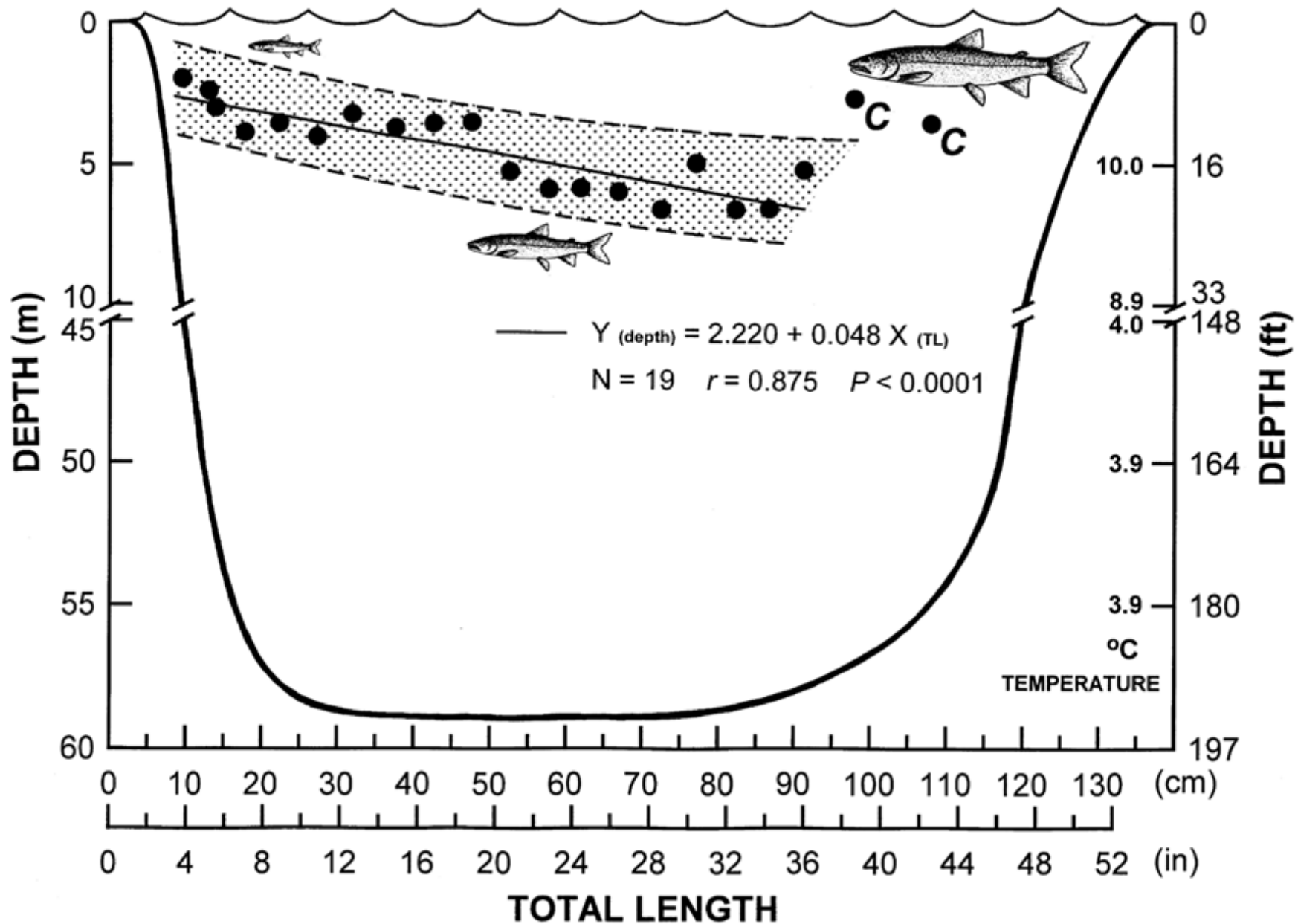


## LAKE TROUT DEPTH DISTRIBUTION



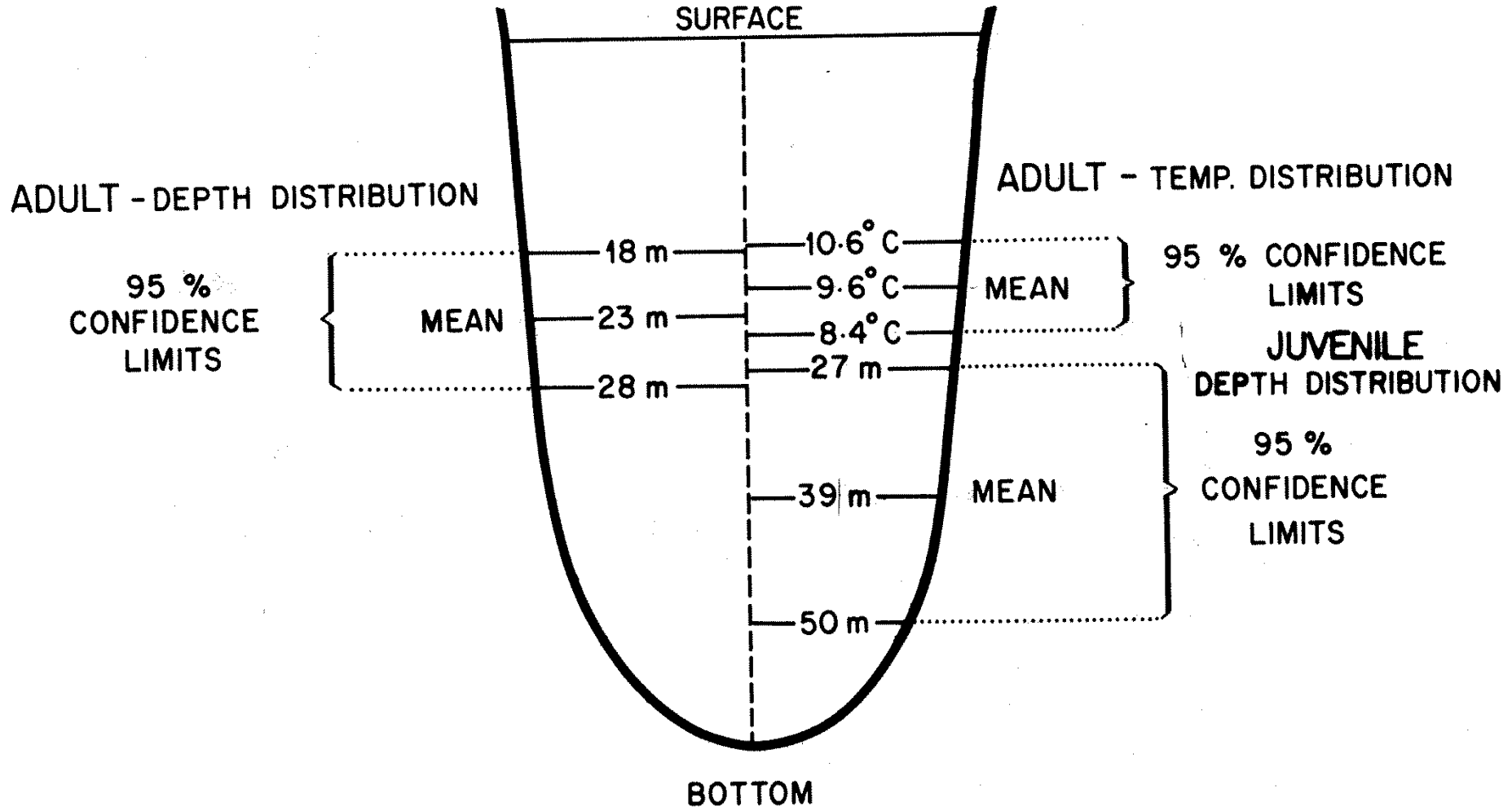
*Lake trout populations in cool northern waters are not thermally restricted to deeper water in midsummer*

# DEPTH DISTRIBUTION — ARCTIC



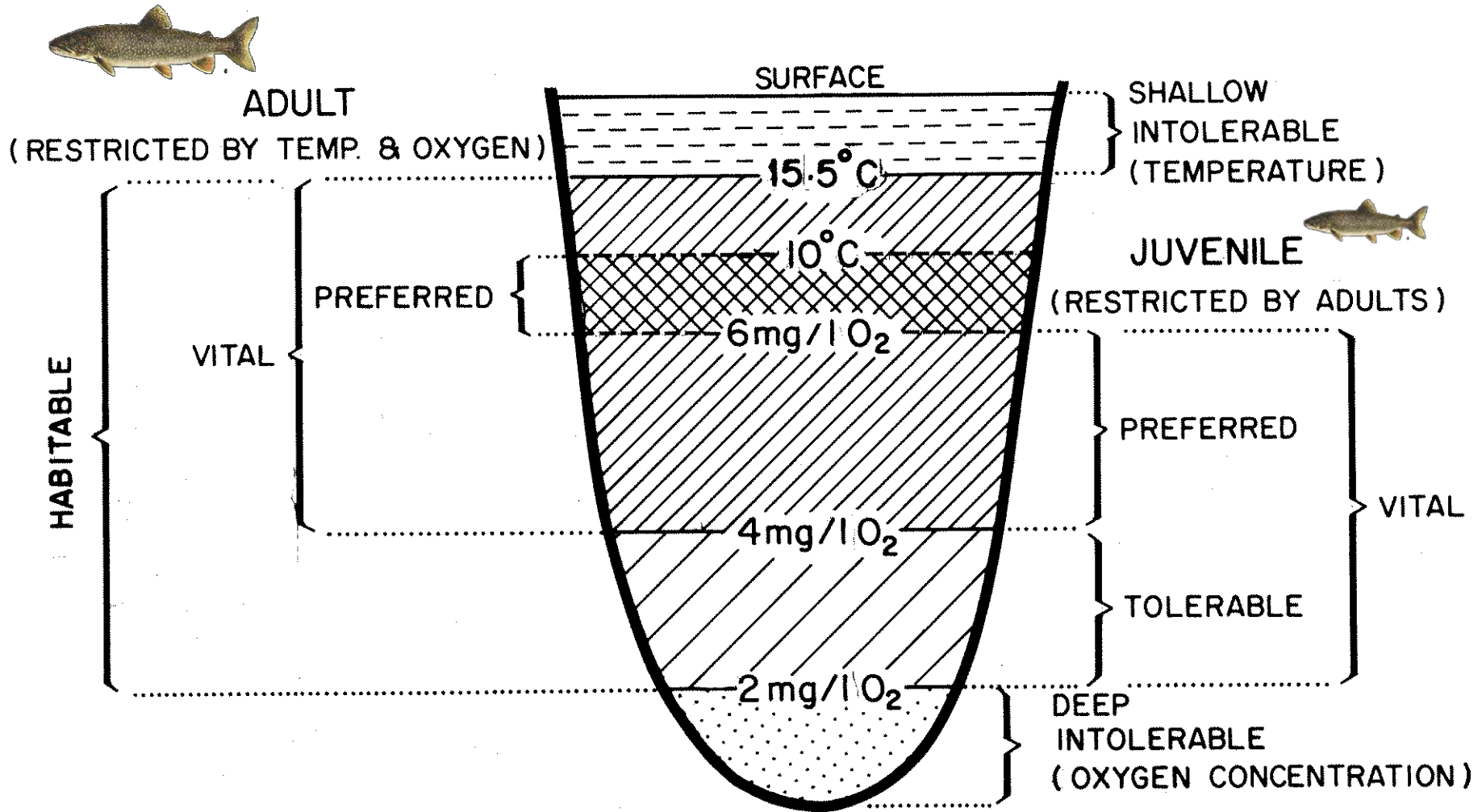
# *Depth and Temperature*

## MIDSUMMER TEMPERATURE AND DEPTH DISTRIBUTIONS OF JUVENILE AND ADULT LAKE TROUT



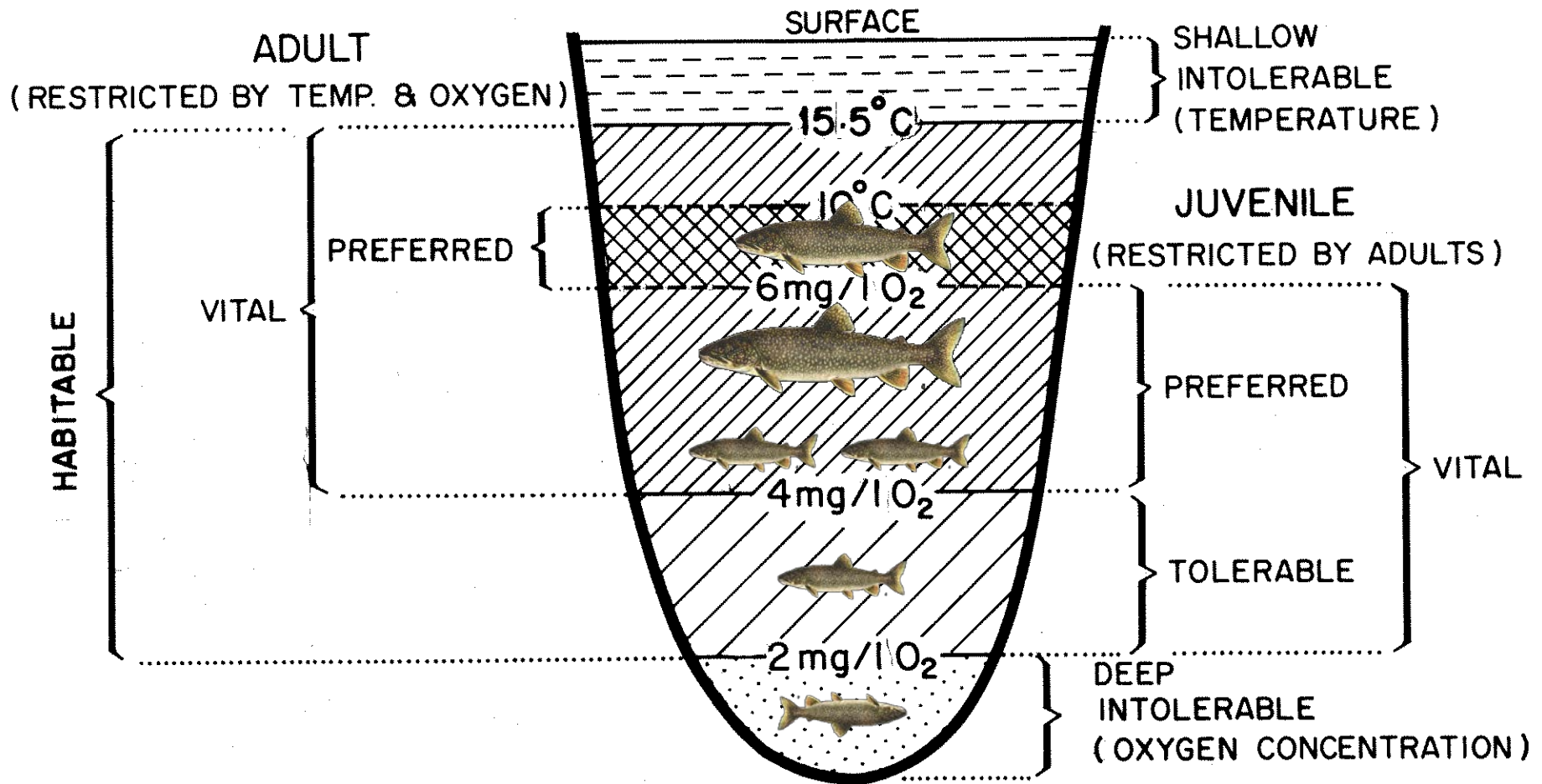
# Depth, Temperature, Oxygen Concentration, and Survival

## PARTITIONING OF JUVENILE AND ADULTS LAKE TROUT HABITATS SUMMER TEMPERATURE AND OXYGEN



# *Depth, Temperature, Oxygen Concentration, and Survival*

## PARTITIONING OF JUVENILE AND ADULTS LAKE TROUT HABITATS SUMMER TEMPERATURE AND OXYGEN



# Midsummer Depth Distribution, Behaviour, and Global Warming

*Effects on lake trout survival,  
growth, and production*

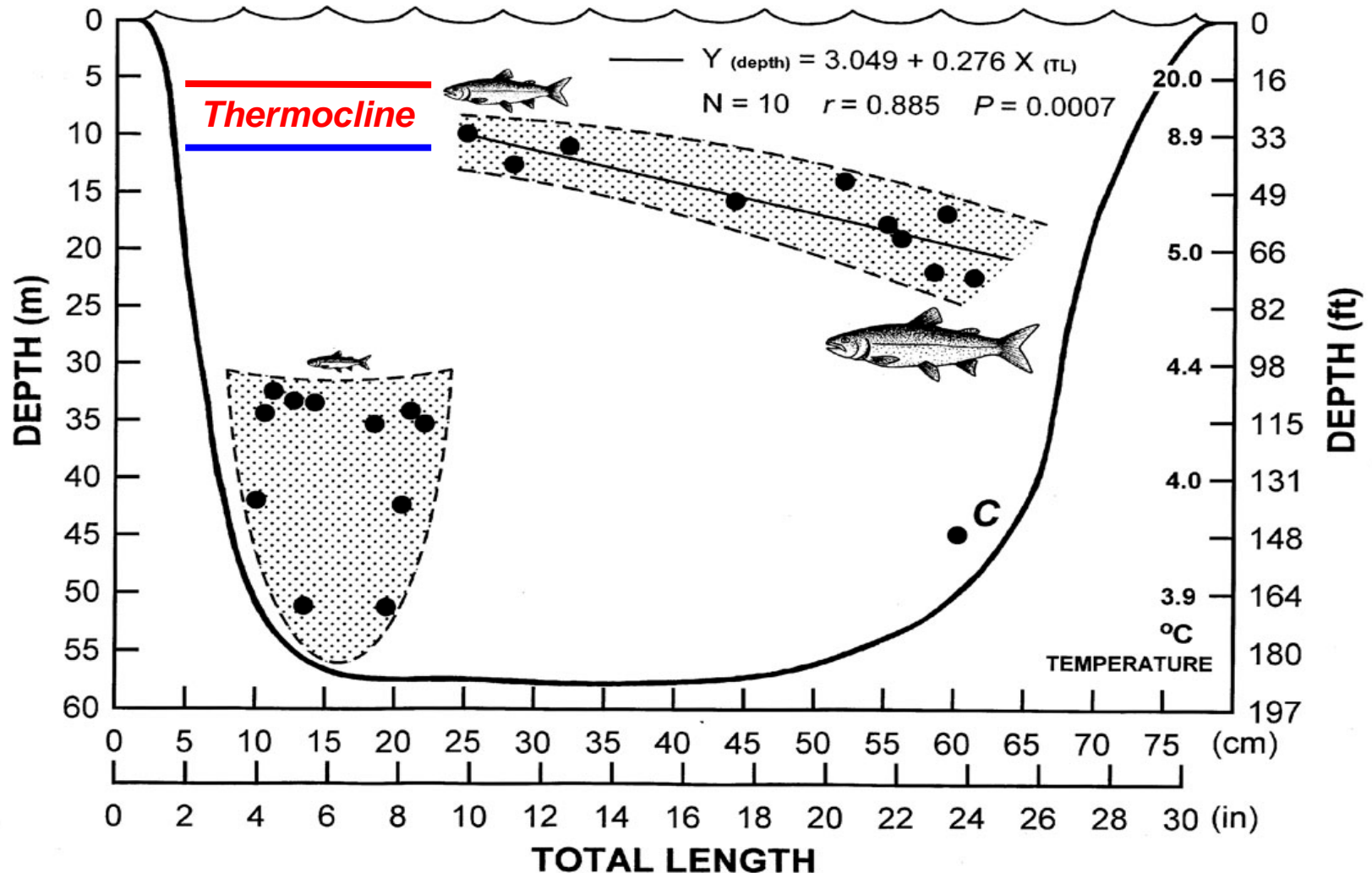
*New insights were acquired !*

# INCREASING SUMMER TEMPERATURES

## Depth of the thermocline



### MIDSUMMER DEPTH DISTRIBUTION – TEMPERATE LAKES

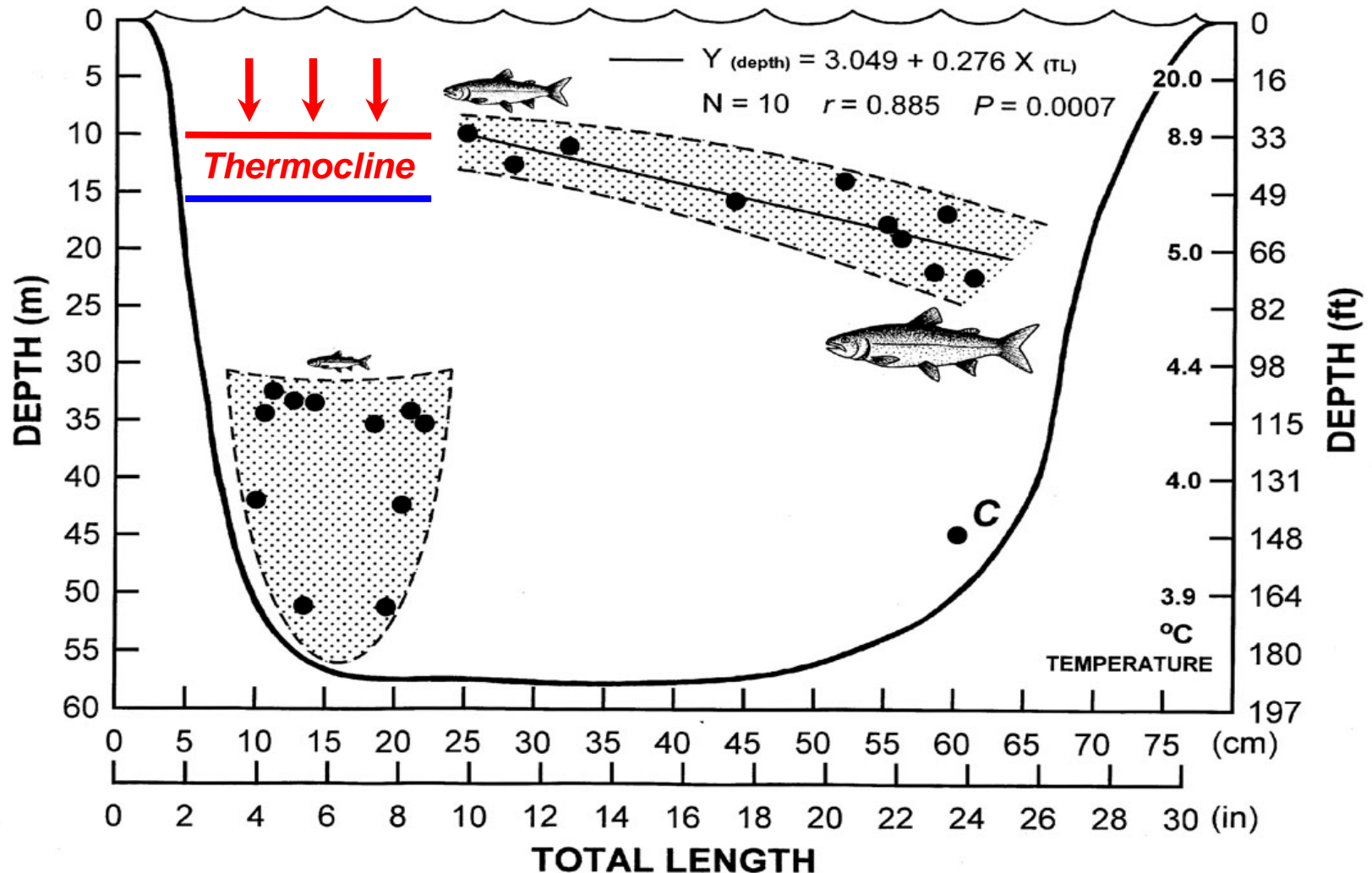


# INCREASING SUMMER TEMPERATURES

## Thermocline deepening



### MIDSUMMER DEPTH DISTRIBUTION – TEMPERATE LAKES

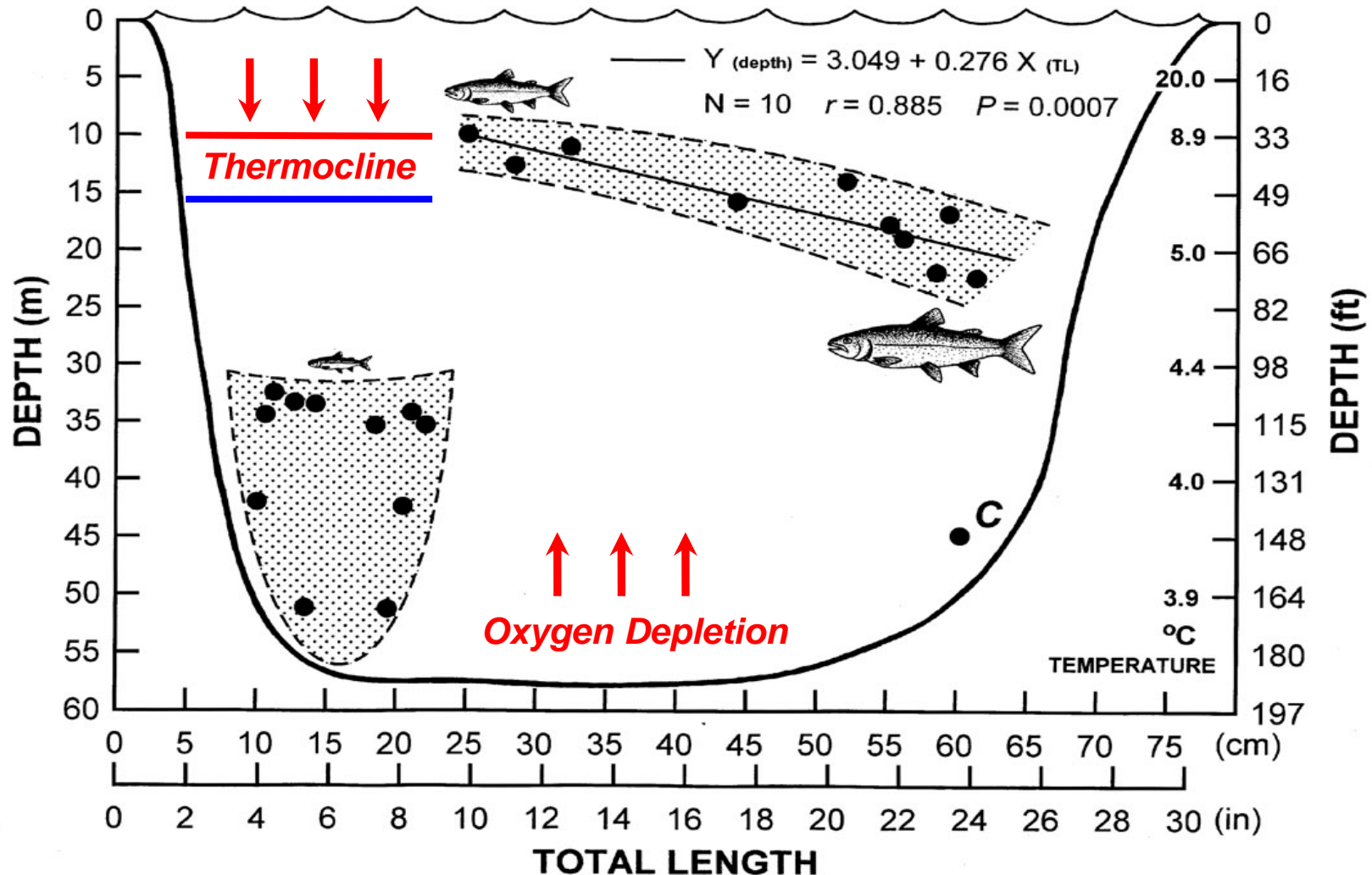


# INCREASING SUMMER TEMPERATURES

Thermocline deepening – bottom oxygen depleting



## MIDSUMMER DEPTH DISTRIBUTION – TEMPERATE LAKES

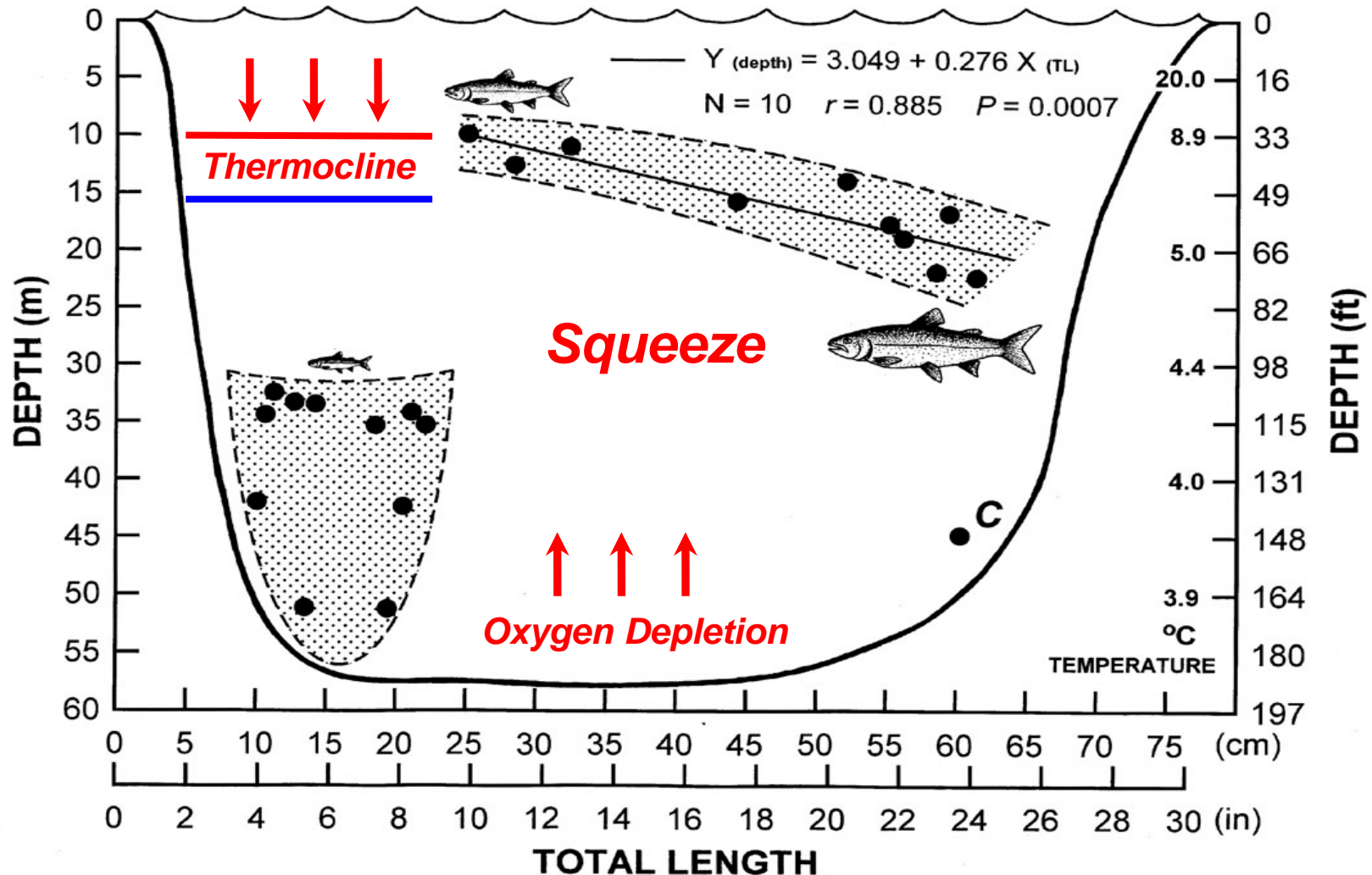


# INCREASING SUMMER TEMPERATURES

Temperature – oxygen squeeze, results in cannibalism



## MIDSUMMER DEPTH DISTRIBUTION – TEMPERATE LAKES



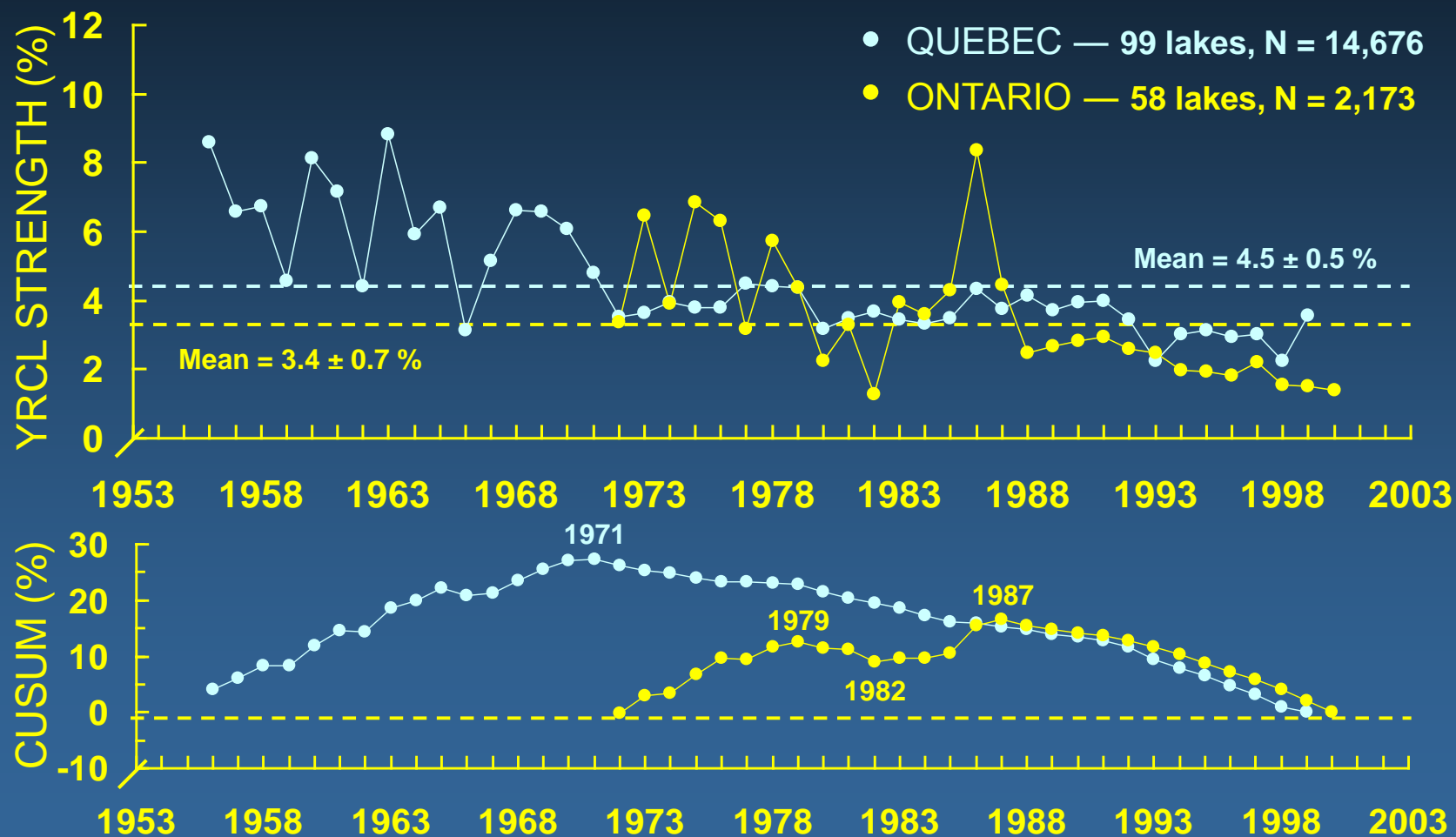
# Long-Term Changes in Lake Trout Recruitment and Climate Warming

*Ontario and Quebec  
lake trout populations and fall  
spawning temperatures*

*New insights were acquired !*

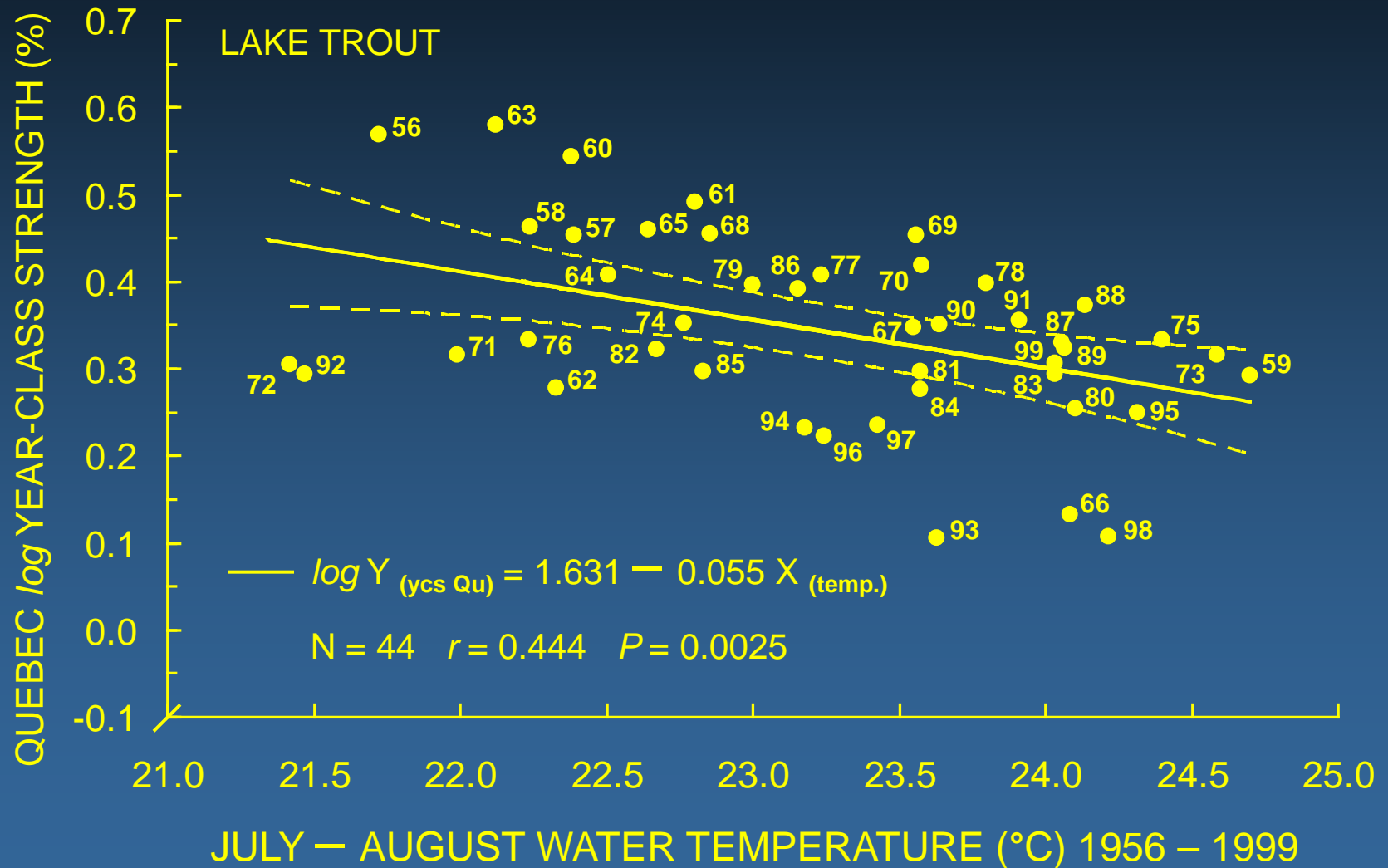
# LONG-TERM YEAR-CLASS STRENGTH

Central Quebec-Ontario lake trout lakes



# RECRUITMENT – MIDSUMMER TEMPERATURE RELATION

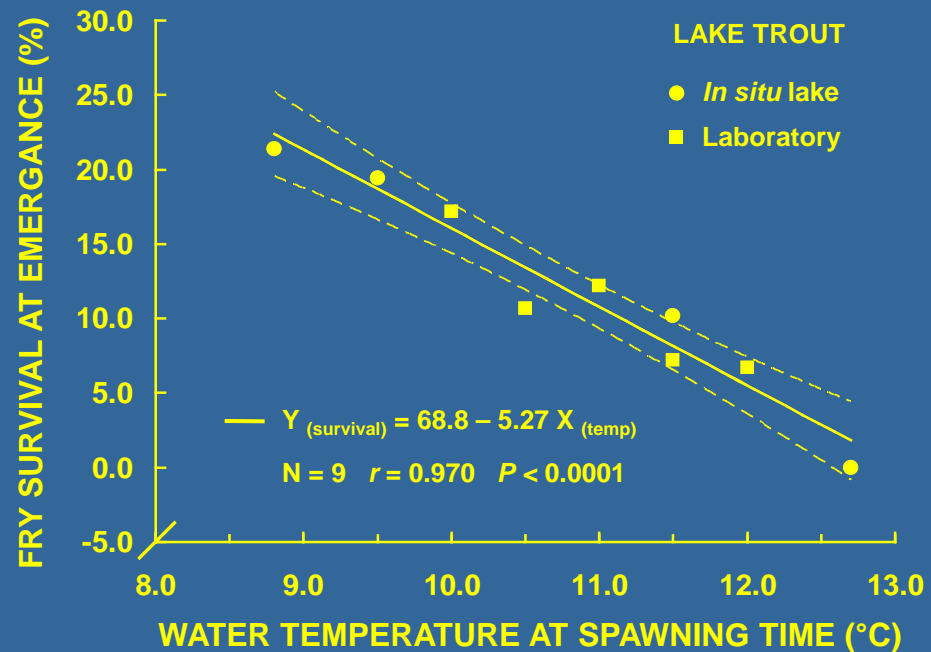
Five decades of Quebec lake trout year-class strength



# COLDWATER SPECIES

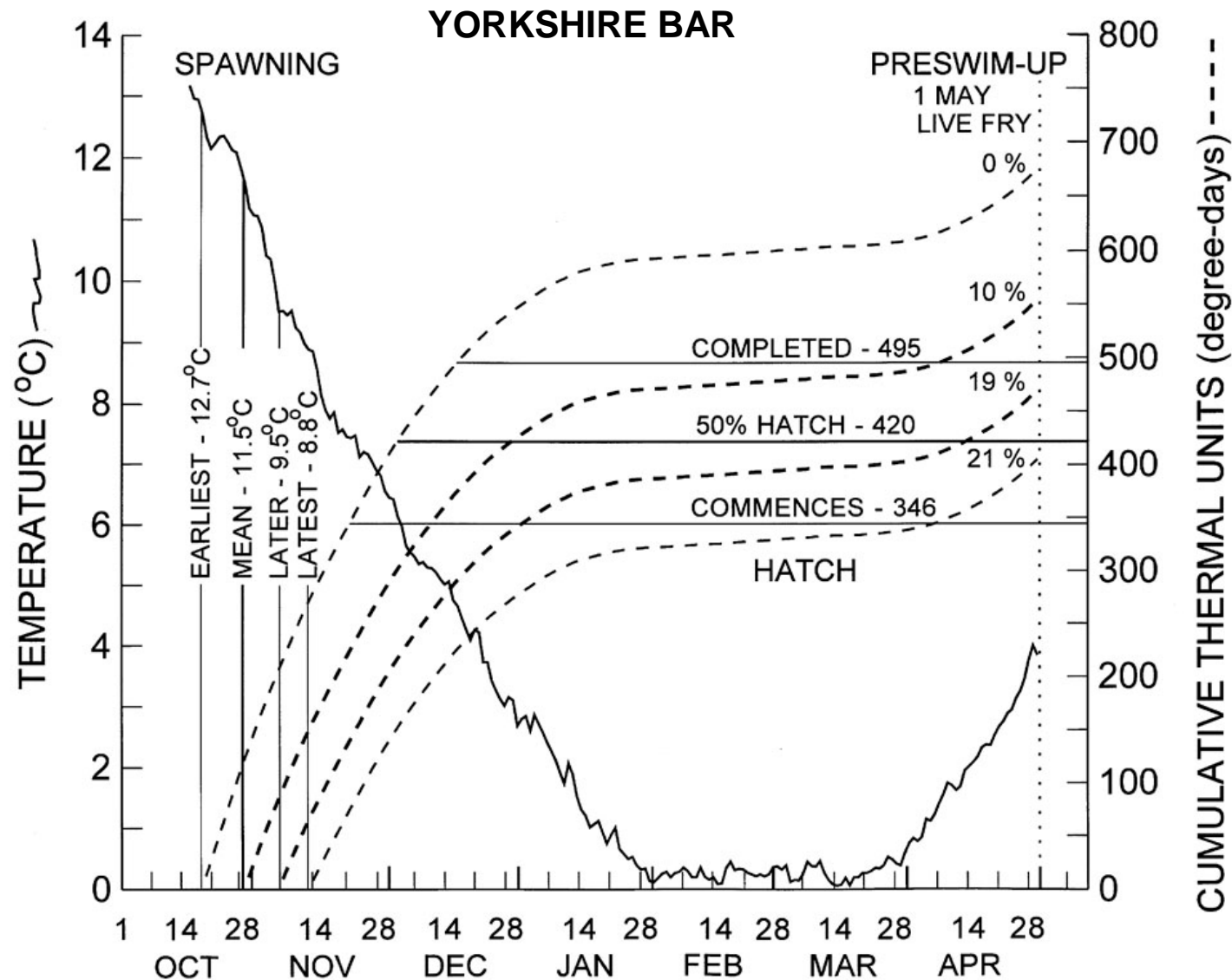
*Optimum Temperature  
for Growth – 11.5°C*

e.g., lake trout



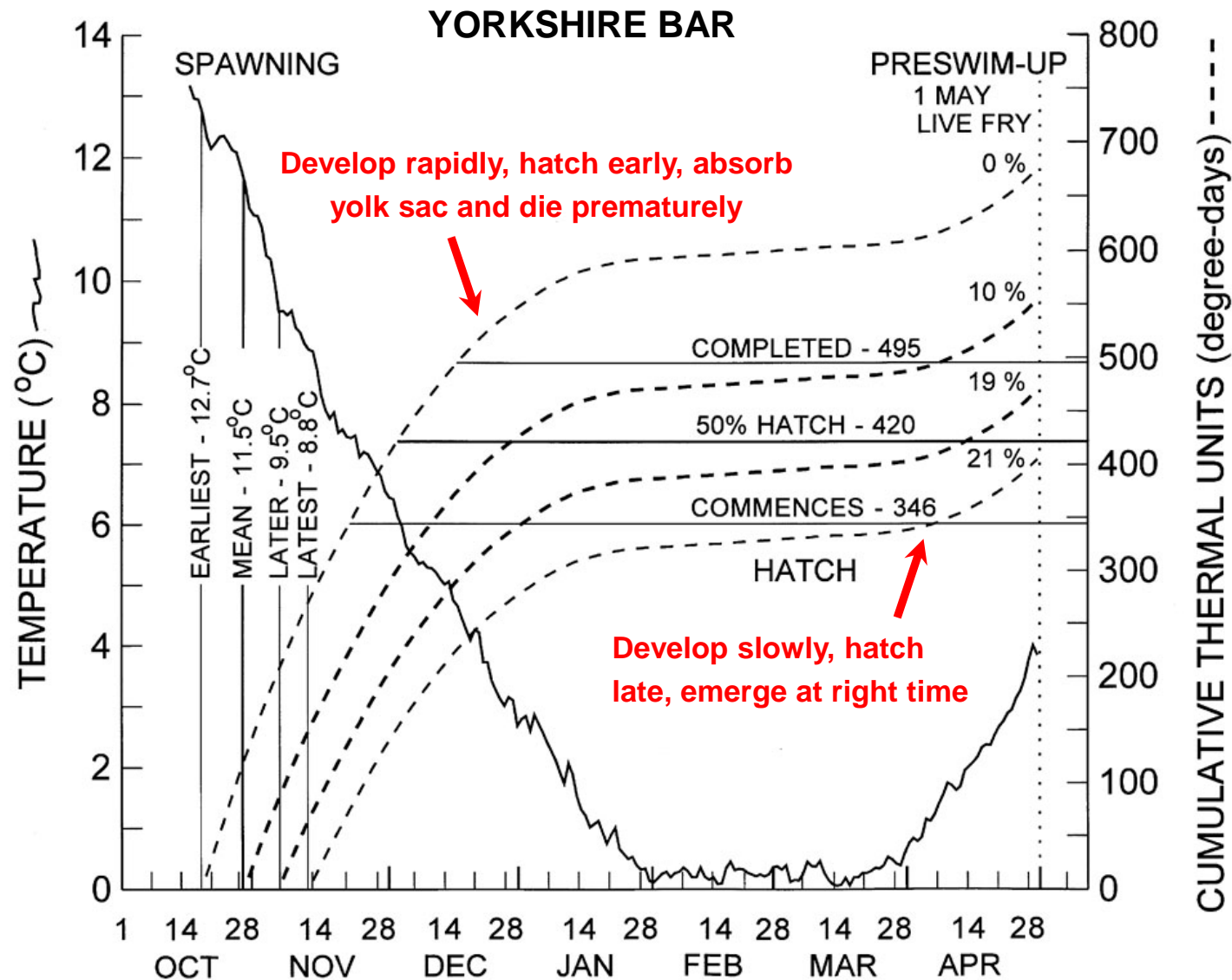
# TEMPERATURE, SPAWNING TIME, AND EMERGENCE

## Measured fry survival and predicted hatch times, using CTUs



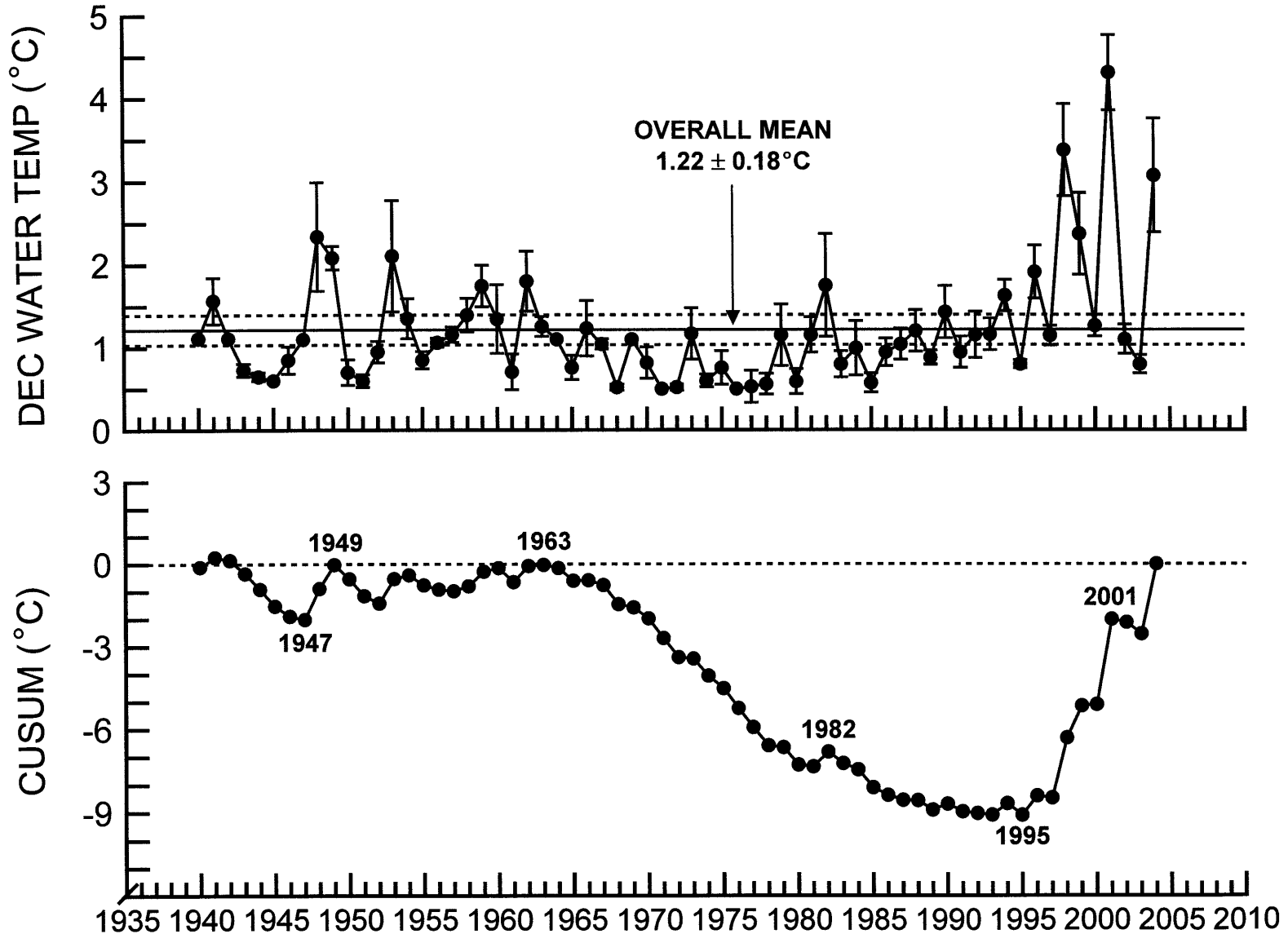
# TEMPERATURE, SPAWNING TIME, AND EMERGENCE

## Measured fry survival and predicted hatch times, using CTUs



# DECEMBER WATER TEMPERATURES

## Bay of Quinte, inshore



**Survival of lake trout fry at emergence time in spring in eastern Lake Ontario in relation to temperature at spawning time the preceding fall. Temperatures at spawning are averaged for the last two weeks in October and the first week in November.**

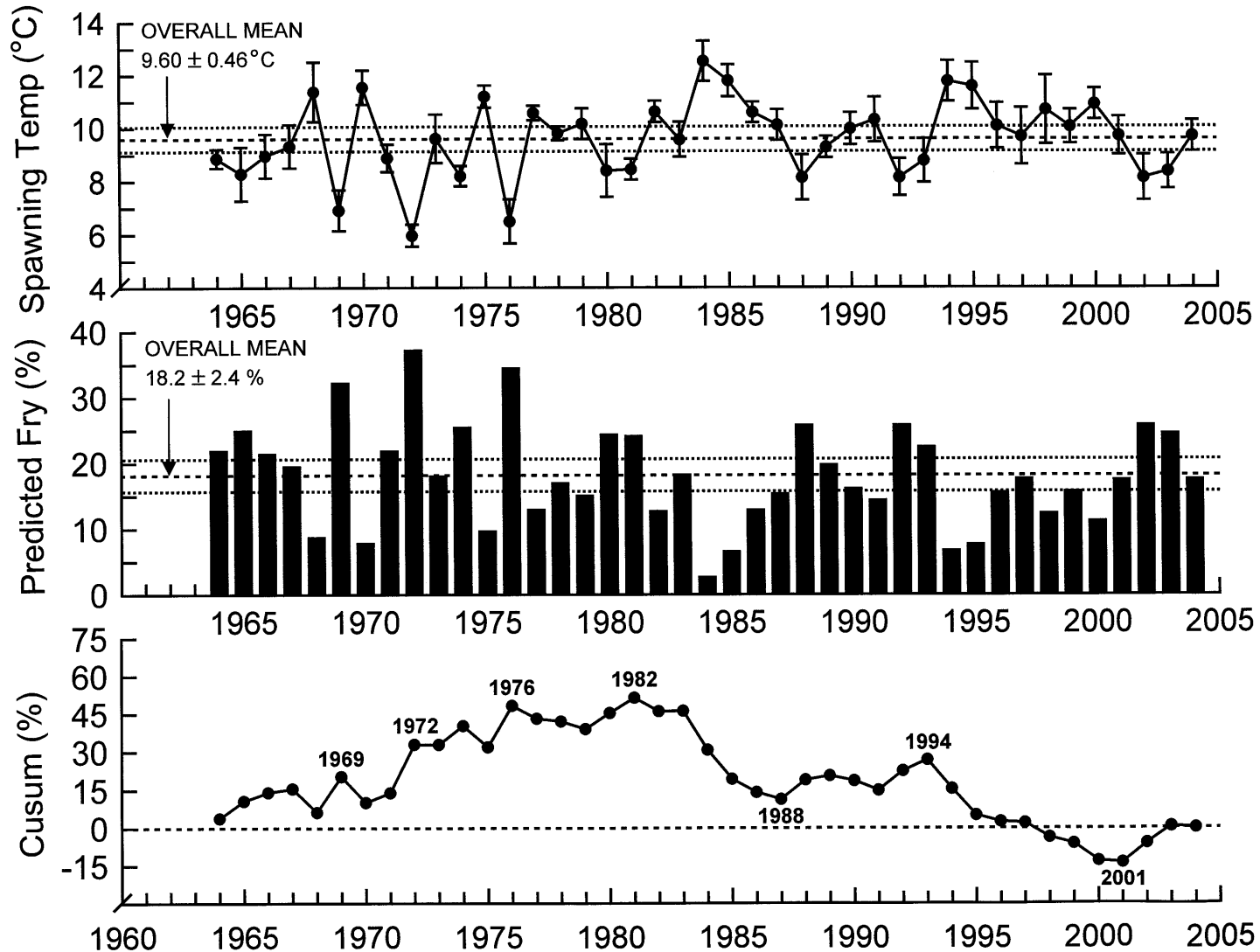
Water temperatures at spawning		Survival at emergence	
Average	Deviation	Mean (%)	Fold change
6.84 <sup>a</sup>	-3.00	32.45	+1.92
7.84 <sup>a</sup>	-2.00	27.18	+1.67
8.84	-1.00	22.53	+1.35
9.84	0	16.65	0
10.84	+1.00	11.37	-1.47
11.84	+2.00	6.93	-2.40
12.84	+3.00	0.83	-20.06

<sup>a</sup> **Extrapolated**



# SPAWNING TEMPERATURE AND YEAR-CLASS STRENGTH

## Predicted emergence from Oct – Nov spawning temperatures



# Lake Trout Spawning

## Adaptation, Timing, and Depth

*Spawn later in southern part of range (e.g., Oneida Lake); increasing evidence of spawning deeper, below the thermocline, in Ontario lakes*



# Invasive Species and Climate Warming

*Impact on prey abundance,  
growth, and survival*

*New insights were acquired !*



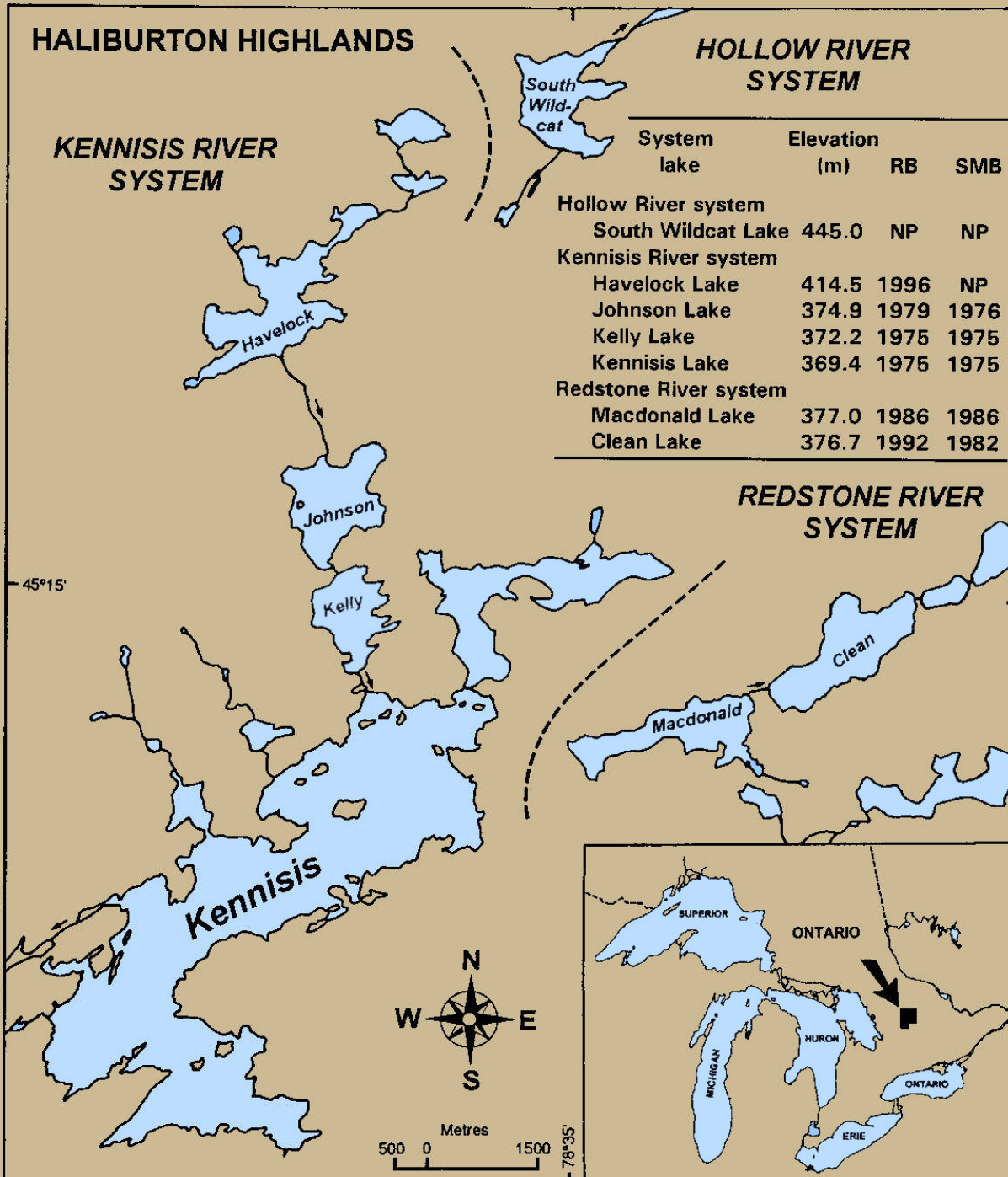
## HALIBURTON HIGHLANDS

### KENNISIS RIVER SYSTEM

### HOLLOW RIVER SYSTEM

System lake	Elevation (m)	RB	SMB
Hollow River system			
South Wildcat Lake	445.0	NP	NP
Kennisis River system			
Havelock Lake	414.5	1996	NP
Johnson Lake	374.9	1979	1976
Kelly Lake	372.2	1975	1975
Kennisis Lake	369.4	1975	1975
Redstone River system			
Macdonald Lake	377.0	1986	1986
Clean Lake	376.7	1992	1982

### REDSTONE RIVER SYSTEM



## BASS INVASION IN LAKE TROUT LAKES

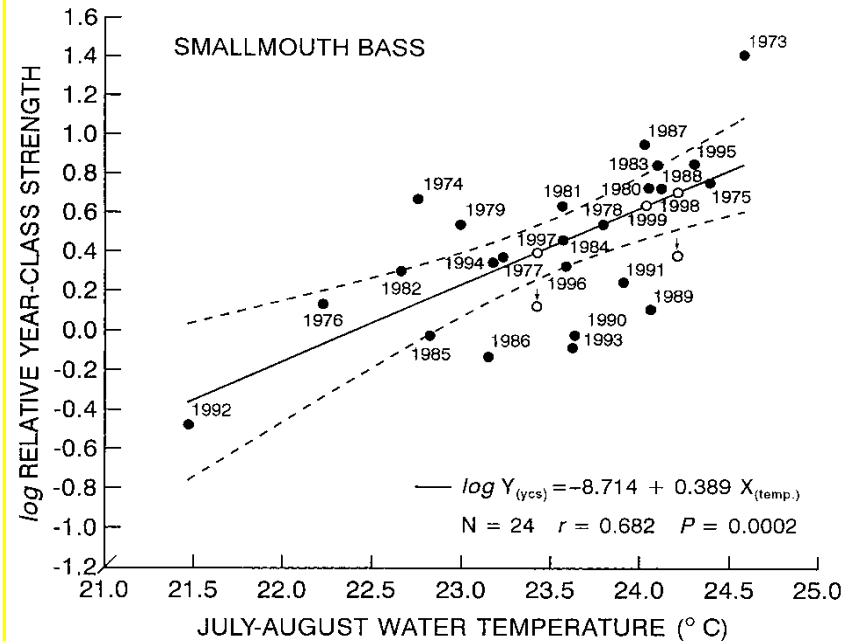
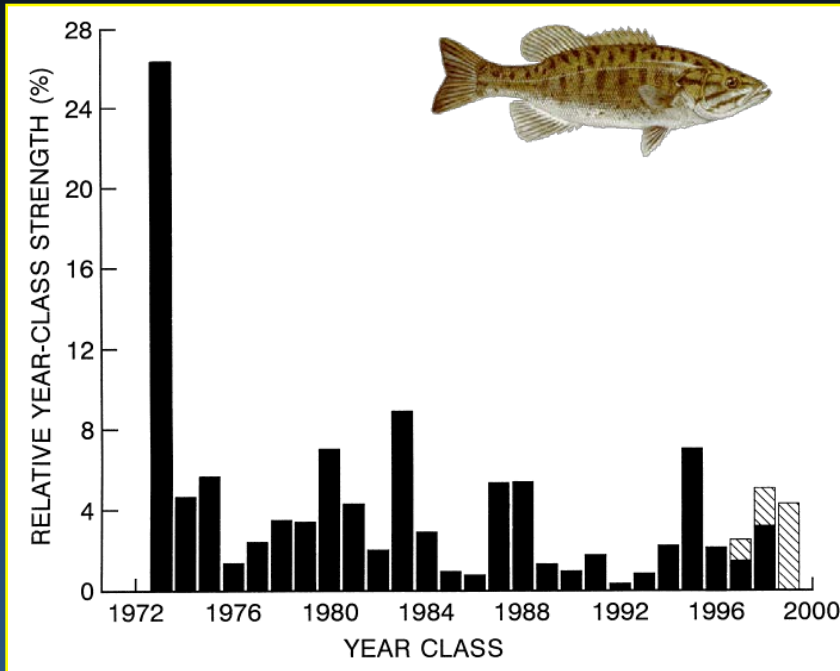


**Loss of the  
prey fish  
resource**



# WARM-WATER SPECIES

## Optimum Temperature for Growth >25°C (smallmouth bass)



### July-August water temperature

Mean

Deviation

23.42

0

24.42

+1.00

25.42

+2.00

26.42

+3.00

### Year-class strength

Relative

Fold change

2.49

0

6.10

+2.45

14.94

+6.00

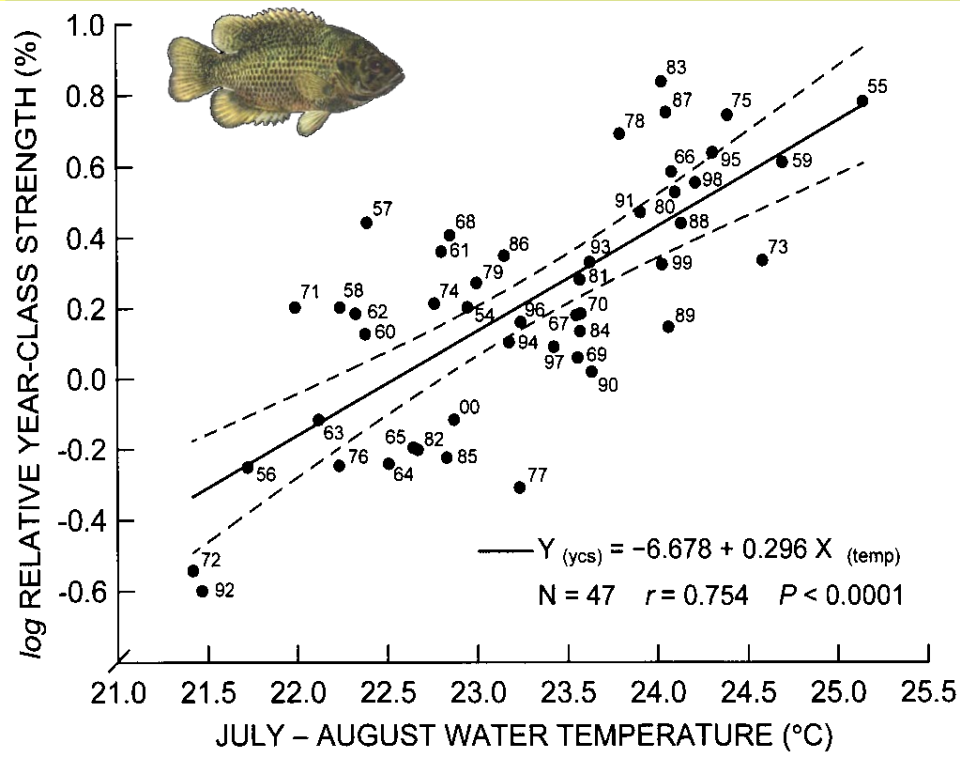
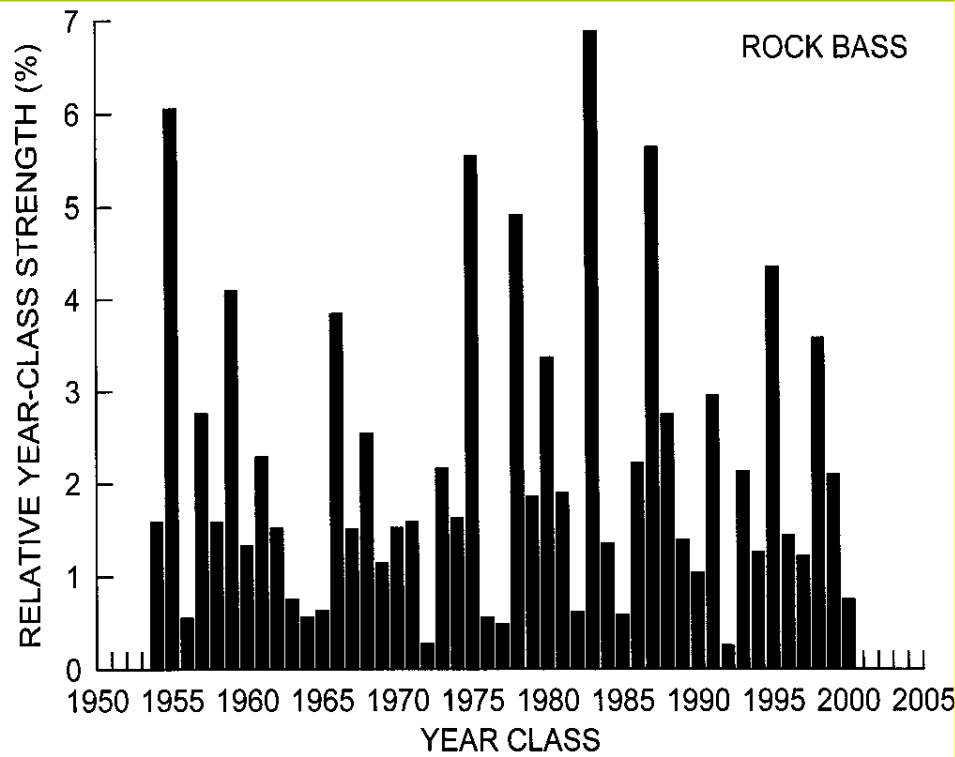
36.59

+14.69

# WARM-WATER SPECIES

*Optimum Temperature  
for Growth – 26°C*

e.g., rock bass



# WARM-WATER SPECIES

e.g., rock bass



Relative year-class strength of rock bass in Lake Ontario.

July-August water temperature		Year-class strength	
Average	Deviation	Relative	Fold change
20.31 <sup>a</sup>	-3.00	0.22	-7.66
21.31	-2.00	0.43	-3.89
22.31	-1.00	0.85	-1.96
23.31	0	1.68	0
24.10	+0.79	2.87	+1.71
24.31	+1.00	3.31	+1.96
25.31	+2.00	6.53	+3.89
26.31 <sup>a</sup>	+3.00	12.88	+7.66

<sup>a</sup> Extrapolated

# CENTRARCHID INVASIONS IN LAKE TROUT LAKES

## Species relative abundance – native, exotic, and prey fish

Species	Status		Lake trout prey	Abundance (100 m <sup>-2</sup> )	
	Native	Exotic		Number ( <i>N</i> )	Biomass ( g )
1 Fathead minnow	x		x	14.394	15.547
2 Yellow perch		x <sup>a</sup>	x	13.606	29.864
3 Rock bass		x <sup>b</sup>		2.891	34.629
4 Bluntnose minnow		x <sup>a</sup>	x	2.372	4.339
5 Smallmouth bass		x <sup>b</sup>		2.052	13.240
6 Common shiner		x <sup>a</sup>	x	0.387	1.496
7 Spottail shiner		x <sup>a</sup>	x	0.342	1.260
8 Brook stickleback	x		x	0.326	0.361
9 Pumpkinseed		x <sup>b</sup>		0.323	1.070
10 Burbot	x		x <sup>c</sup>	0.306	7.668
11 Creek chub	x		x	0.290	4.406
12 White sucker	x		x <sup>c</sup>	0.175	4.583
13 Pearl dace	x		x	0.123	0.950
14 Golden shiner		x <sup>a</sup>	x	0.112	0.403
15 Blacknose shiner		x <sup>a</sup>	x	0.075	0.099
16 Longnose dace		x <sup>b</sup>	x	0.062	0.137
17 Lake trout	x		x <sup>c</sup>	0.043	3.154
18 Blacknose dace		x <sup>a</sup>	x	0.043	0.110
19 Brown bullhead		x <sup>b</sup>		0.038	1.014
20 Northern redbelly dace	x		x	0.013	0.022
21 Lake chub	x		x	0.008	0.257
22 Emerald shiner		x <sup>a</sup>	x	0.004	0.004
All species	9	13		36.795	126.220
Lake trout prey <sup>c</sup>			18	31.286	64.253

<sup>a</sup> Initial invader.

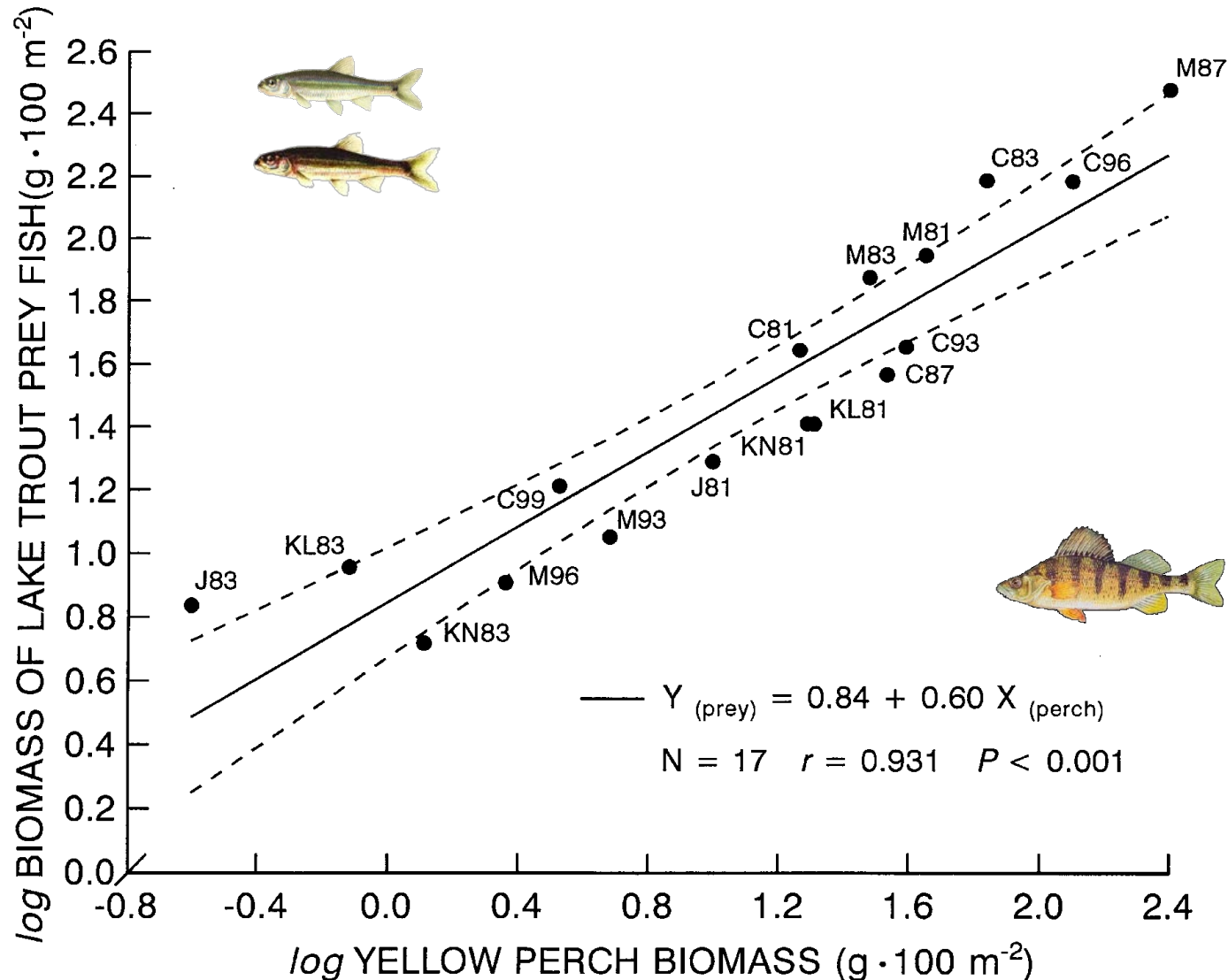
<sup>b</sup> Secondary invader.

<sup>c</sup> Individuals < 200 mm TL.



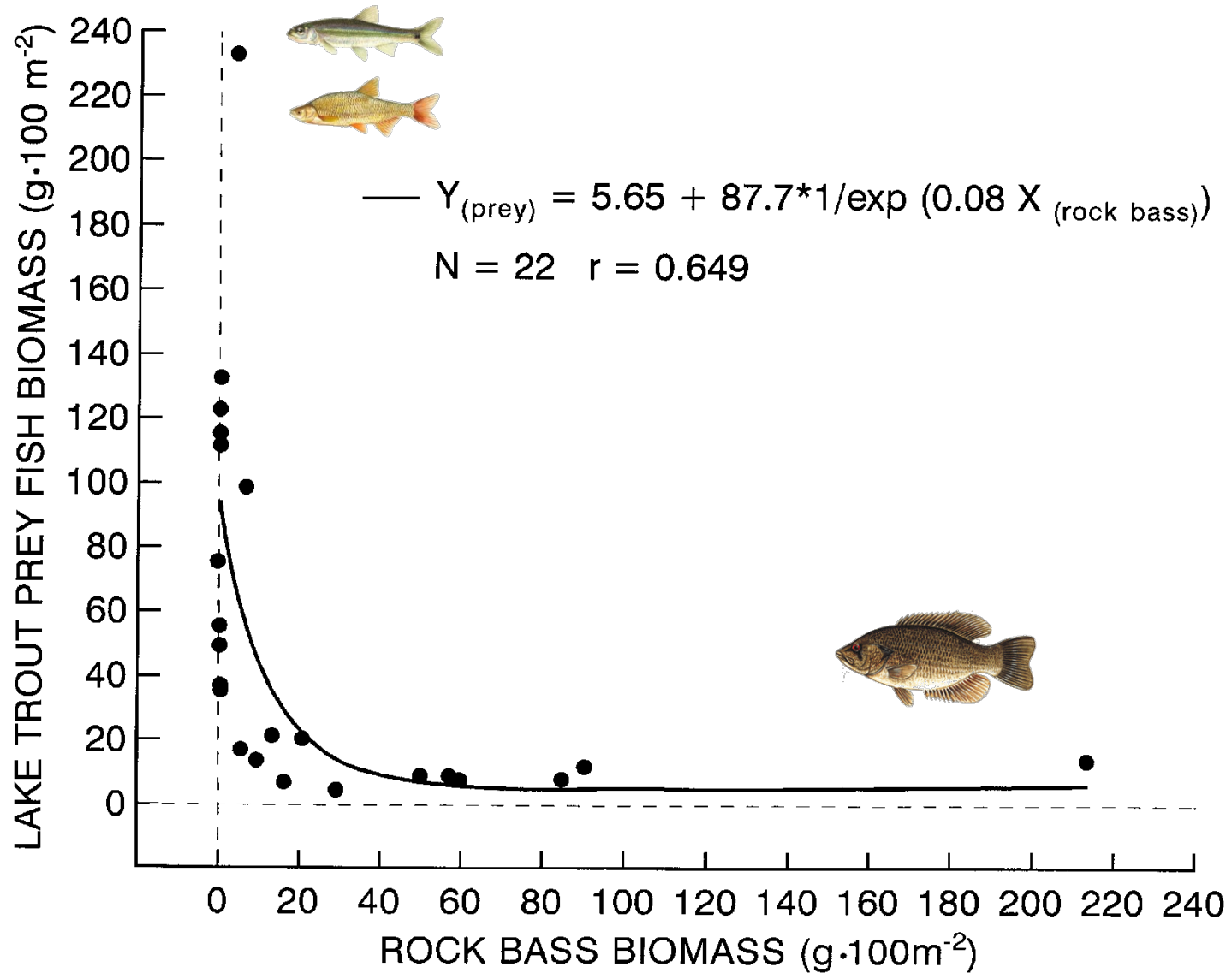
# CENTRARCHID INVASIONS IN LAKE TROUT LAKES

## Log relationship of prey fish to yellow perch



# CENTRARCHID INVASIONS IN LAKE TROUT LAKES

## Lake trout prey fish vs. rock bass



**Invasion chronology of rock bass and smallmouth bass in lake trout lakes in the Haliburton Highlands of Ontario, 1970s to 1990s. El Niño year-classes in pink.**

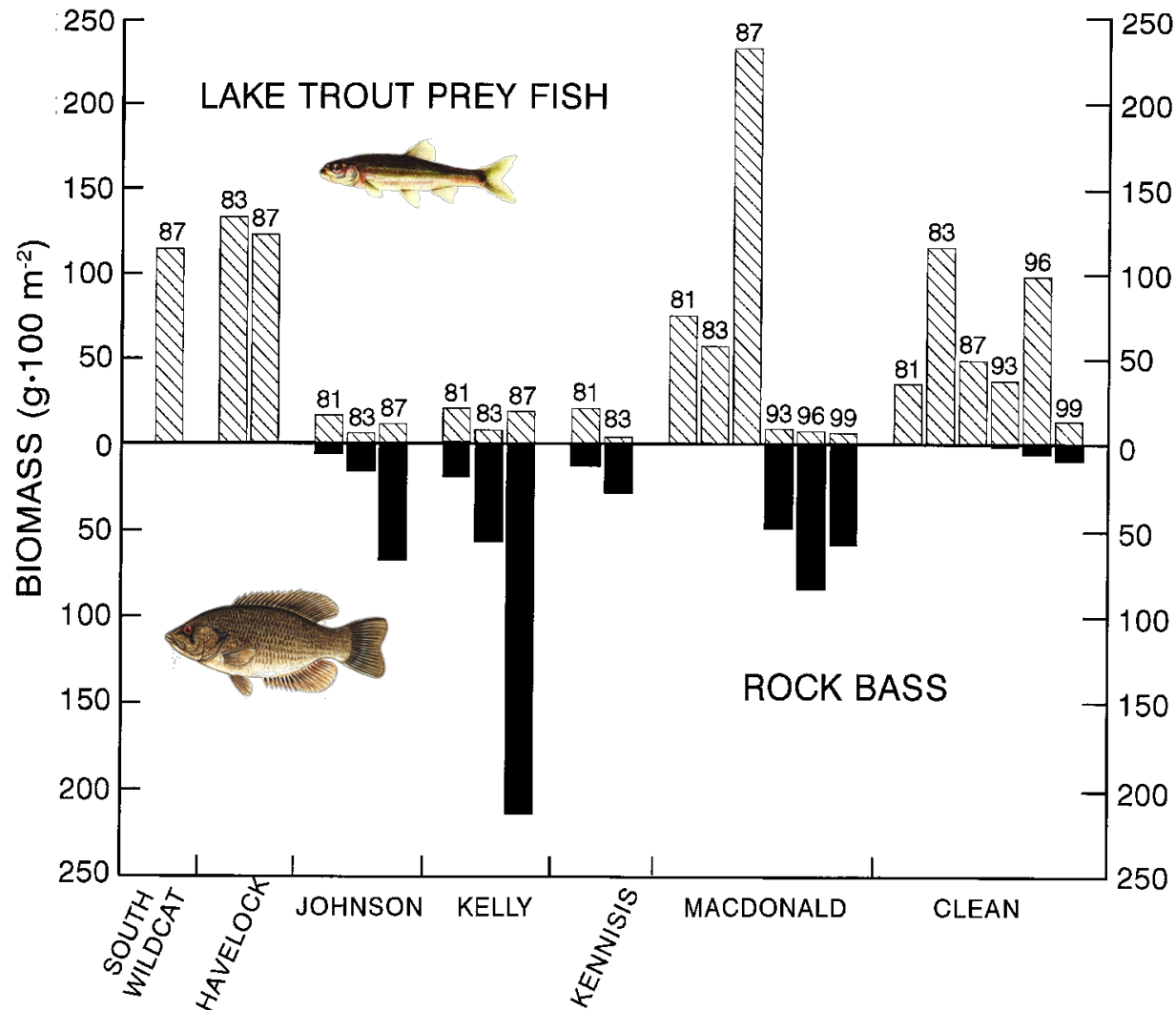
System and lake	Elevation (m)	Rock bass		Smallmouth bass	
		Year	Year-class	Year	Year-class
Kennisis River system					
Kennisis Lake	369.4	1975	1973	1975	1973
Johnson Lake	374.9	1975	1973	1975	1973
Kelly Lake	272.2	1979	1978	1976	1973
Havelock Lake	414.5	1996	1993 <sup>a</sup>	NP	
Redstone River system					
Clean Lake	376.7	1992	1991	1982	1975
Macdonald Lake	377.0	1987	1983	1986	1983
Hollow River system					
South Wildcat Lake	445.0	NP		NP	

<sup>a</sup> Not an El Niño year-class

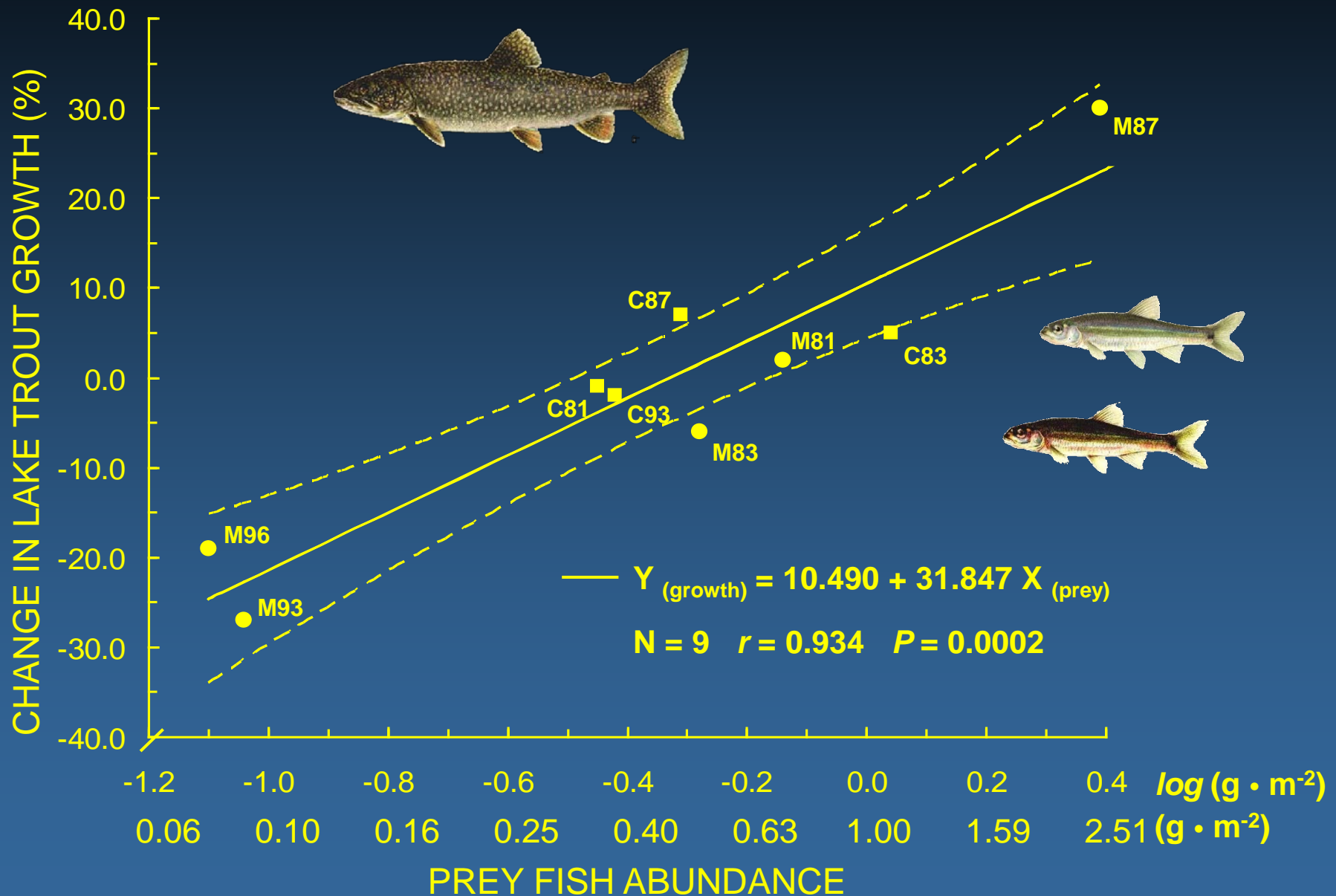


# CENTRARCHID INVASIONS IN LAKE TROUT LAKES

## Biomass of prey fish vs. rock bass



# LAKE TROUT GROWTH AND PREY FISH ABUNDANCE



# Isotopic Analysis Confirmed That Food Web Changes Occurred With Bass Invasion

*First confirmed through  
invasion of basses in  
Macdonald and Clean lakes*

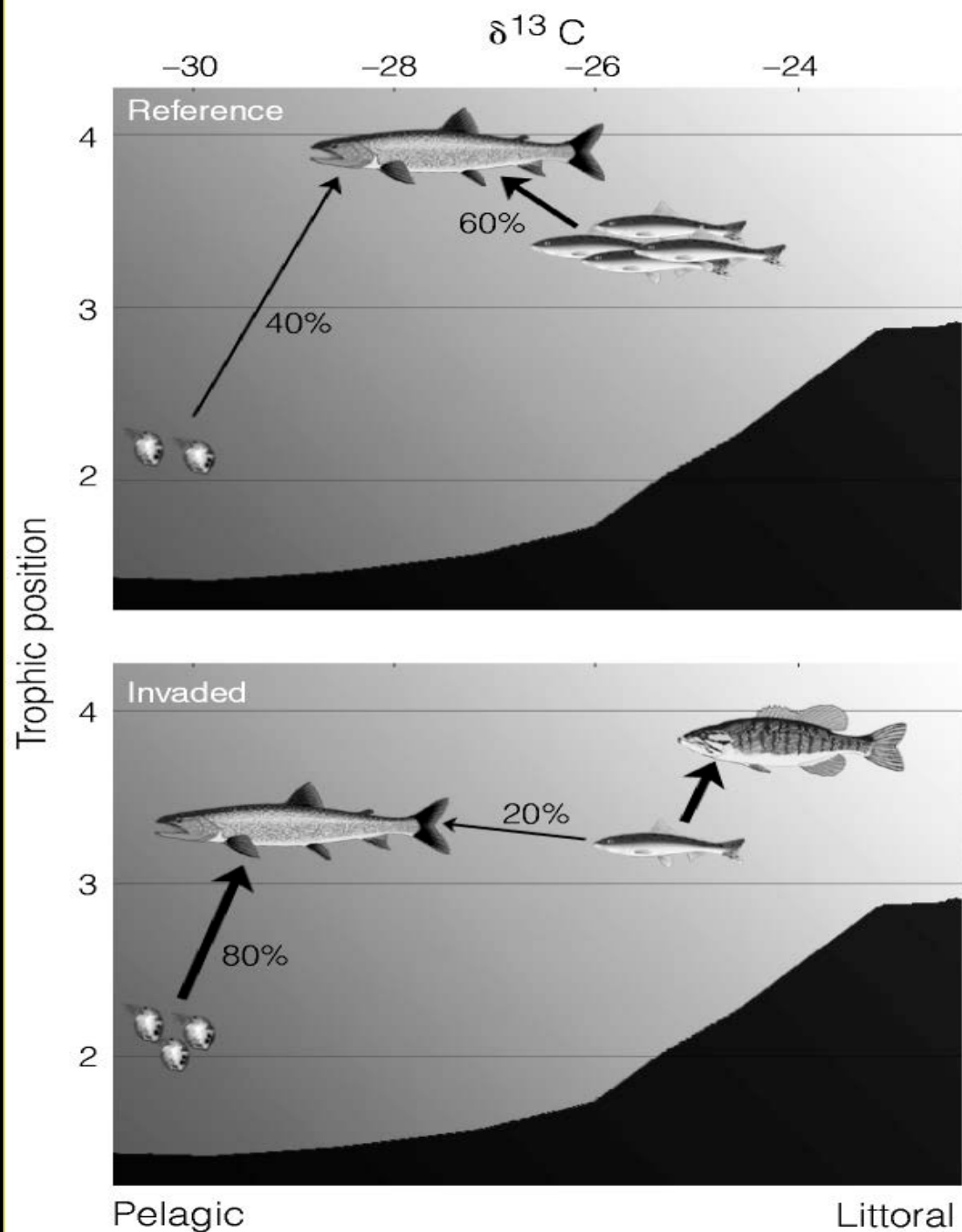


*New insights were acquired !*



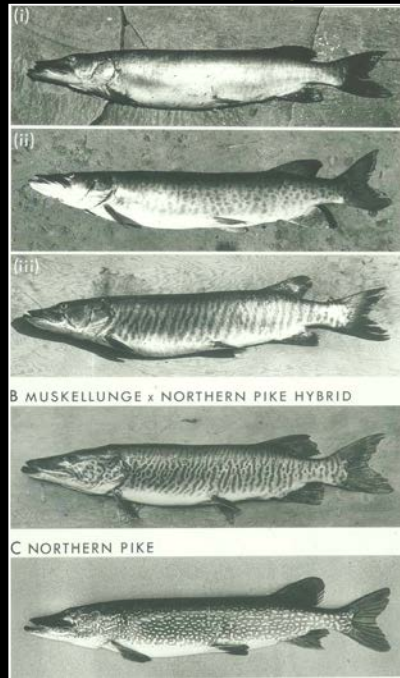
***After bass invasion, lake trout fed more heavily on plankton and were 30% slower-growing, producing small-bodied lake trout, with ultimate size decreasing by 27%, and producing 50% fewer eggs.***

***The resulting lake trout population was much less productive.***



# *The pikes (esocids) can be important invaders, showing greatly increasing growth and recruitment and altering fish communities*

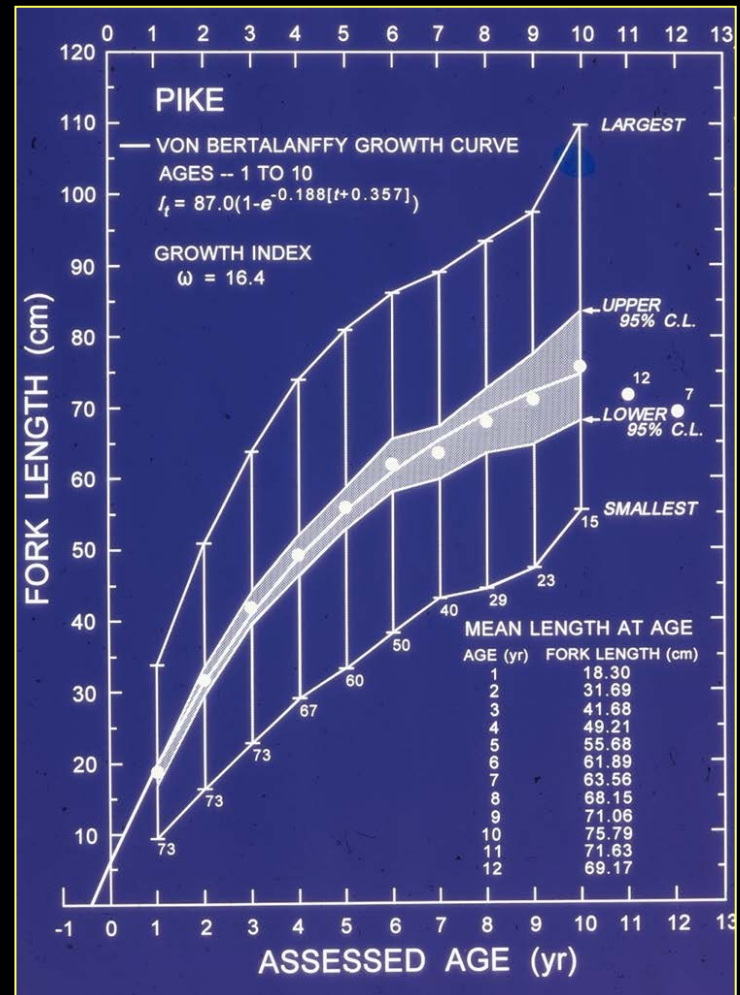
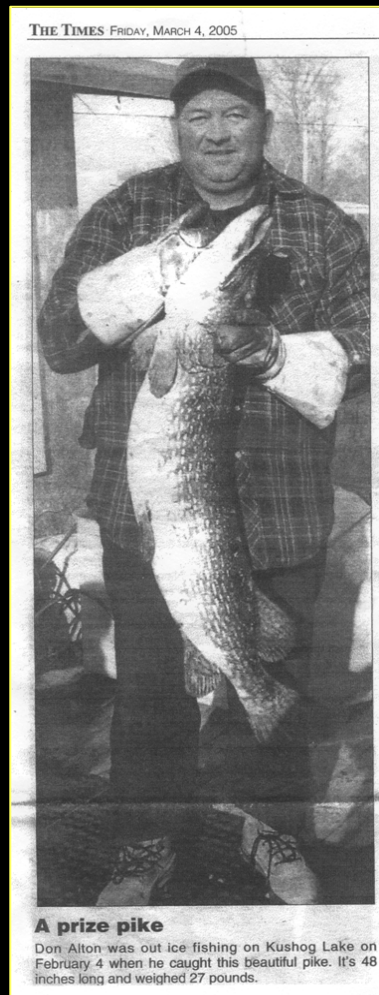
**muskellunge**



**northern pike**



**chain pickerel**



# Management Rationale for the Haliburton Lake Trout: Biological Basis

*Maintain and enhance reproductive capacity of the population by maximizing abundance of mature females, using specific biological criteria*

1. Determine age and size at first maturity **and set size limits to reduce the harvest of mature fish – consider maximum limits**
2. Minimize selective mortality **and seasonal harvest of mature females in mid-to-late summer**
3. Research and recommend best handling procedures **to reduce catch-and-release angling mortality**
4. Conduct routine assessment – **creel and abundance**

# Important Factors for Sustaining Productive Lake Trout Stocks in the Haliburton Highlands of Ontario

1. Recognize and protect genetically unique and productive native stocks – glacial relicts of the Haliburton Highlands
2. Protect spawning and deep-water nursery habitat – these can limit natural recruitment of lake trout populations
3. Maximize reproductive capacity – minimize selective harvest of mature females
4. Maintain productivity – prevent introductions of such littoral-zone predators and competitors as rock bass



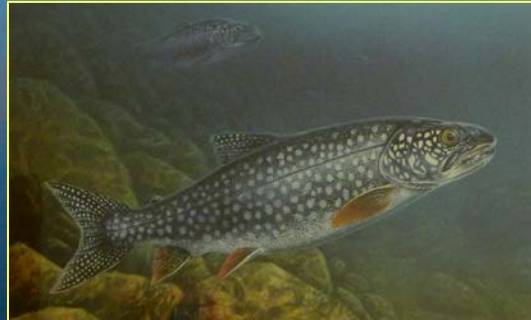
***The question is . . .***

***What does the future hold for these  
ancient fish and our association  
and use as a sustainable resource?***

***This depends upon us – we are the  
custodians***

***Will the skies and waters be . . .***

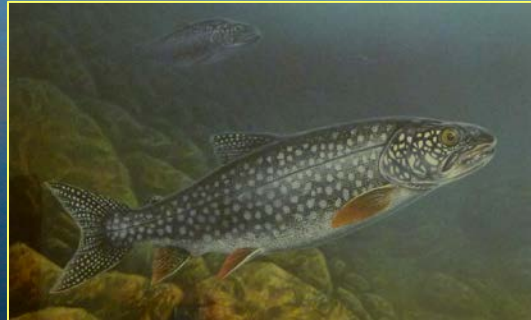
***Bright and blue !***



***Dark and stormy !***



*Thank you !*



*Thank you !*



**Haliburton**  
**Forest** and Wild Life  
Reserve Ltd.



**TRENT** UNIVERSITY



*Questions ?*

