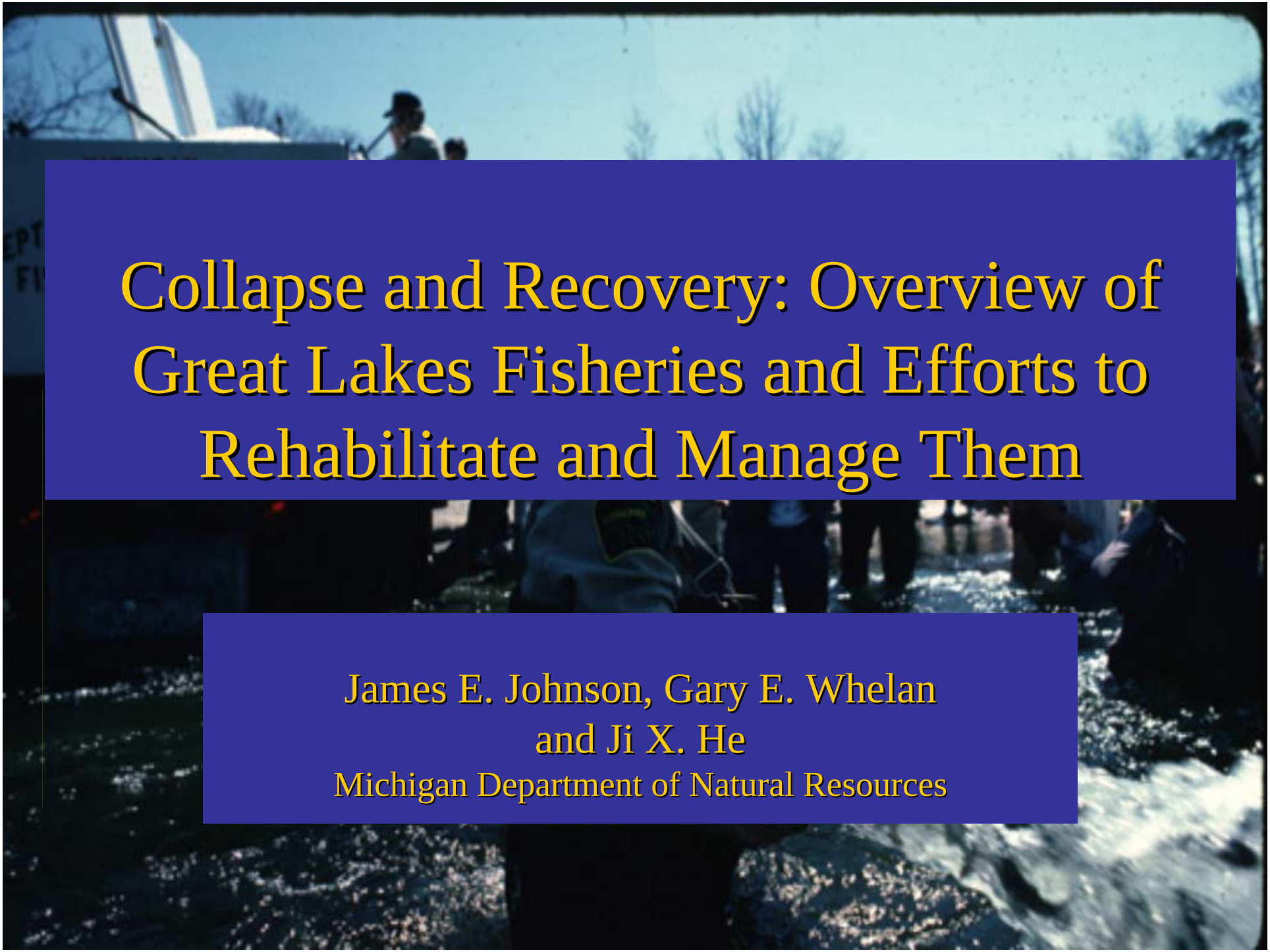


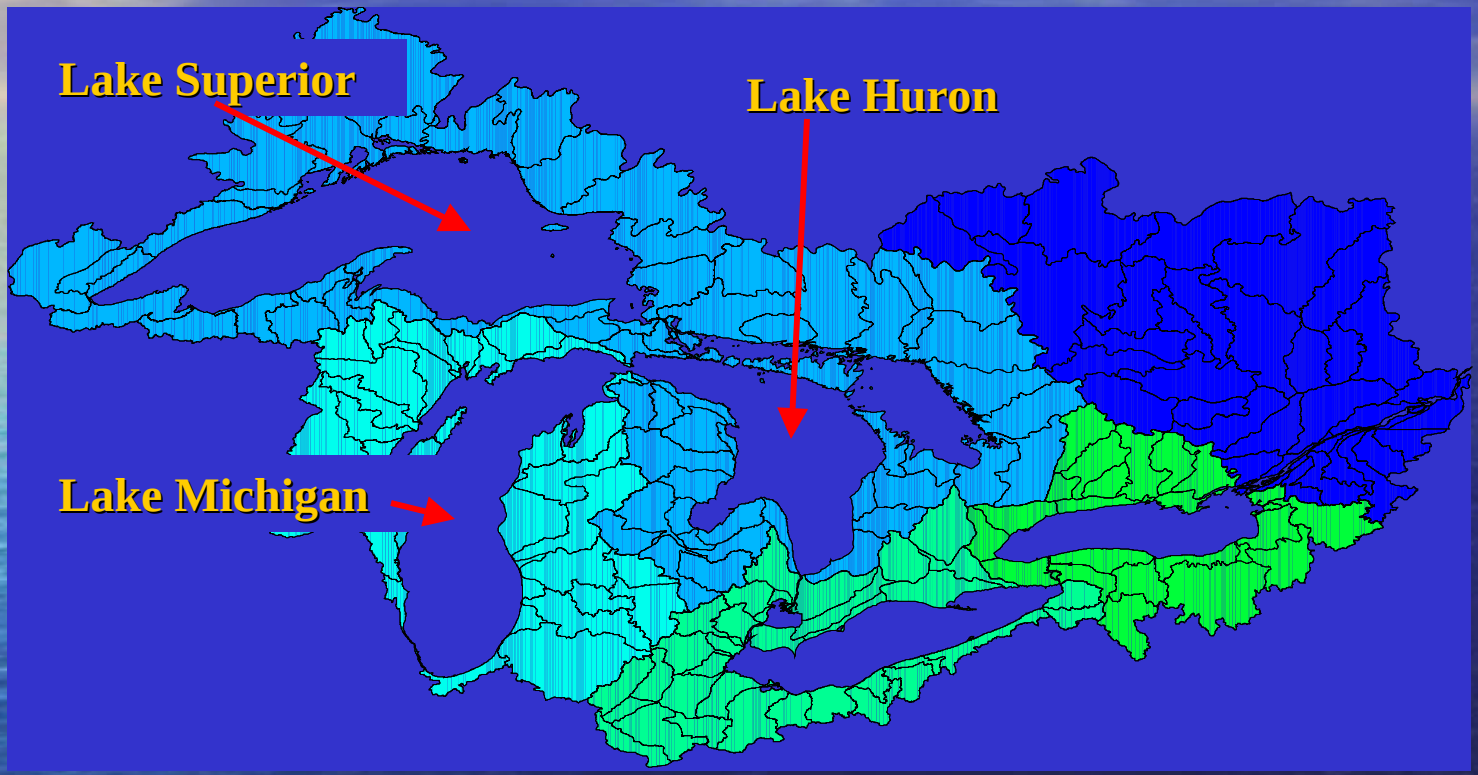
Collapse and Recovery: Overview of Great Lakes Fisheries and Efforts to Rehabilitate and Manage Them

James E. Johnson, Gary E. Whelan
and Ji X. He
Michigan Department of Natural Resources

Objectives

- Discuss the history of the predator-prey problem in the Upper Great Lake
  - the causative agents of this imbalance
- Discuss how propagated fish have and are being used in this system
- Explore reasons for their continued dependency on stocking
  - Describe remaining impediments to reproduction
- Describe present management technology

Physical Setting: Upper 3 Lakes

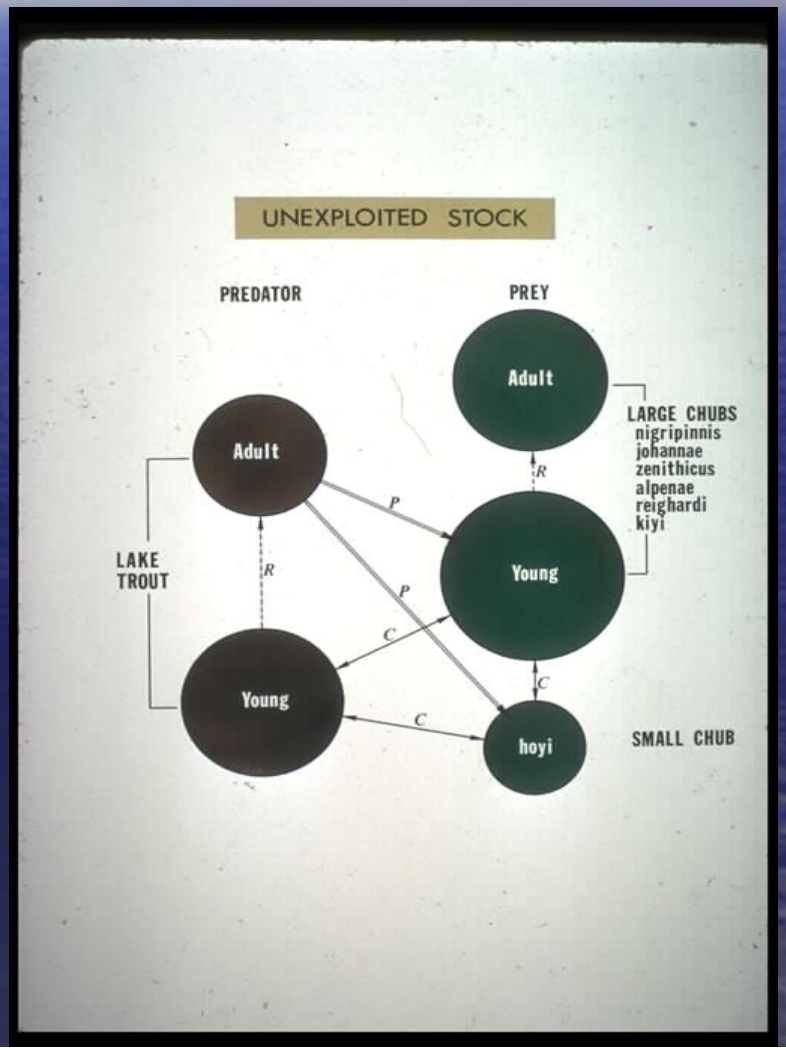


- Surface area of 50,000,000 acres
- Shoreline length of 8,436 miles

- Mean depths range from 193 ft in Lake Huron to 490 ft in Lake Superior
- Max depths range from 751 ft in Lake Huron to 1,328 ft in Lake Superior.

Historical Fish Community

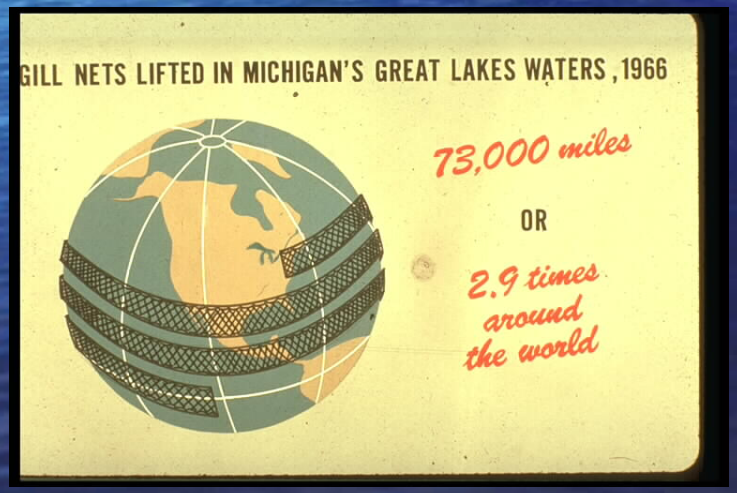
- Dominated and structured by lake trout (*Salvelinus namaycush)*
- Large populations of coregonids, particular lake whitefish (*Coregonus clupeaformis*)
- Nearshore areas of Lake Superior and northern Lakes Huron and Michigan had coaster brook trout (*Salvelinus fontinalis*)




Background

What Happened?

- Overharvest - Both commercial and sport
  - By 1870s nearshore populations depressed
  - By 1930, most valuable species depressed or lost



What Happened?

- Habitat Destruction
  - Landscape scale deforestation
  - Dam construction
  - Urbanization and Industrialization

Invading sea lampreys
In the 1940s
combined with

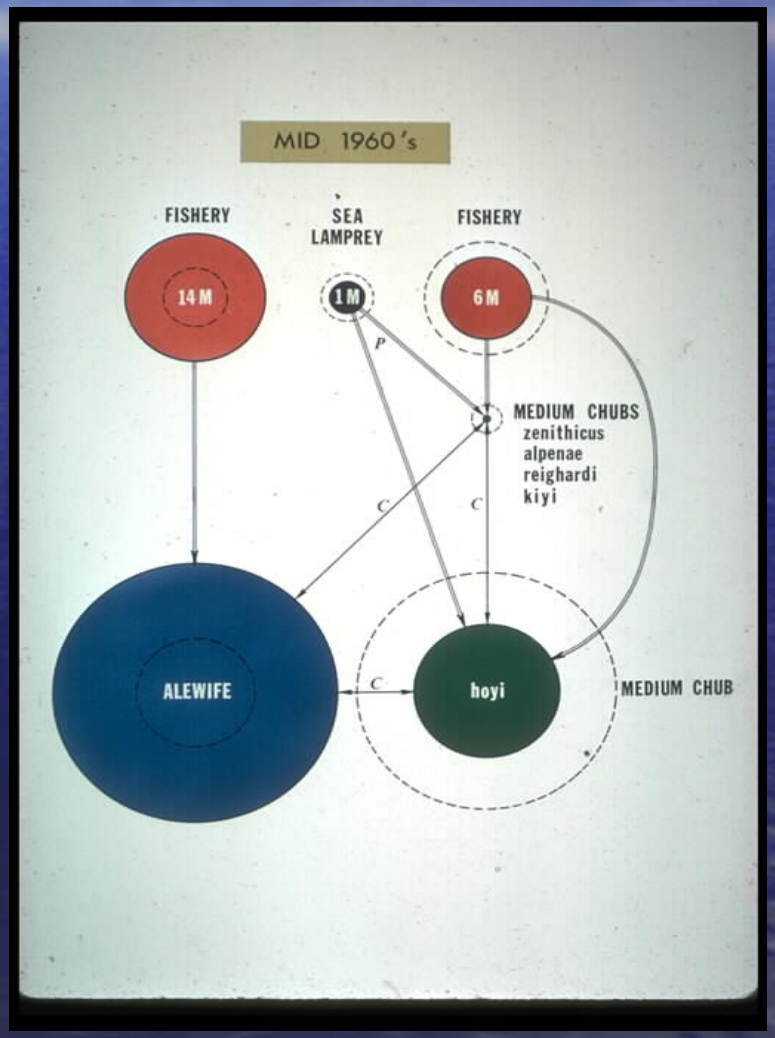
Overfishing (principally
Commercial)

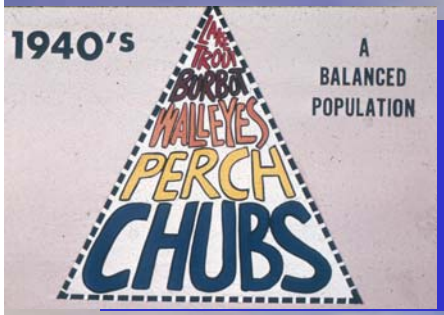
Extirpated lake trout and…

Paved the way for another invasion: the alewife

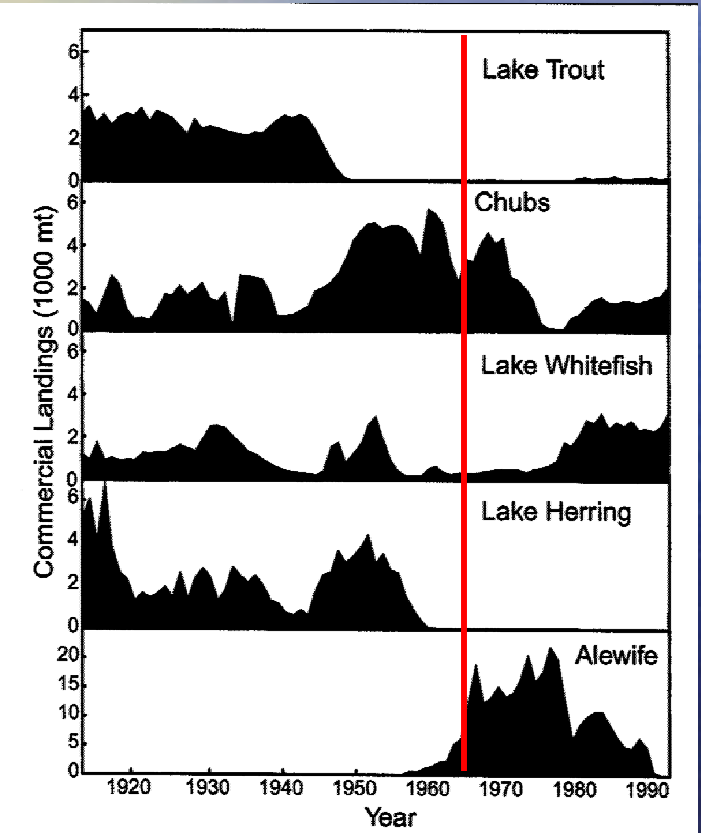
1960s Fish Community

- **System dominated by alewives (*Alosa psuedoharengus)***
- **Complete loss of large salmonid piscivores and lake whitefish**

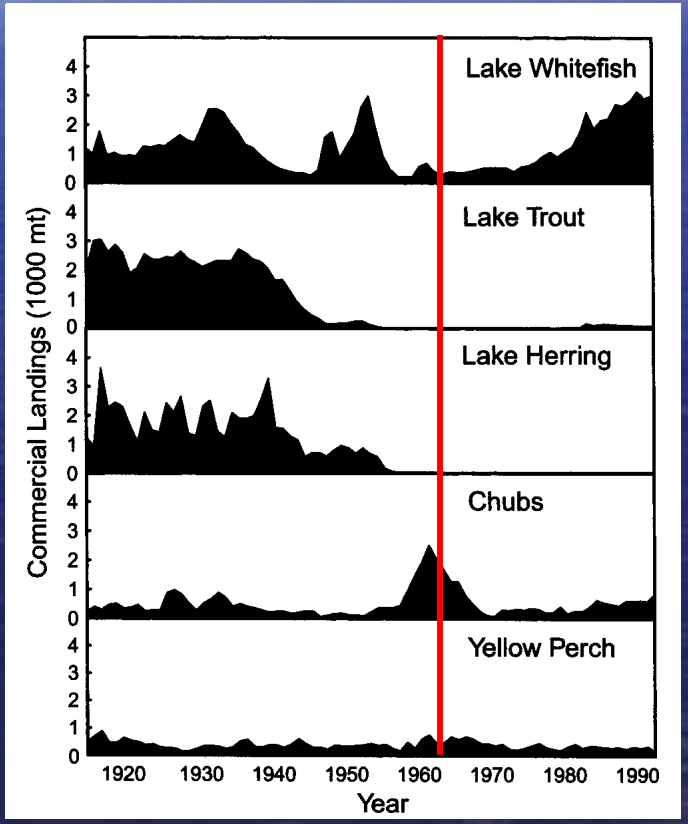




The Consequences



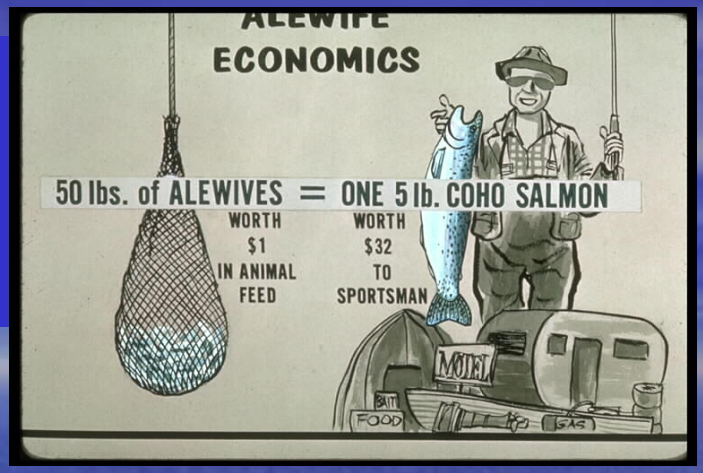
Lake Michigan



Lake Huron

From: Brown et al. 1999

Setting the Stage



- Fisheries Policy - Tanner and Tody (1966)
  - Recreational fishery management primary goal in the Great Lakes
  - Commercial fishing to a secondary role
  - Utilize the abundant low value commercial fish as forage for high value sportfish instead of developing an industrial fishery for the overabundant alewives.
    - Biomanipulation from top-down
  - Termination of legal-sized planting
- Environmental Conditions

Biomanipulation Objectives

- Achieve predator-prey balance
  - Suppress alewives and smelt populations
- Develop a Upper Great Lakes salmonid sportfishery
- Development of self-sustaining salmonid predator populations
- Re-establish native coregonid populations

Summary of Salmonid Stocking in the Upper Great Lakes (1950-2000)

Lake	Total Stocked	Mean Annual	Annual Density (#/km^2)	Minimum Annual	Maximum Annual
Lake Superior	191,348,324	3,905,068	47.6	49,888	9,661,486
Lake Michigan	461,647,368	11,259,692	197.2	9,200	19,716,748
Lake Huron	253,156,391	6,842,065	114.8	805,000	15,386,918
Total	906,152,083				

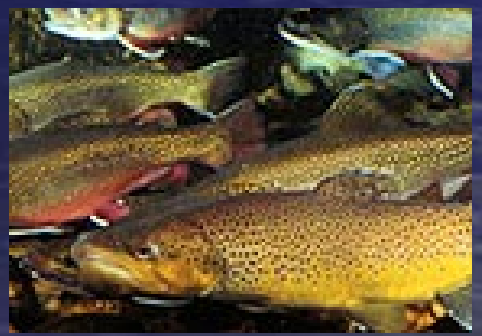
Summary of Salmonid Stocking Biomass in the Upper Great Lakes (1950-2000)

Lake	Total Estimated Biomass (kg)	Mean Annual Biomass (kg)	Density (kg/km2)	Minimum Annual (kg)	Maximum Annual (kg)
Lake Superior	4,604,554.5	93,970.5	1.1	703.4	326,080.4
Lake Michigan	9,809,429.6	239,254.4	4.2	336.7	373,028.0
Lake Huron	3,454,653.7	93,369.0	1.6	3,139.5	229,804.7
Total	17,868,637.8 (39,311,000 lb)				

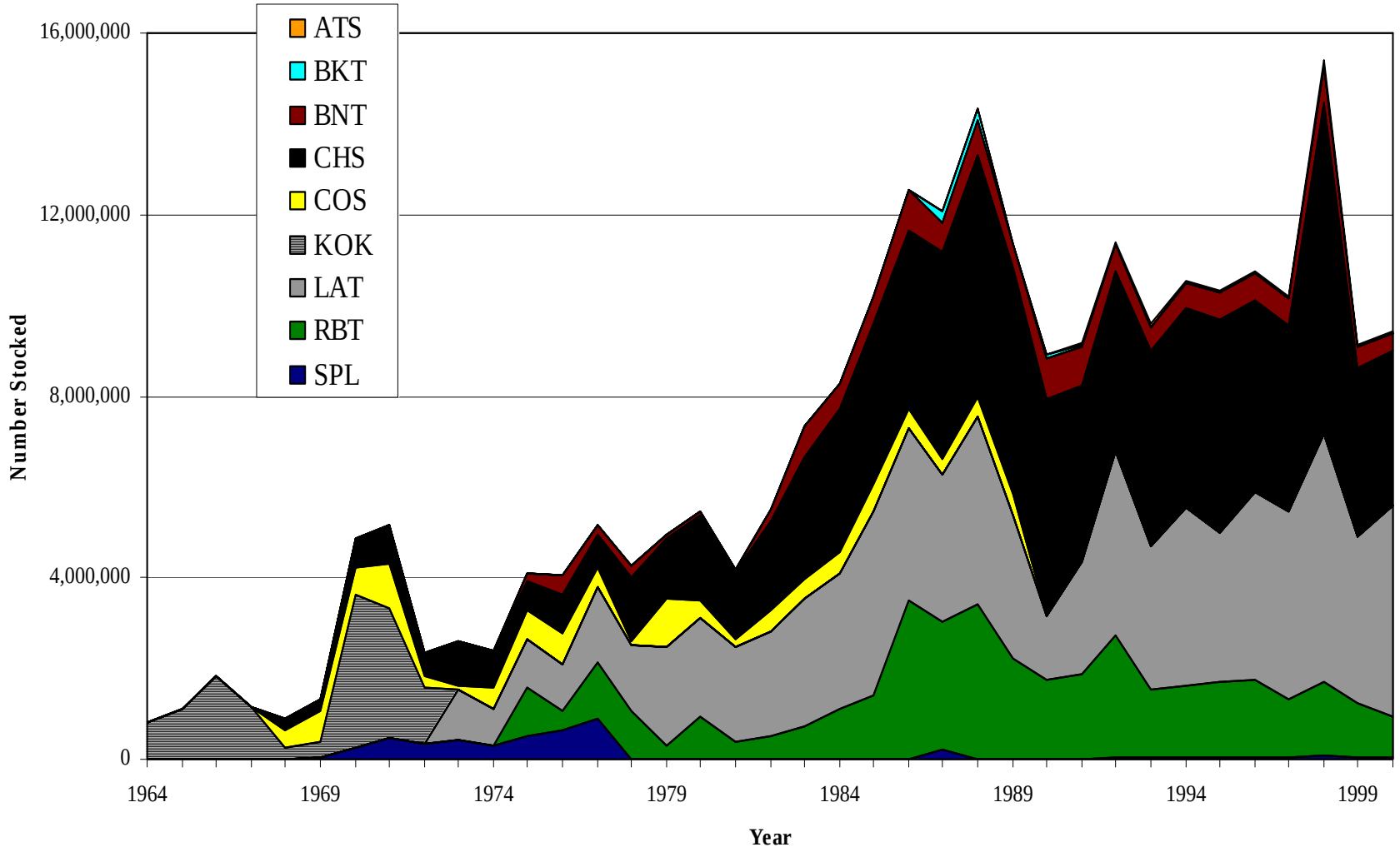


Estimated Stocking Cost for the Upper Great Lakes (1950-2000)

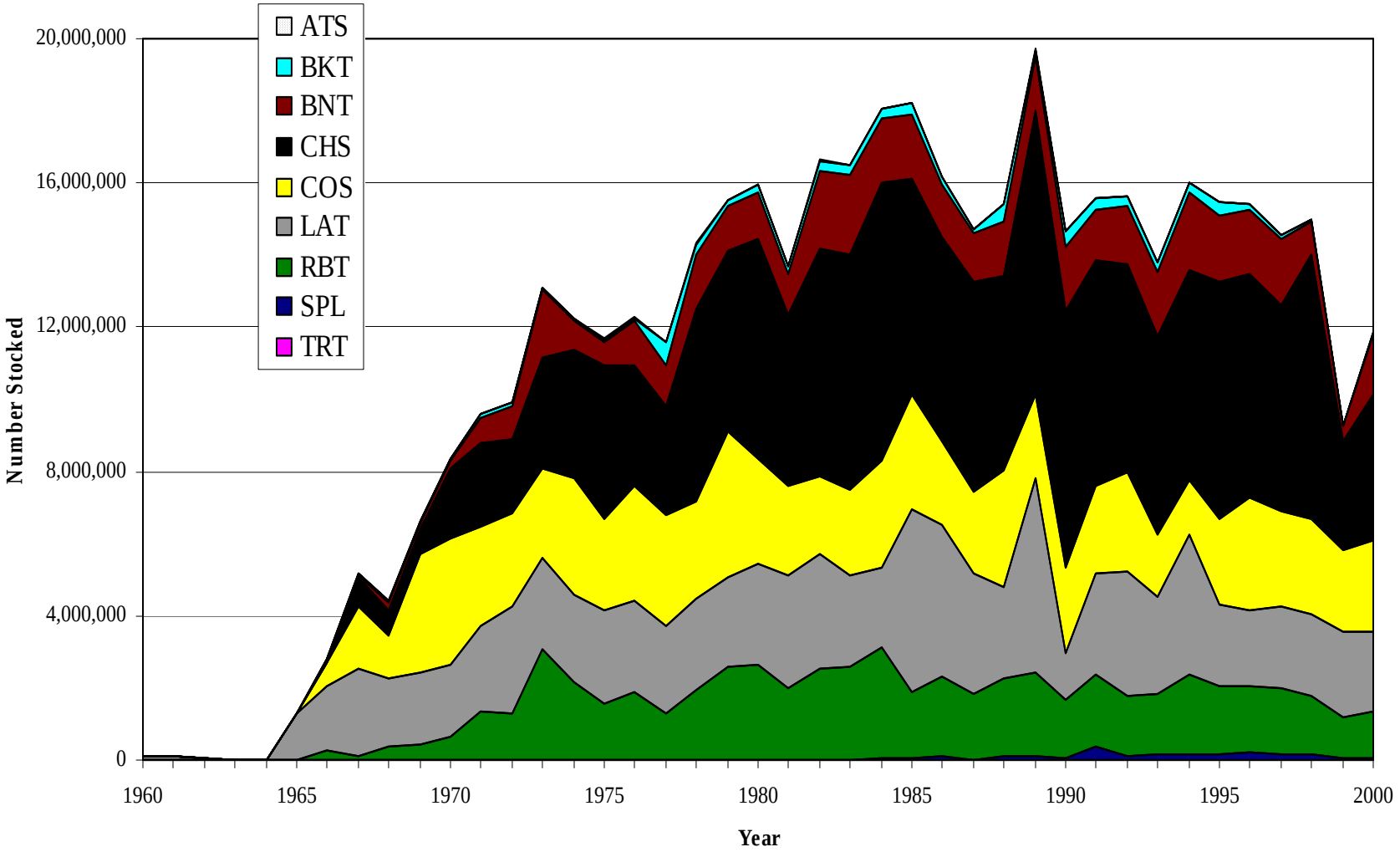
Lake	Total Cost	Mean Annual Cost	Minimum Annual Cost	Maximum Annual Cost
Lake Superior	$65,891,174.50	$1,344,717.85	$10,065.95	$4,666,210.77
Lake Michigan	$140,372,937.85	$3,423,730.19	$4,818.46	$5,338,030.13
Lake Huron	$49,436,094.55	$1,336,110.66	$44,926.25	$3,288,505.94



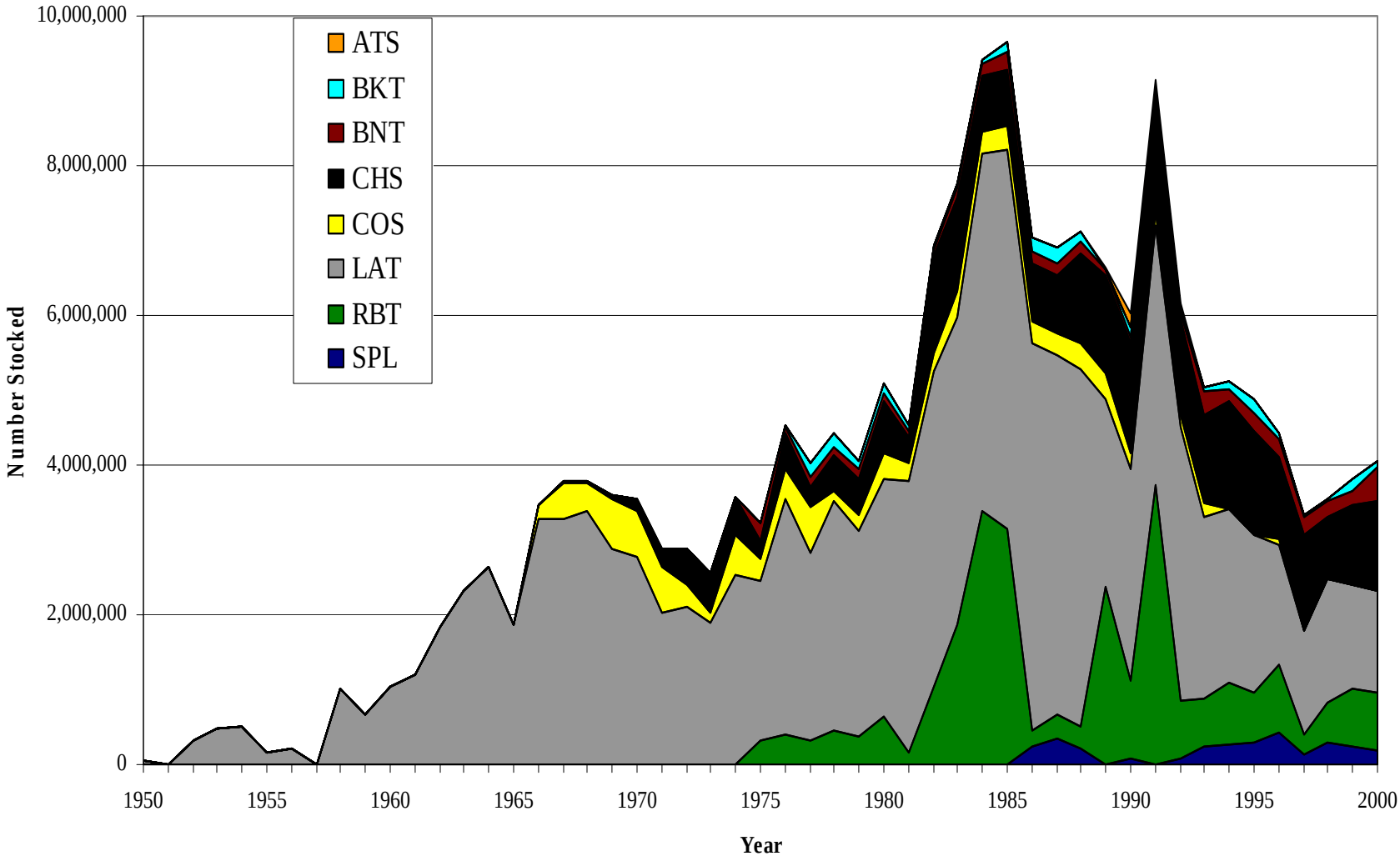
Lake Huron Stocking 1964-2000



Lake Michigan Stocking (1960-2000)

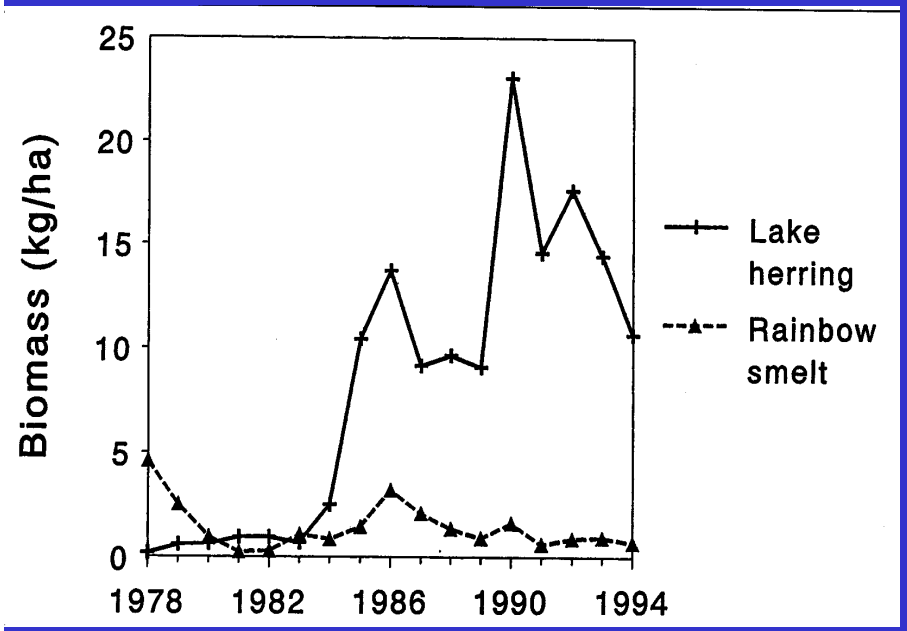


Lake Superior Stocking Summary (1950-2000)

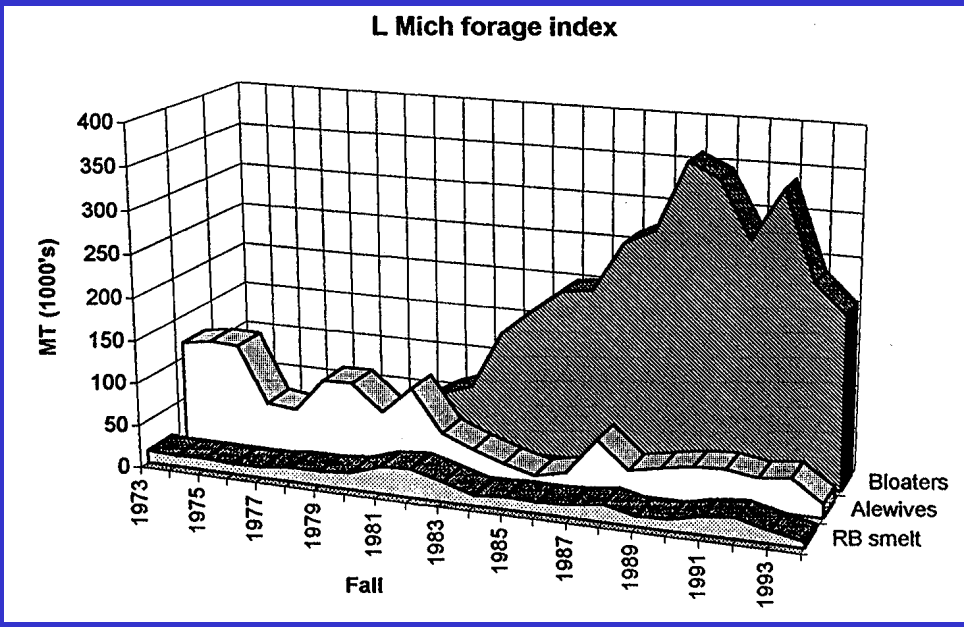


Results

- Did we control alewife and smelt populations? Yes



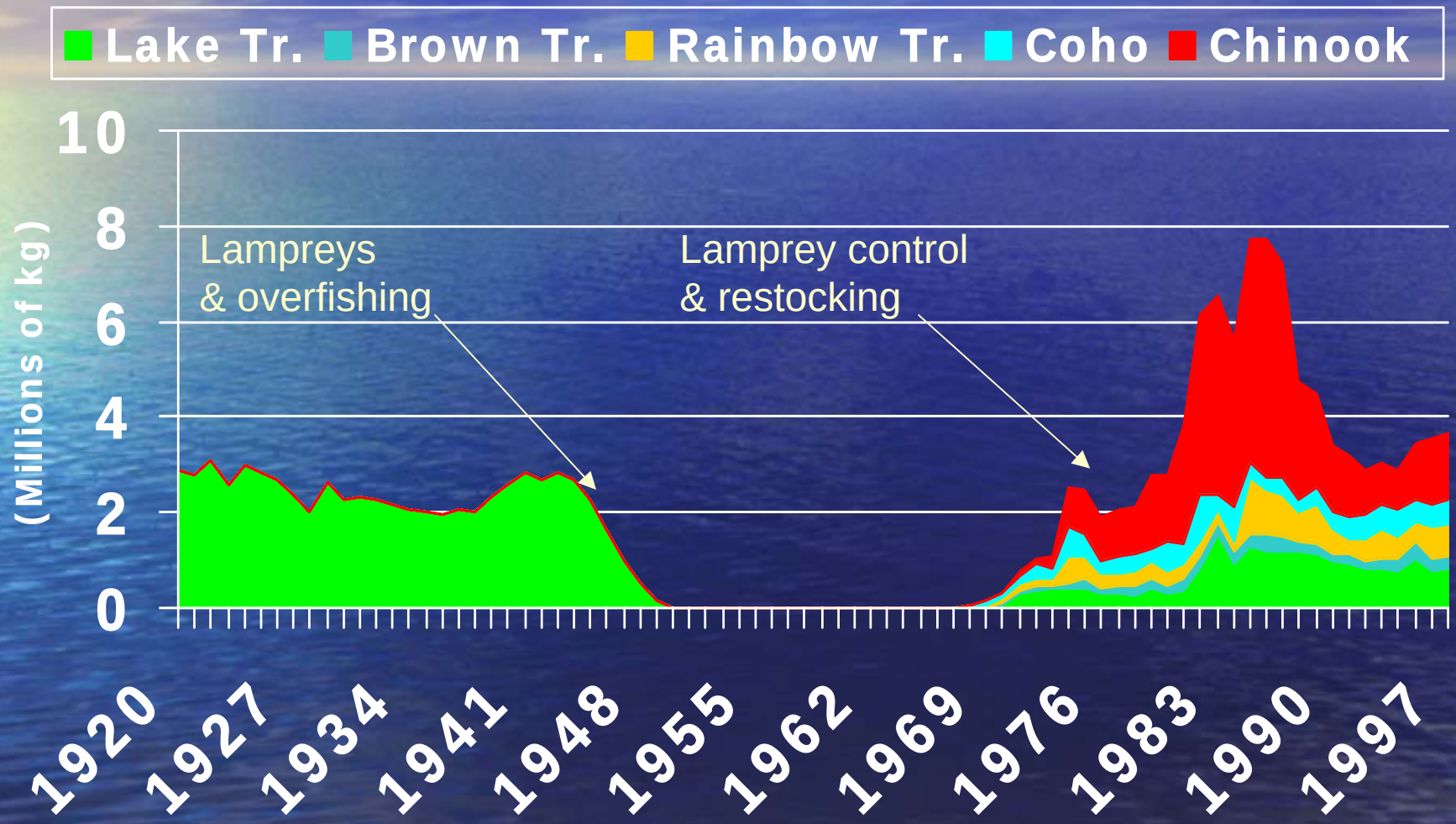
Lake Superior



Lake Michigan

From: Brown et al. 1999

Relative biomass of trout & salmon

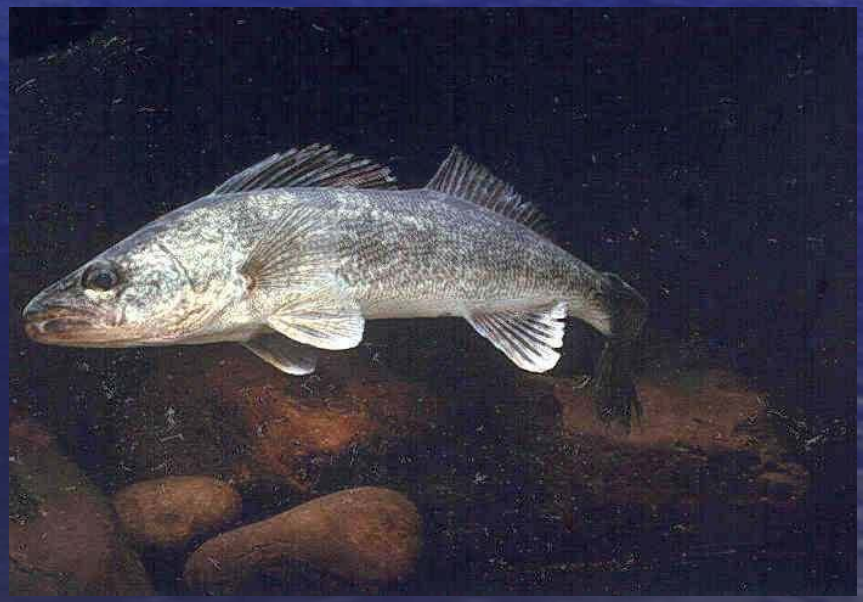


Results

- Developing Self-sustaining salmonid stocks - Mostly no
  - Lake trout -
    - Lake Superior - Yes
    - Lakes Michigan and Huron - No
  - Coaster brook trout, brown trout and Atlantic salmon - No
  - Chinook salmon
    - Lake Superior - Mostly No
    - Lake Michigan - 30%
    - Lake Huron - Mostly No
  - Coho salmon
    - Lake Superior - Mostly
    - Lakes Michigan and Huron - Mostly No
  - Rainbow trout (mostly steelhead)
    - Lake Superior - Mostly Yes
    - Lake Michigan - 50%
    - Lake Huron - Mostly No

Results

- Developing Self-sustaining walleye stocks - Mostly no…
  - Lake Superior – Yes (maybe)
  - Lake Michigan - No
  - Lake Huron – Mostly no
    - Saginaw Bay: No
    - St. Marys River: Partially
    - North Channel: Maybe?



Results

- Changing the fishery from commercially based to sport fish based
  - YES!!!! -Annual value of $2 billion dollars in 2002 US dollars
- Re-establish native coregonid populations
  - Partly Yes - $30 million commercial fishery
  - Lake whitefish, bloaters, round whitefish
  - Deepwater cisco complex - no

The Future for Propagated Fish in the Upper Great Lakes

- Given the low amount of overall natural recruitment, stocking will likely continue at current rates or the Great Lakes will revert to 1960s condition
  - Why
    - Lake trout: excessive mortality (sea lamprey and harvest) in Lakes Michigan and Huron
    - Broodstock problems for coaster brook trout
    - Tributary spawning habitat: barriers and historic land abuses
    - Continual invasions of new exotics, problems with the old ones.

Conclusion: Stocking

- The stocking of 906,152,083 salmonids (17,868,638 kg) at an estimated cost of $255,700,206 did cause number of ecosystem level and social changes

Great Lakes
Fish Health and Management

Michigan Department of Natural Resources

Fisheries Division


Some History:
Lake Trout Extinction

Michigan contributes $3 million to sea lamprey control on the St. Marys River!

October, 1997

Pay to the Order of: Sea Lamprey Control — $ 3,000,000

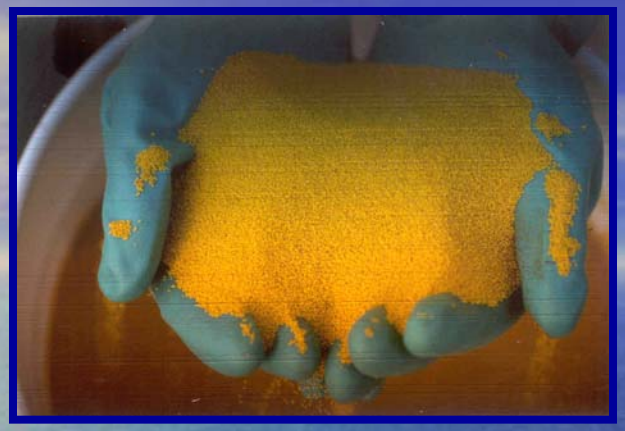
Three Million Dollars

Memo: For the St. Marys River

State of Michigan

"To protect our fish, anglers, and [the fishing] industry, we must stop the lifeblood from literally being sucked out of these fish by sea lampreys."

--Governor John Engler announcing Michigan's contribution to sea lamprey control



Innovations in sea lamprey control have brought lamprey numbers under management *-major advances after 1996*

Overall 58% Reduction in Wounding Since Treatment of the St. Marys River

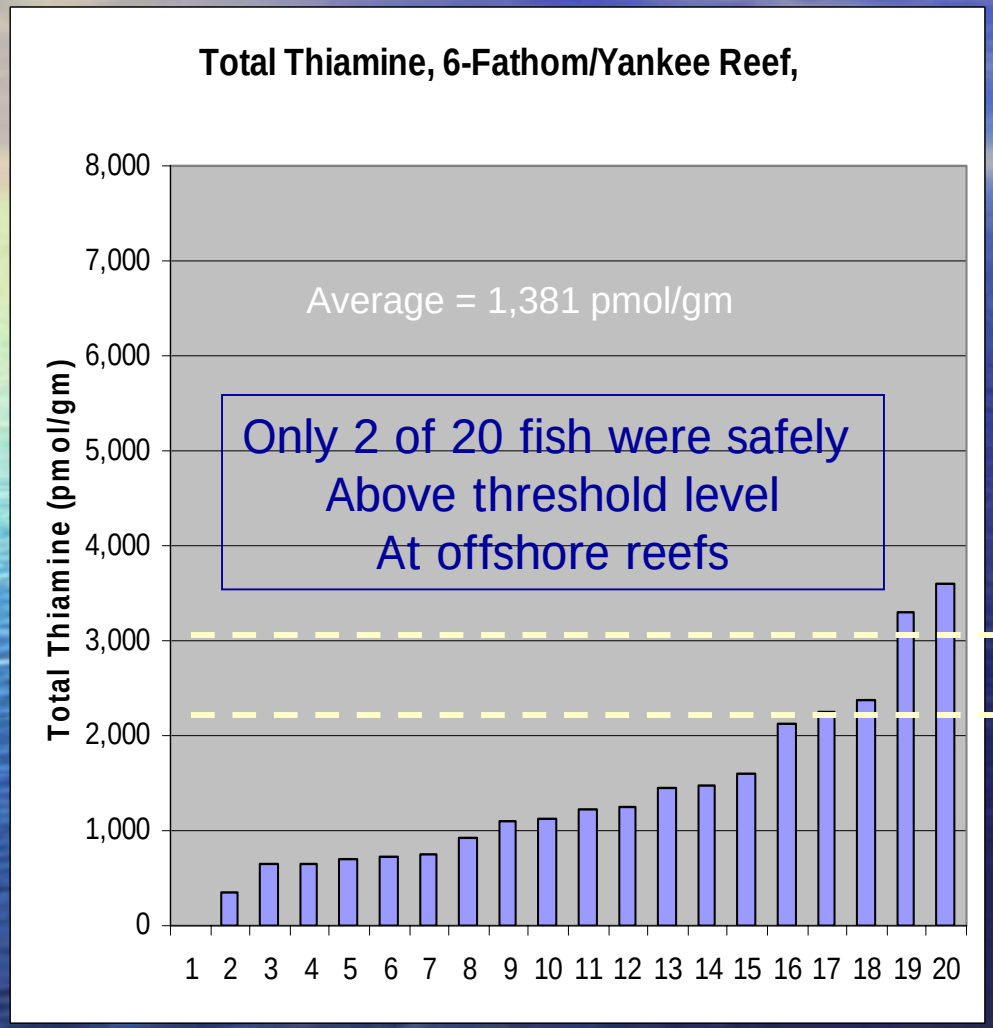
Lake Huron Management Unit	**Prior to 2001** Wounds per 100 trout	**2001 & 2002** Wounds per 100 trout
MH-1 (North)	26.6	6.5
MH-2 (North-Central)	27.5	10.4
MH-3,4,5 (South)	24.3	11.0

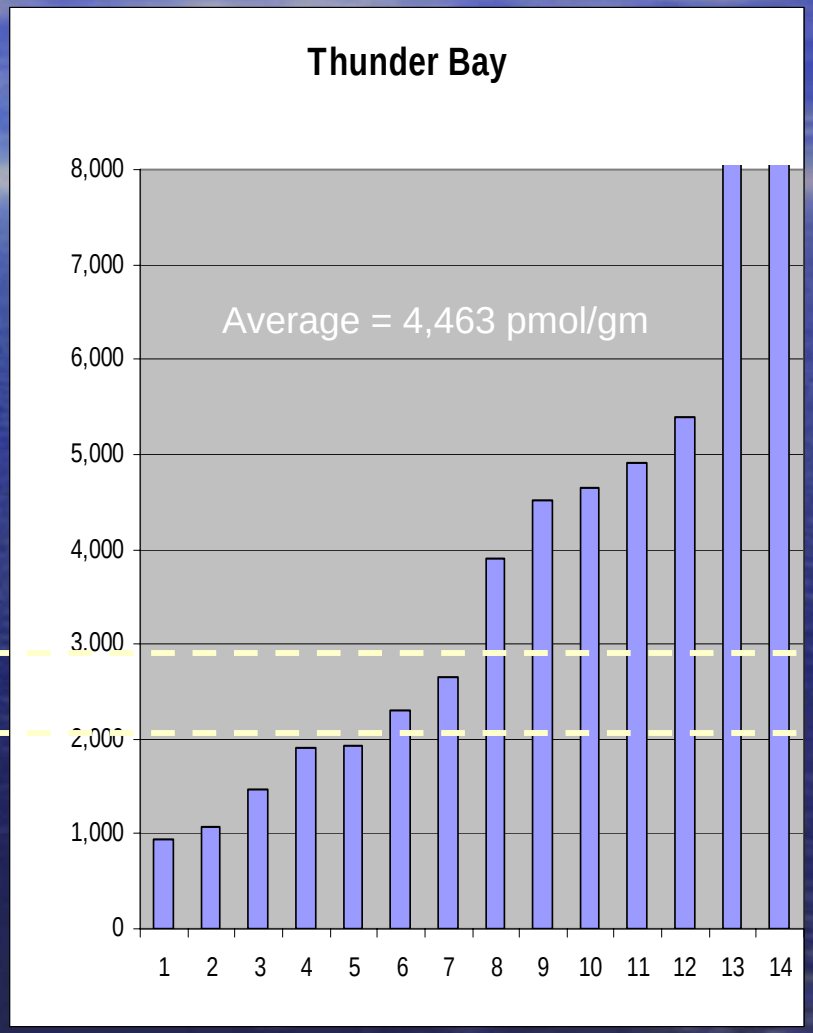
Thiamine deficiency syndrome, or ***the Alewives Revenge***!

Lake Huron Lake Trout, Fall, 2001

	Total Thiamin pmol/g	N
Yankee Reef	3,166	7
Six Fathoms Bank	3,155	6
Grindstone City	2,928	8
Parry Sound	3,917	29
Owen Sound	7,369	12

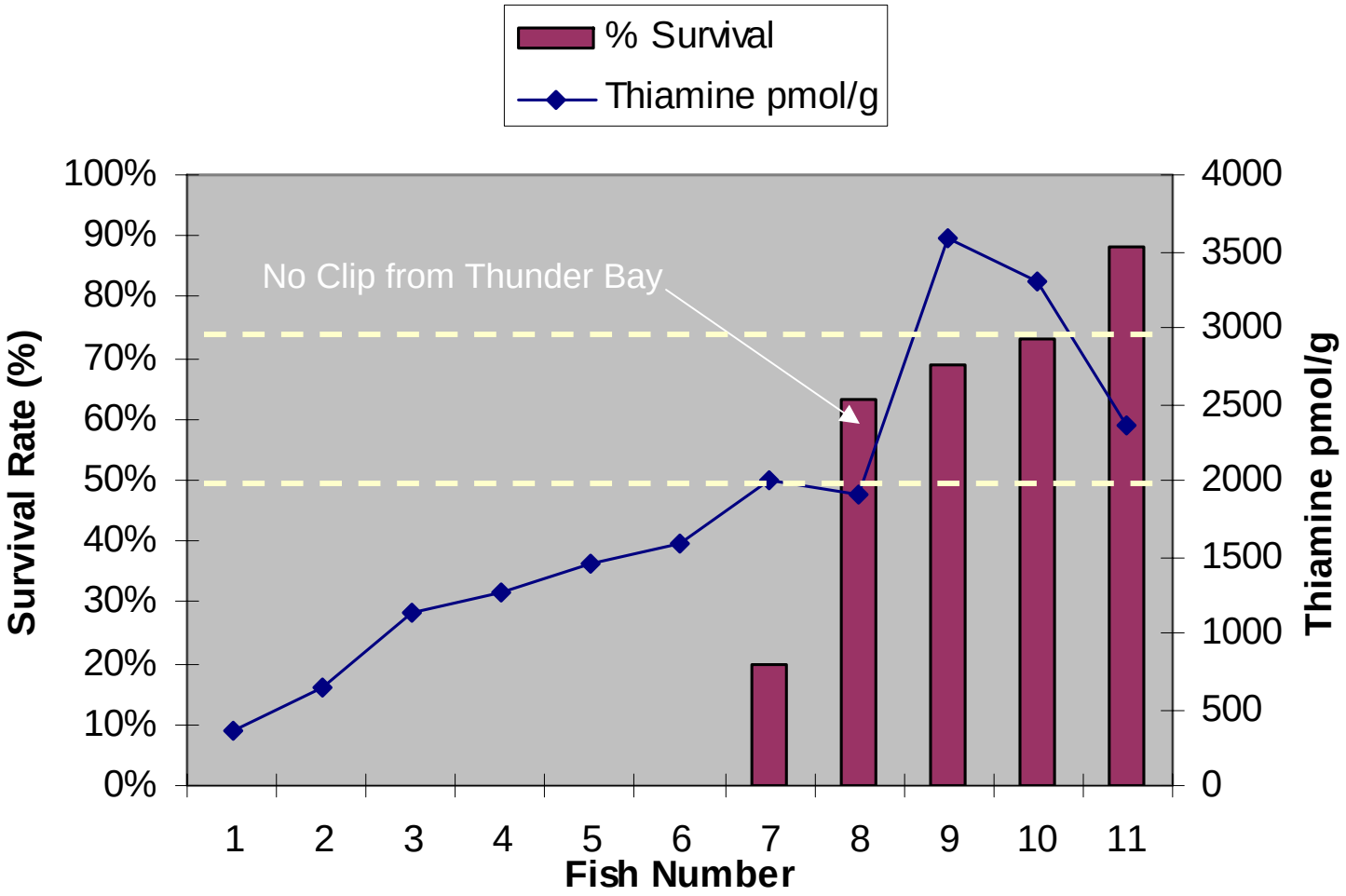
Total Thiamine from Lake Trout Eggs Sampled in Fall 2002

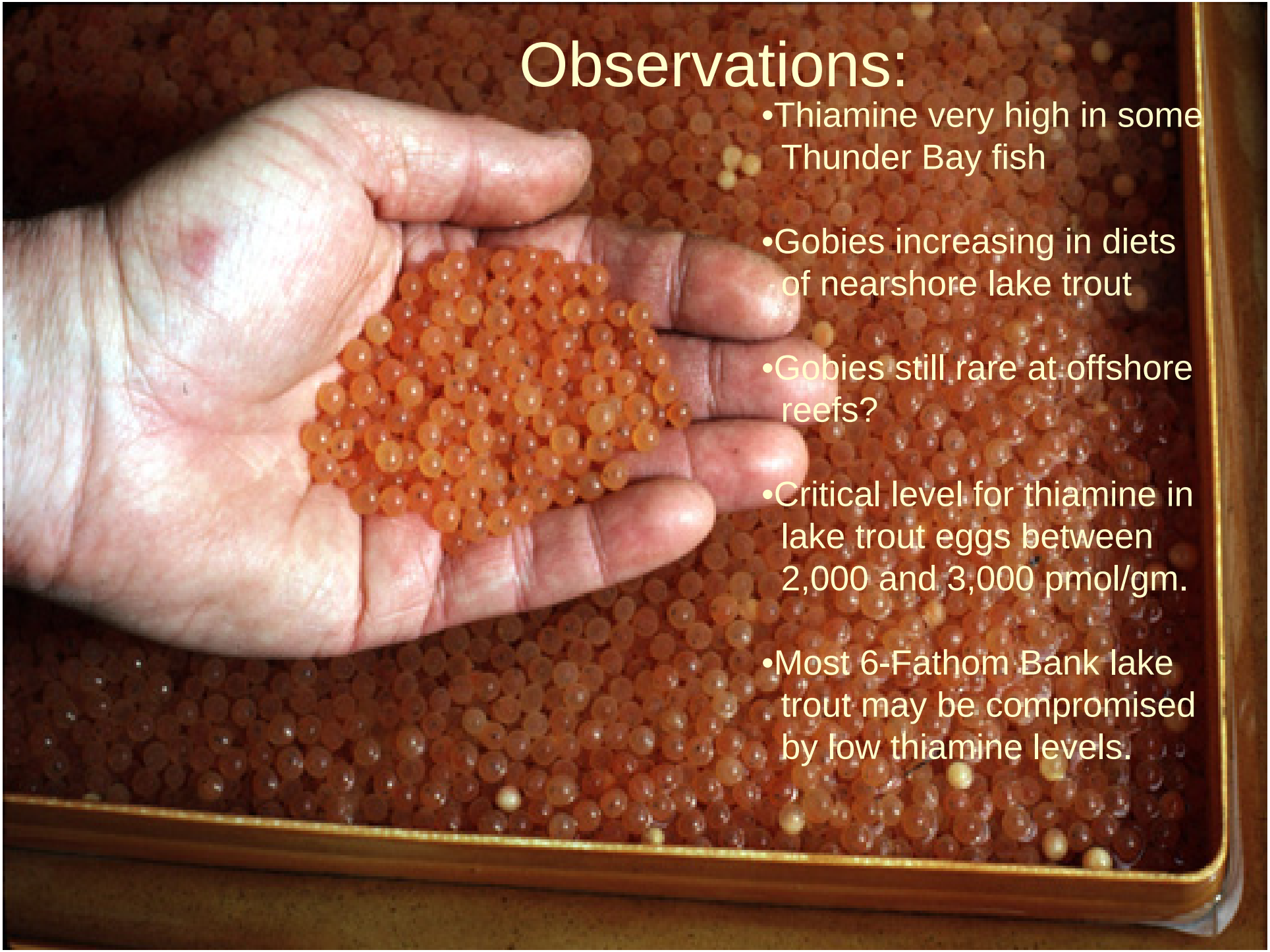




Fish Number

Survival Rate & Total Thiamine Values by Lot (Ascending Survival Rate). All But One Fish from Offshore Reefs.





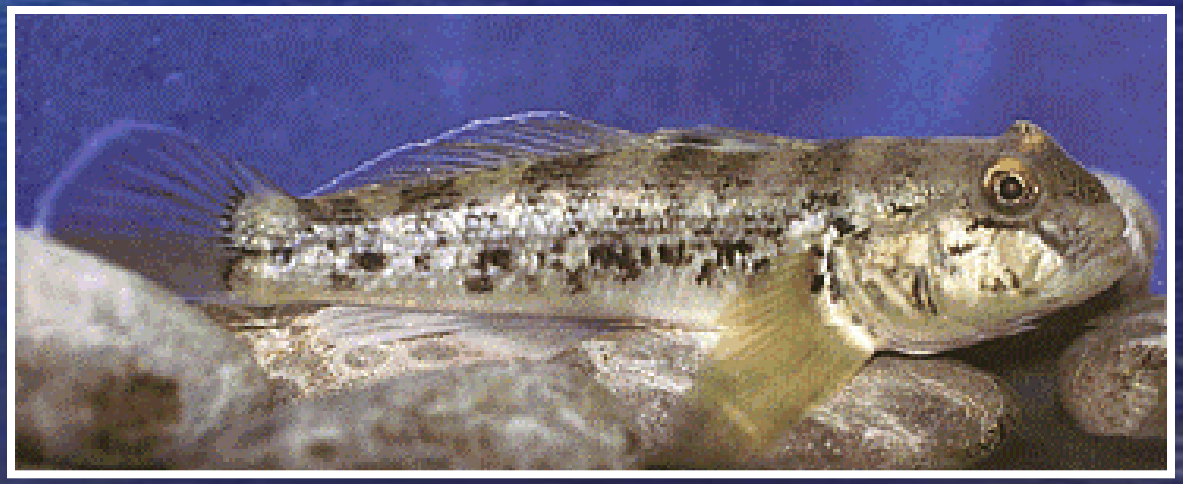
Observations:

- Thiamine very high in some Thunder Bay fish
- Gobies increasing in diets of nearshore lake trout
- Gobies still rare at offshore reefs?
- Critical level for thiamine in lake trout eggs between 2,000 and 3,000 pmol/gm.
- Most 6-Fathom Bank lake trout may be compromised by low thiamine levels.

Other invaders:

Zebra and quagga mussels have fundamentally changed the ecology of the Great Lakes

Round Goby



Gobies & rusty crayfish
eat lake trout
eggs

Tens of thousands of birds and fish have been killed by Botulism Type E toxin in Lake Erie – probably from eating infected gobies or mussels

Location of Botulism Type E Outbreaks Great Lakes- 1998 - 2002

- Southern Lake Huron- 1998-2002
- Western Lake Erie- 1999-2000
- Central Lake Erie- 1999-2000
- Eastern Lake Erie- 2000-2002

- **Species of birds involved:**

  Gulls - ring-billed, herring, Bonaparte's, greater black-backed

  Mergansers Common Loons Coots

  Grebes Shorebirds Long-tailed duck
- **Species of fish involved:**

  Smallmouth bass Freshwater drum

  Round Goby Other benthic species, incl. Mudpuppy

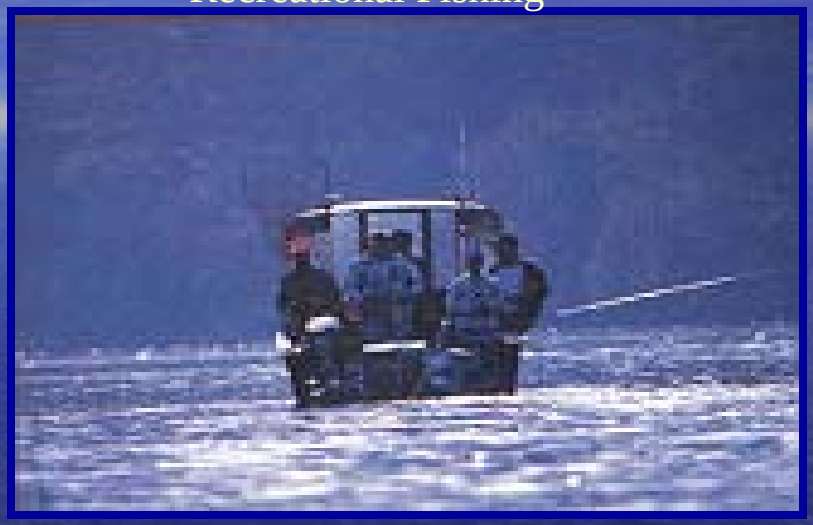
  Lake Sturgeon

Controlling over-fishing: improvements in management of Great Lakes fish harvest

Sources of Mortality

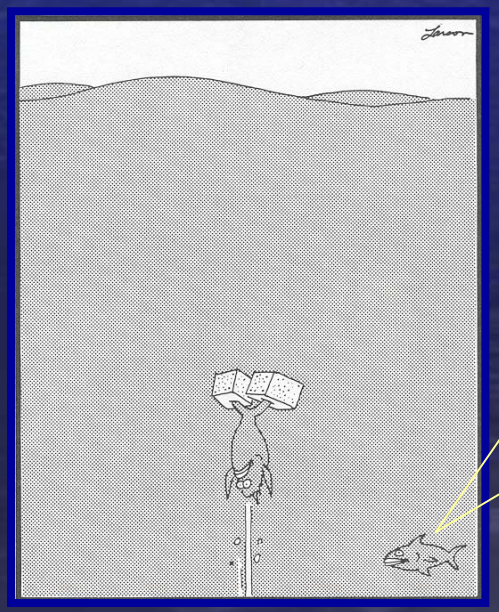
Commercial Fishing

Recreational Fishing

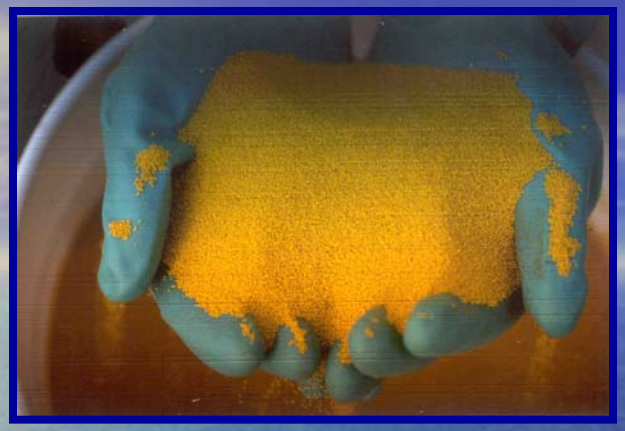


Sea lamprey-induced

Credit:GLFC



Its hard to keep Charlie down these days

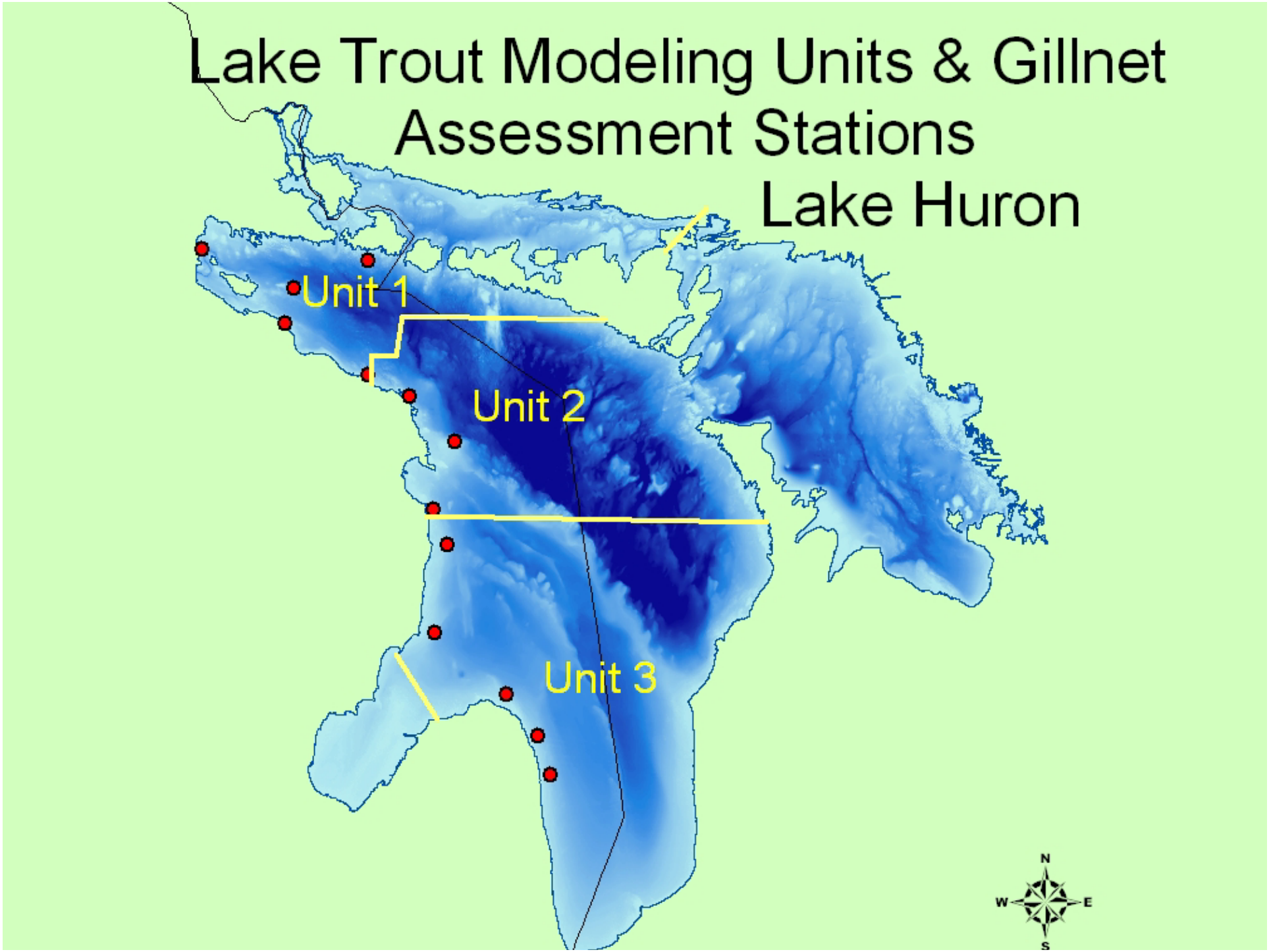


Innovations in sea lamprey control have brought lamprey numbers under management *-major advances after 1996*

Lake trout reintroductions began In the early 1970s.

Goal: Reestablish self-sustaining stocks.

Stocking


Lake Trout Modeling Units & Gillnet Assessment Stations
Lake Huron
Unit 1
Unit 2
Unit 3
N
W
E
S

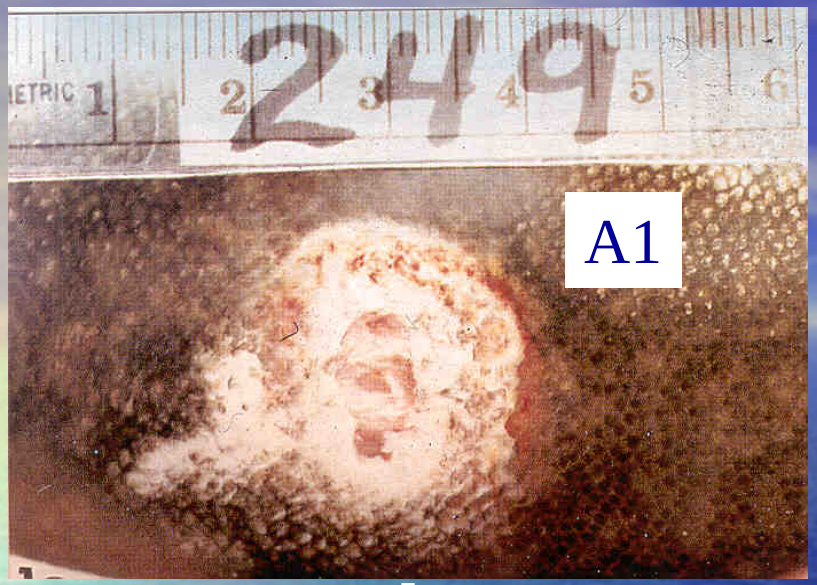
METHODS FOR ASSESSING LAKE TROUT STOCKS

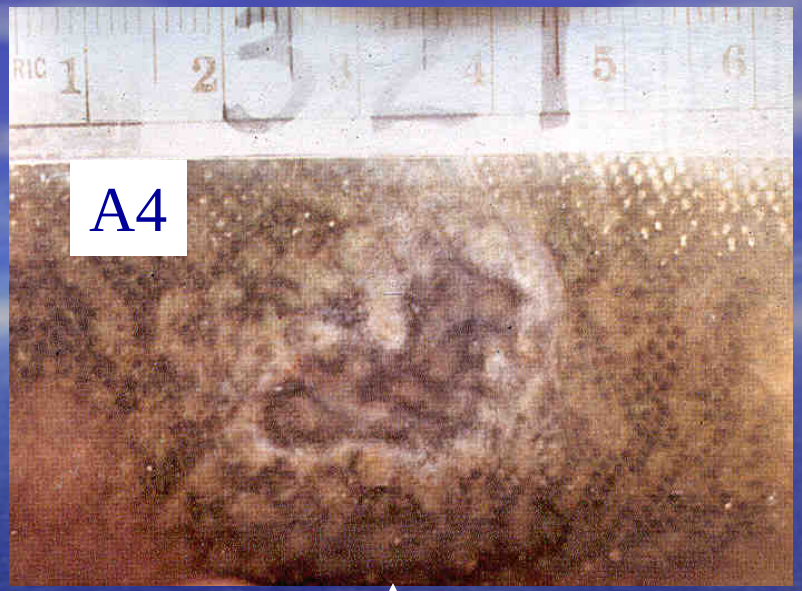

Gillnet
Assessment

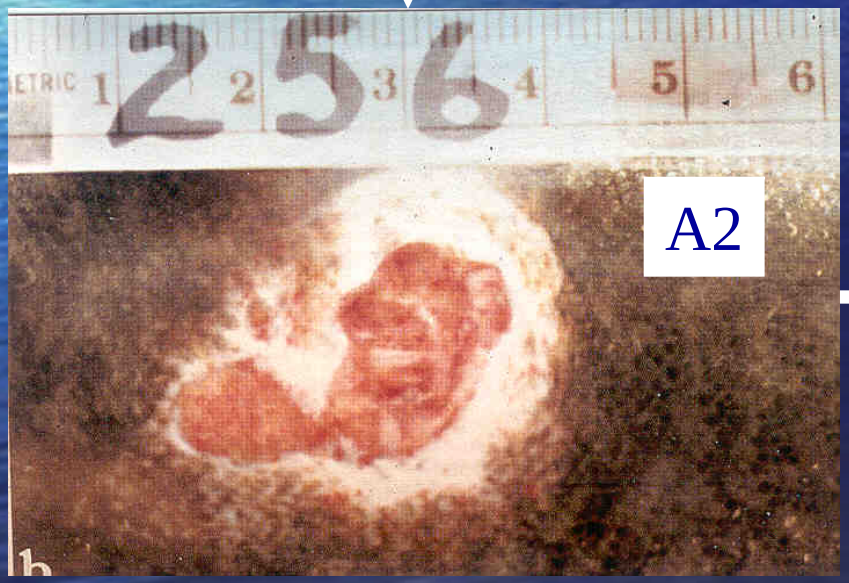
Annual spring assessment, 1975-2002:

- 13 stations;
- Representing 3 modeling units;
- Catch per 1,000 m;
- Aged using fin clips or scales;
- Recorded size parameters;
- Lamprey wounds.

INDEXING LAMPREY WOUNDS

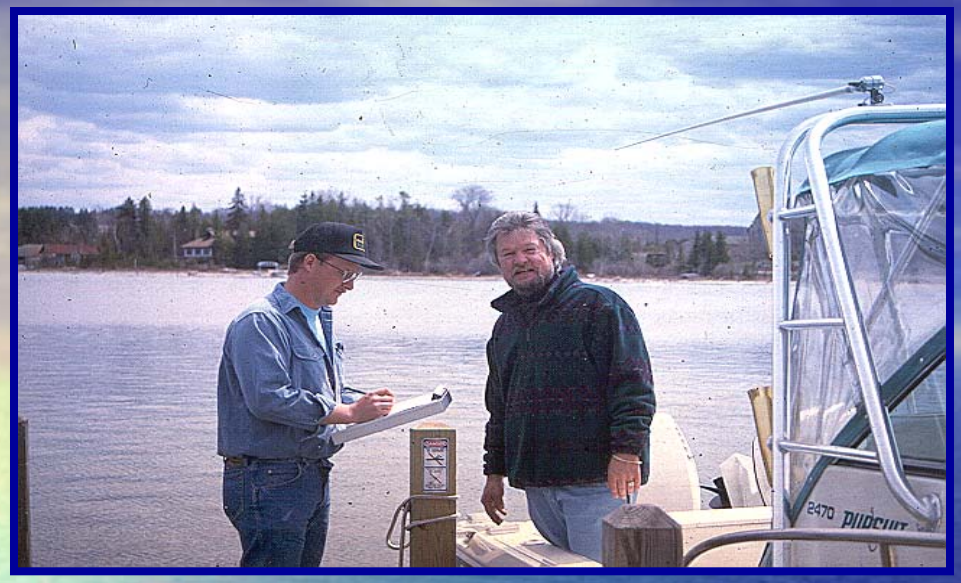






Survival Index:

- Assessment CPE at age 5 and age 6;
- For each cohort;
- Adjusted for number stocked.

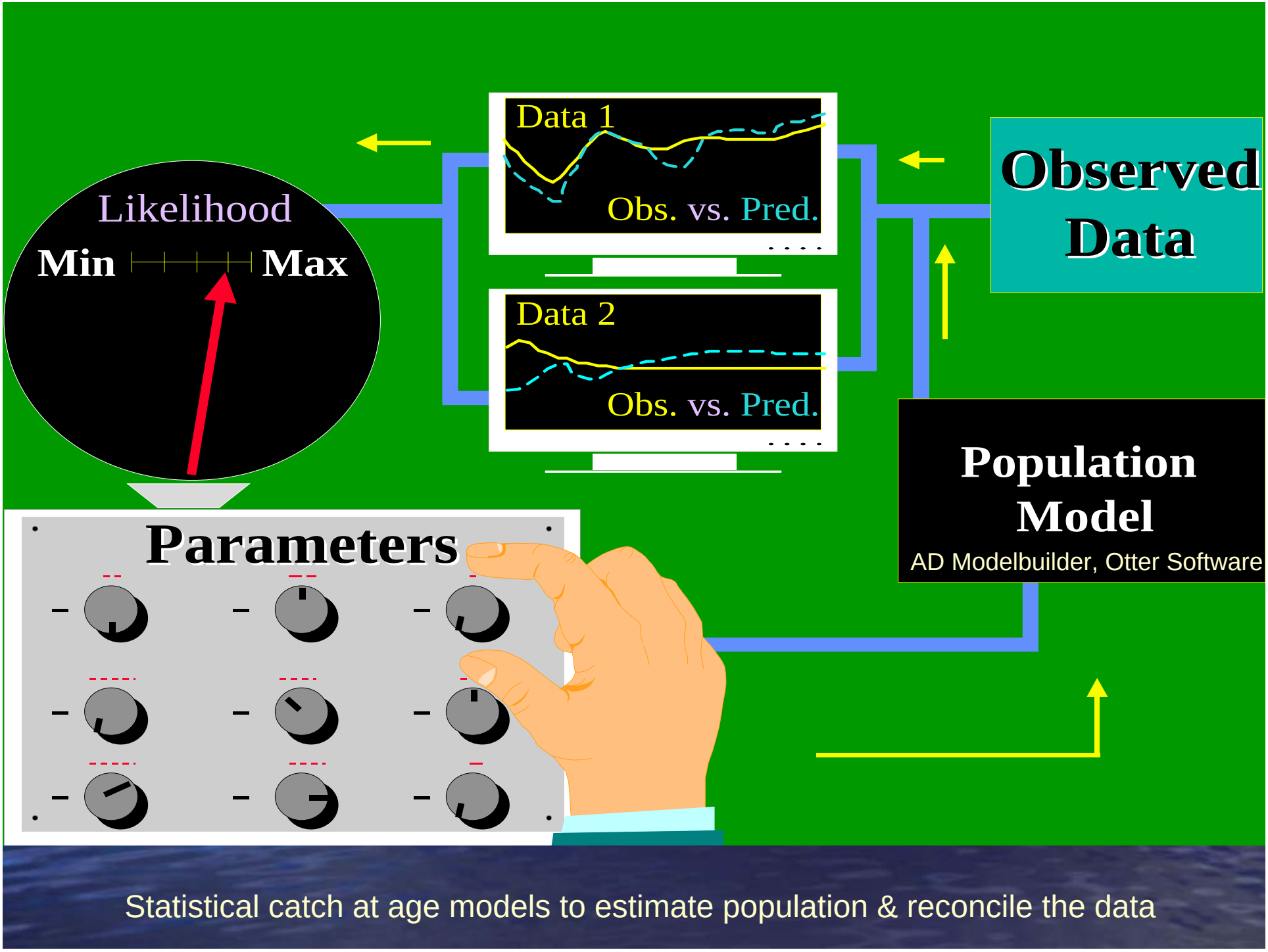


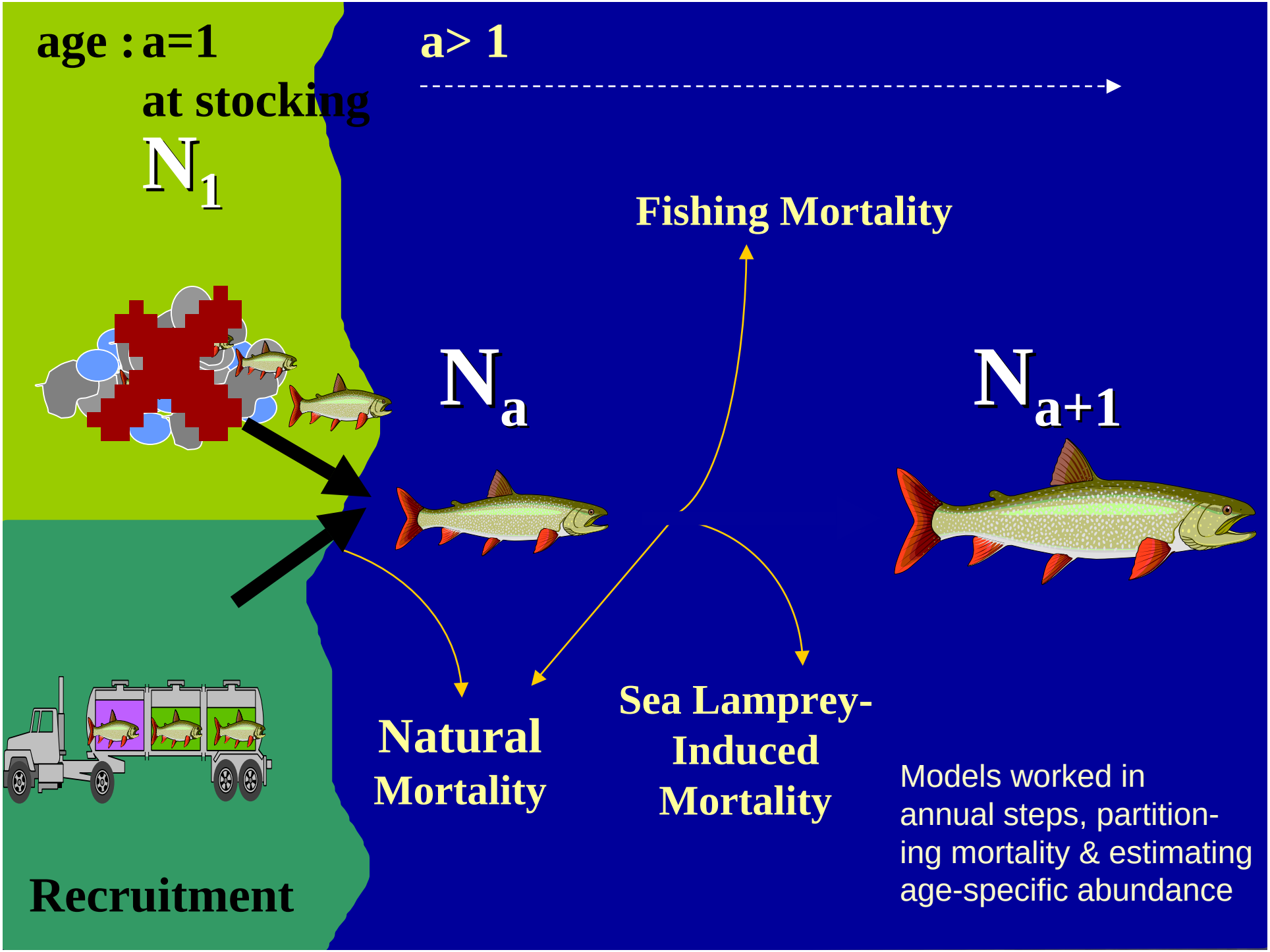
Aged Catch Data were also obtained from:

Creel surveys and biological data

Commercial catch reporting, monitoring, & and biological data

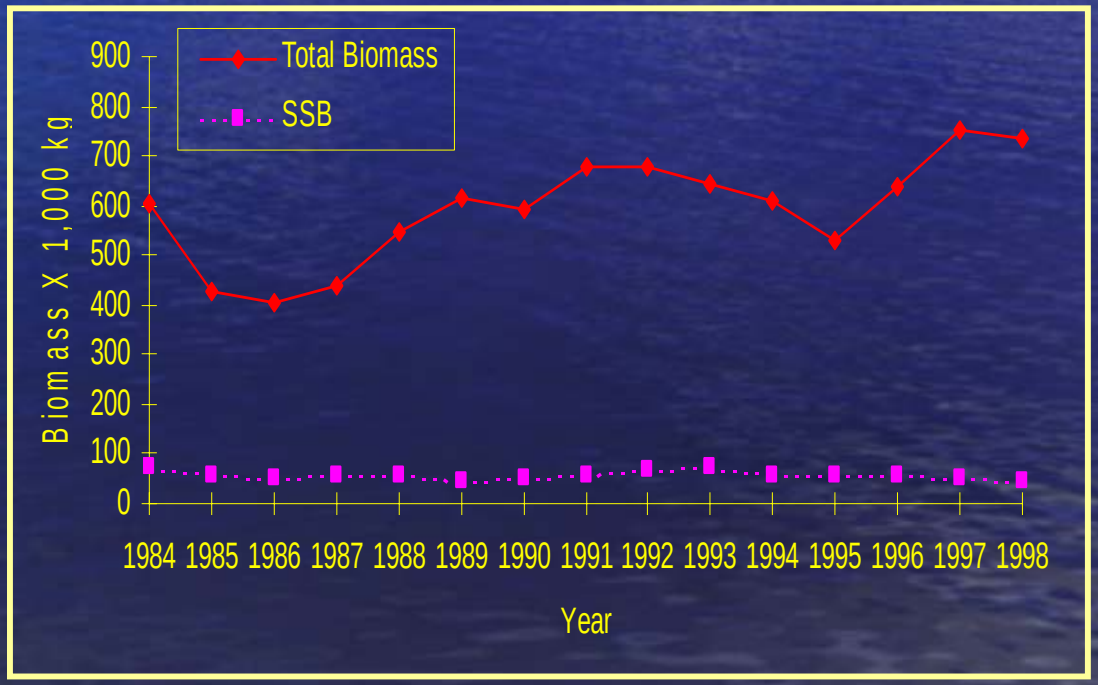

Meeting of the Lake Huron Technical Committee
Great Lakes Fishery Commission
Hillman, Michigan, July 2003

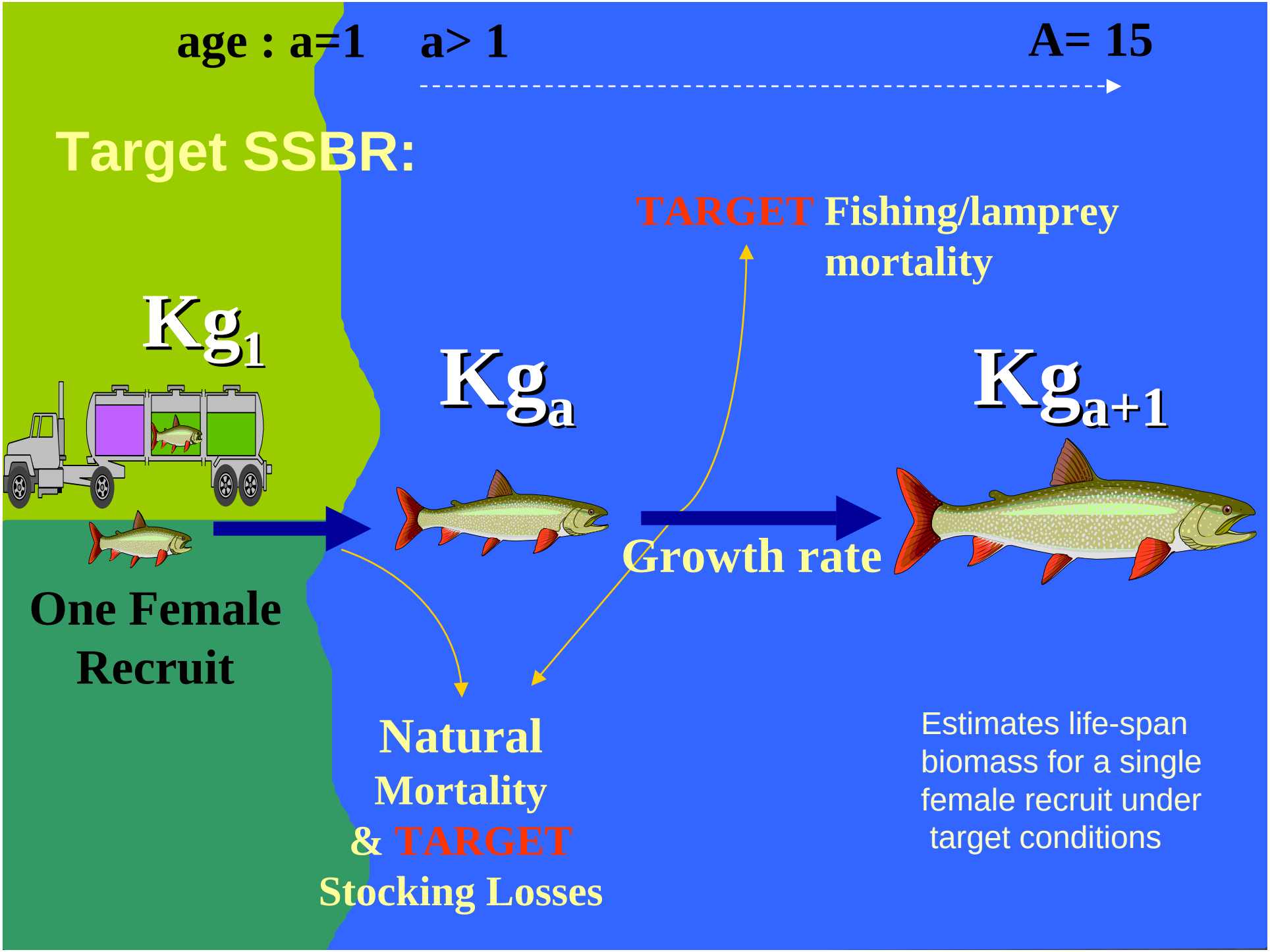

Likelihood
Min
Max
Data 1
Obs. vs. Pred.
Data 2
Obs. vs. Pred.
Observed Data
Population Model
AD Modelbuilder, Otter Software
Parameters
Statistical catch at age models to estimate population & reconcile the data


age : a=1
at stocking
N_1
a> 1
Fishing Mortality
N_a
N_{a+1}
Natural Mortality
Sea Lamprey-Induced Mortality
Recruitment
Models worked in annual steps, partitioning mortality & estimating age-specific abundance

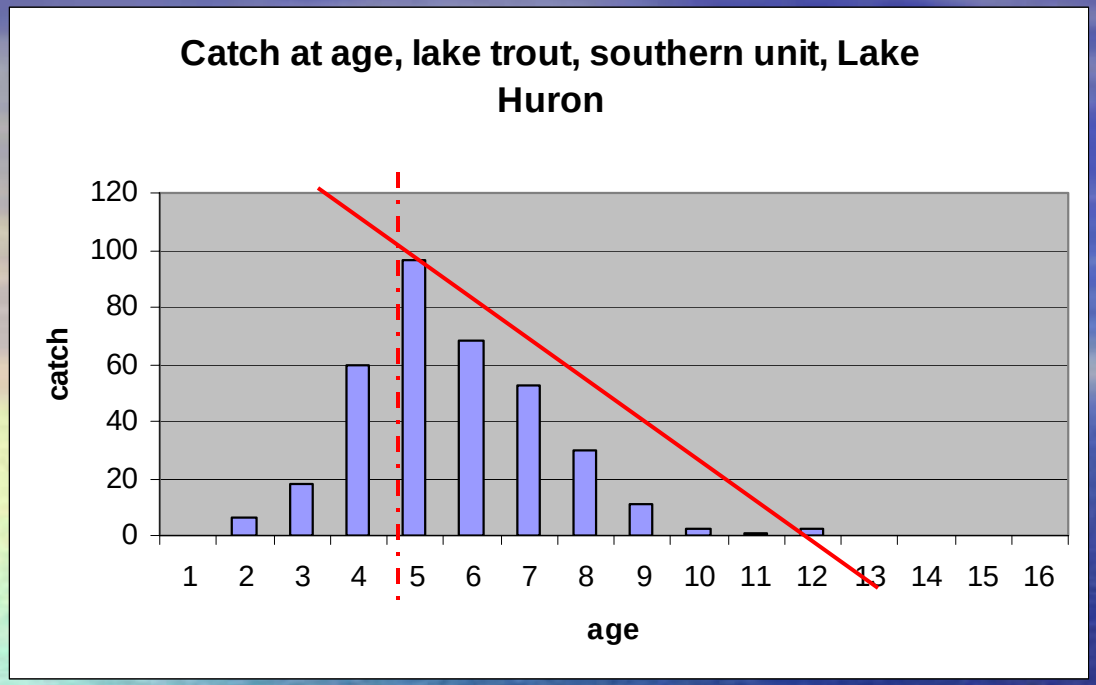
Model output

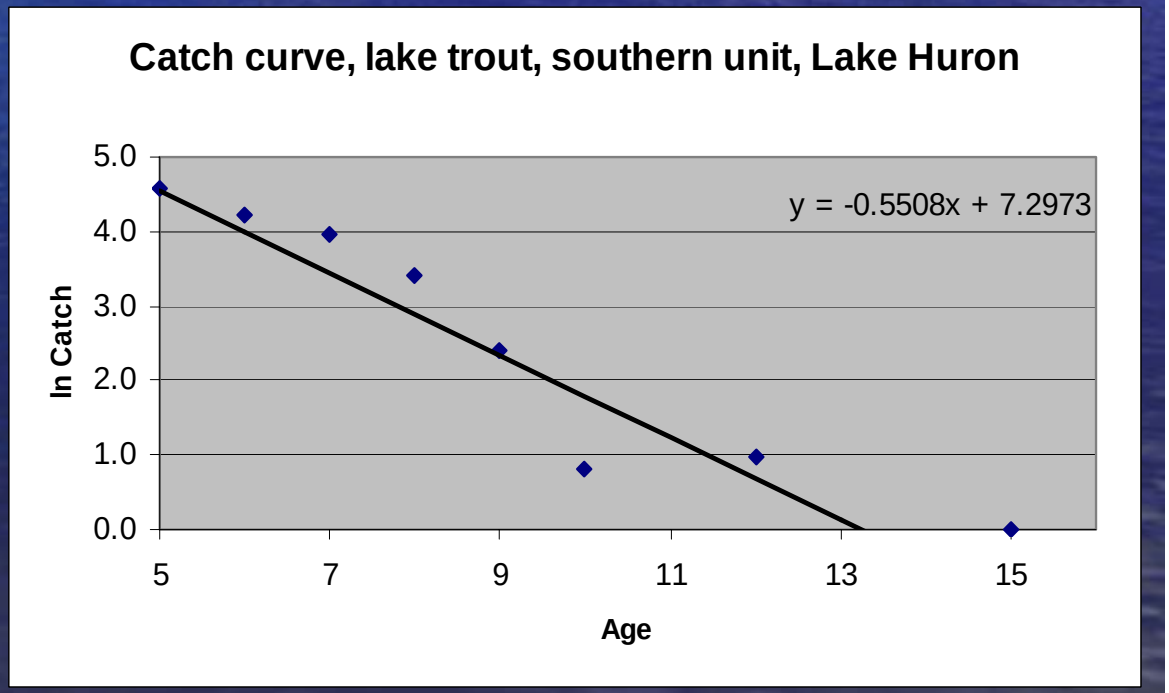
- Partitioned mortality rates
- Abundance & Biomass
- Spawning stock biomass per recruit (SSBR)

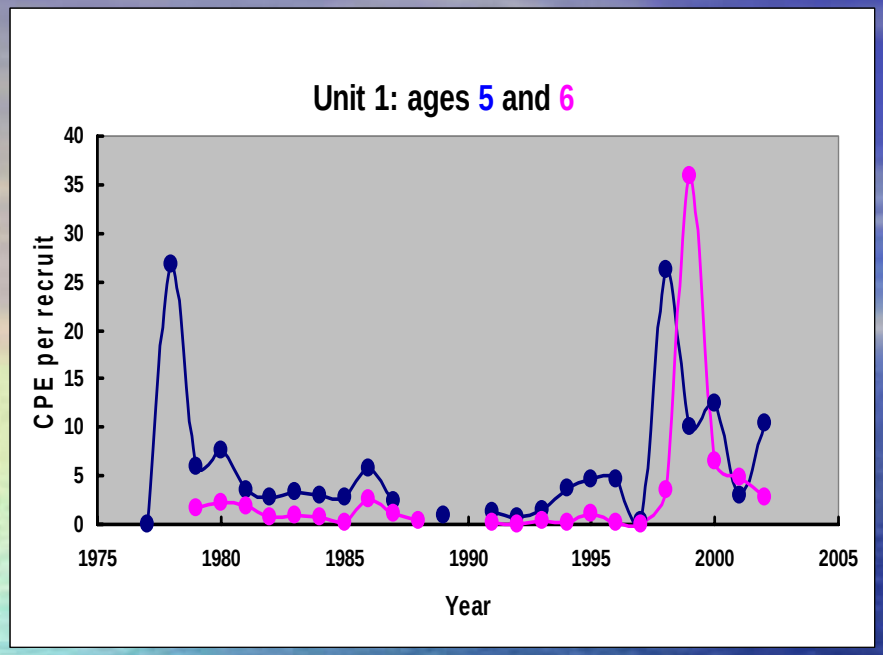


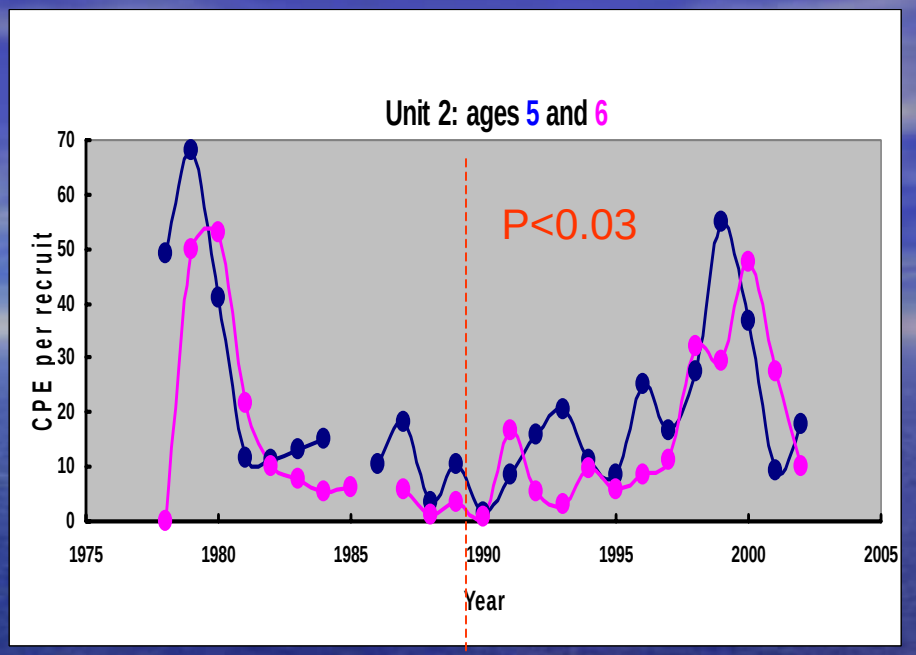

age : a=1
a> 1
A= 15
Target SSBR:
TARGET Fishing/lamprey mortality
Kg_1
Kg_a
Kg_{a+1}
Growth rate
One Female Recruit
Natural Mortality & TARGET Stocking Losses
Estimates life-span biomass for a single female recruit under target conditions

Estimation of Mortality: a Conceptual Model



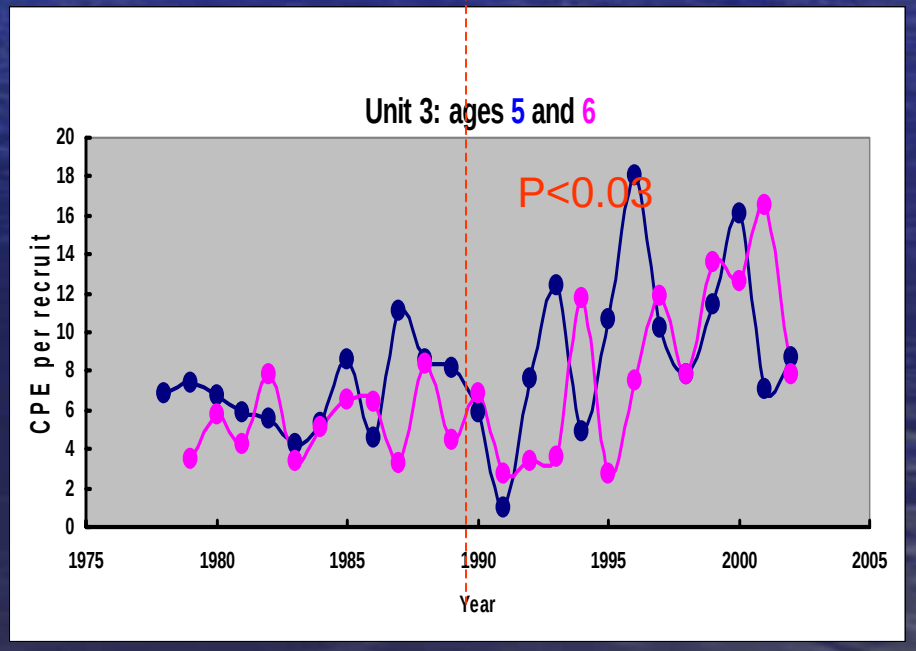


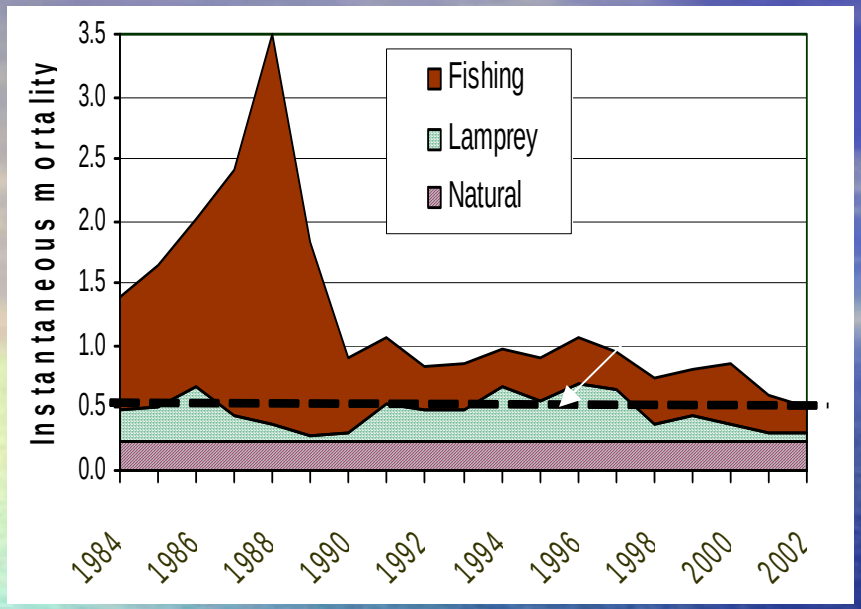


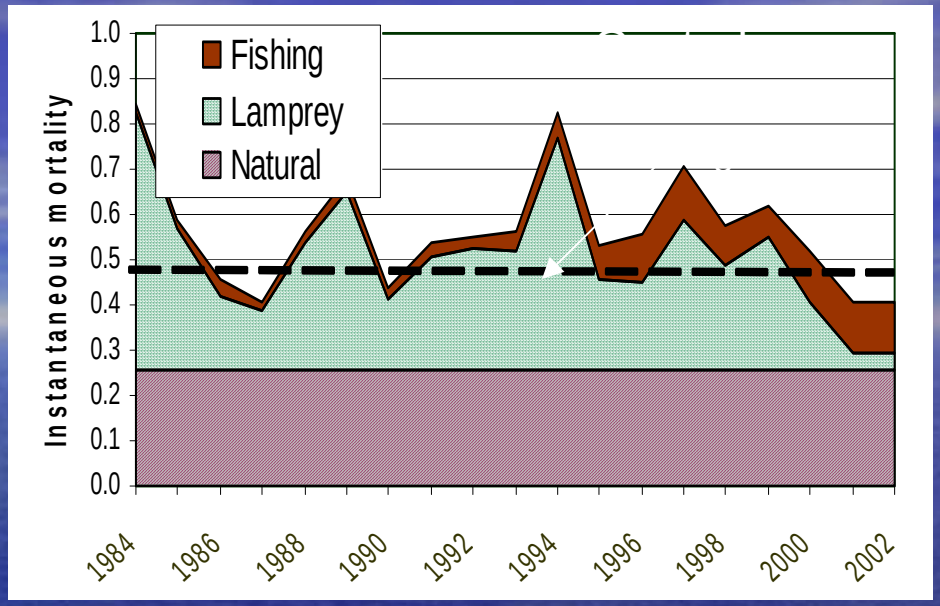


Stocking Survival Index:

- Initial spike in Units 1 & 2
- Considerable variation in cohort survival
- Several strong cohorts after 1990.

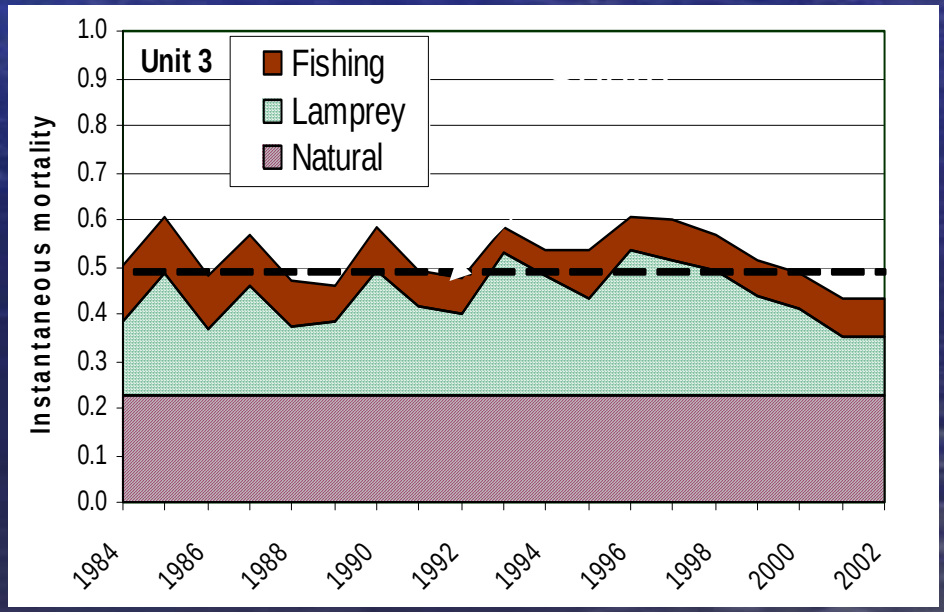


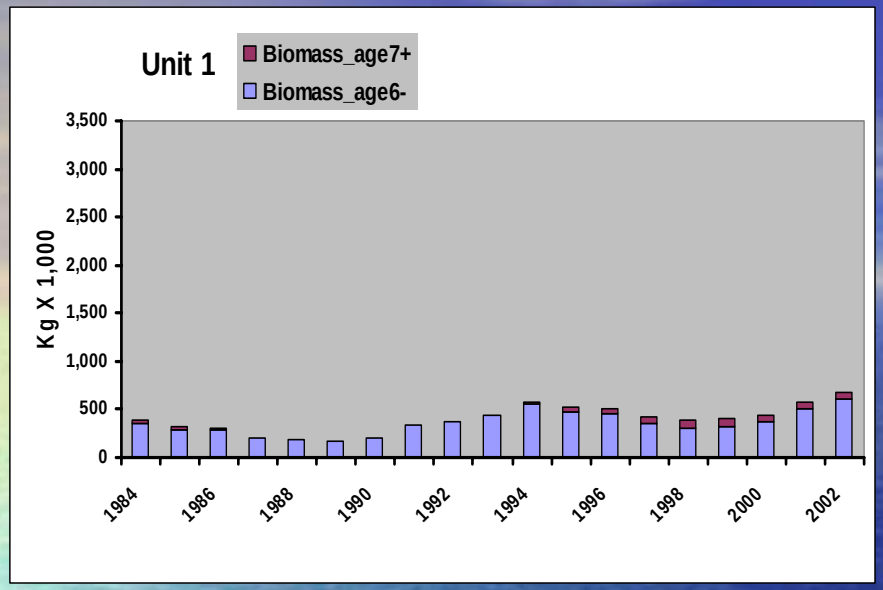


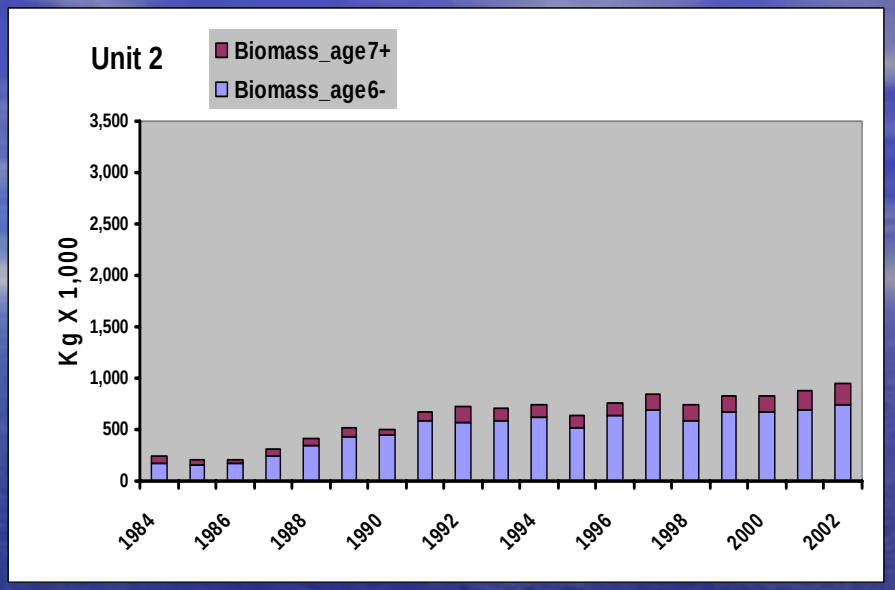


Sources of mortality:

- Natural + Lamprey near or above target in all units
- Fishing rates high in North
- Evidence of improvement after 2000

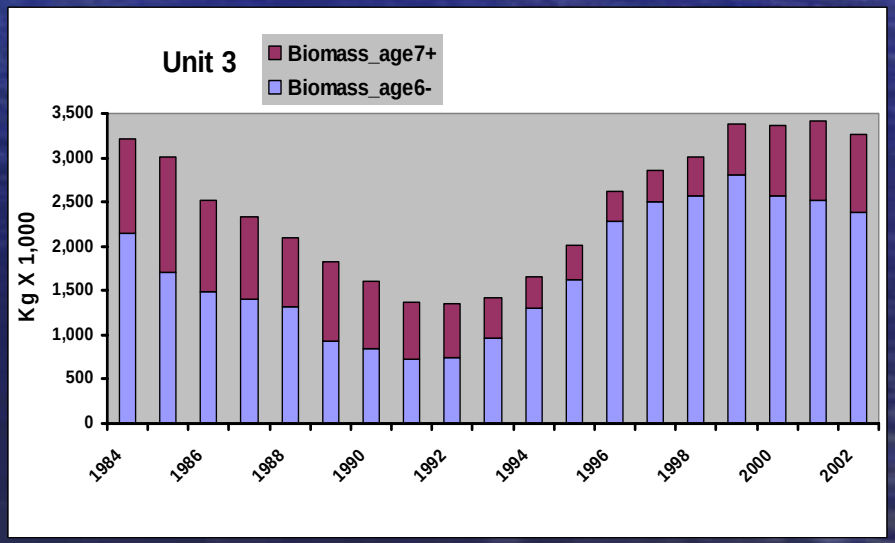


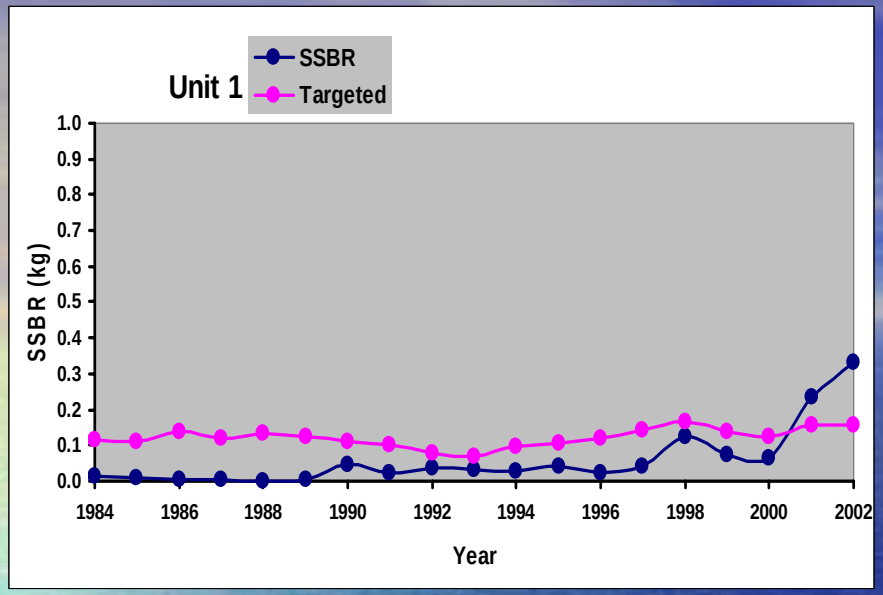


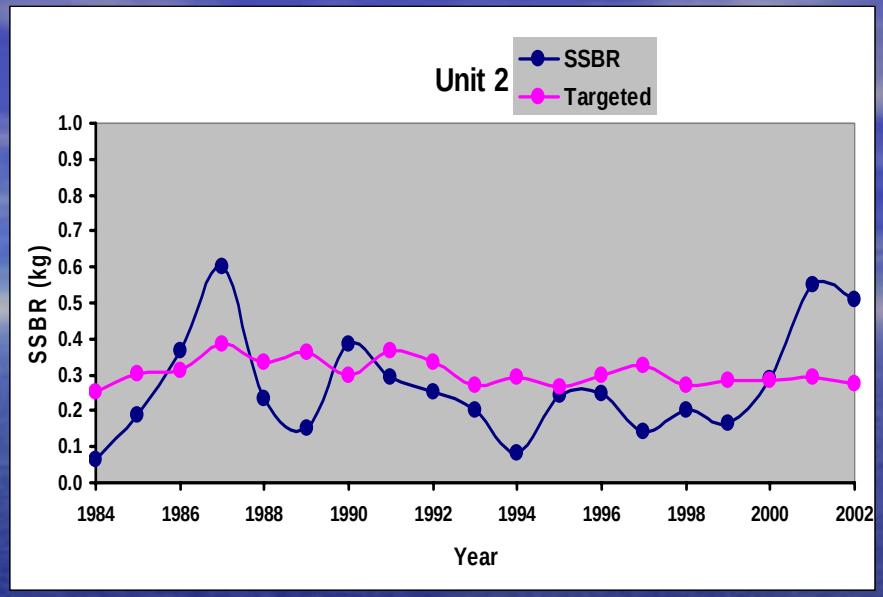


Total biomass:

- Progressively higher going south
- Progressively older going south
- South unit partly a function of its larger area.

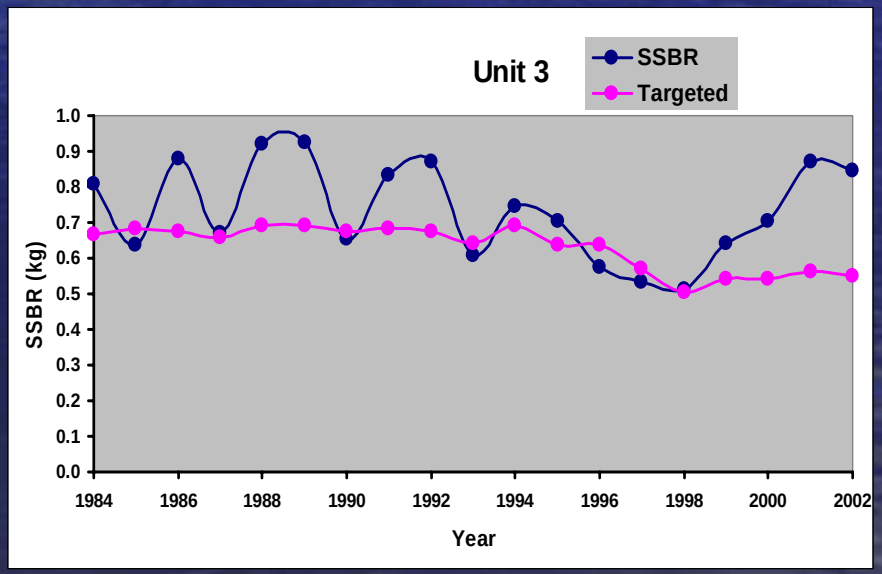






Spawning Stock Biomass Per Recruit (SSBR):

- Target lower in north – slower growth & higher target Z;
- At or below target SSBR in all units;
- Progressively closer to target moving south;
- Improvement since 2000.



Hypotheses:

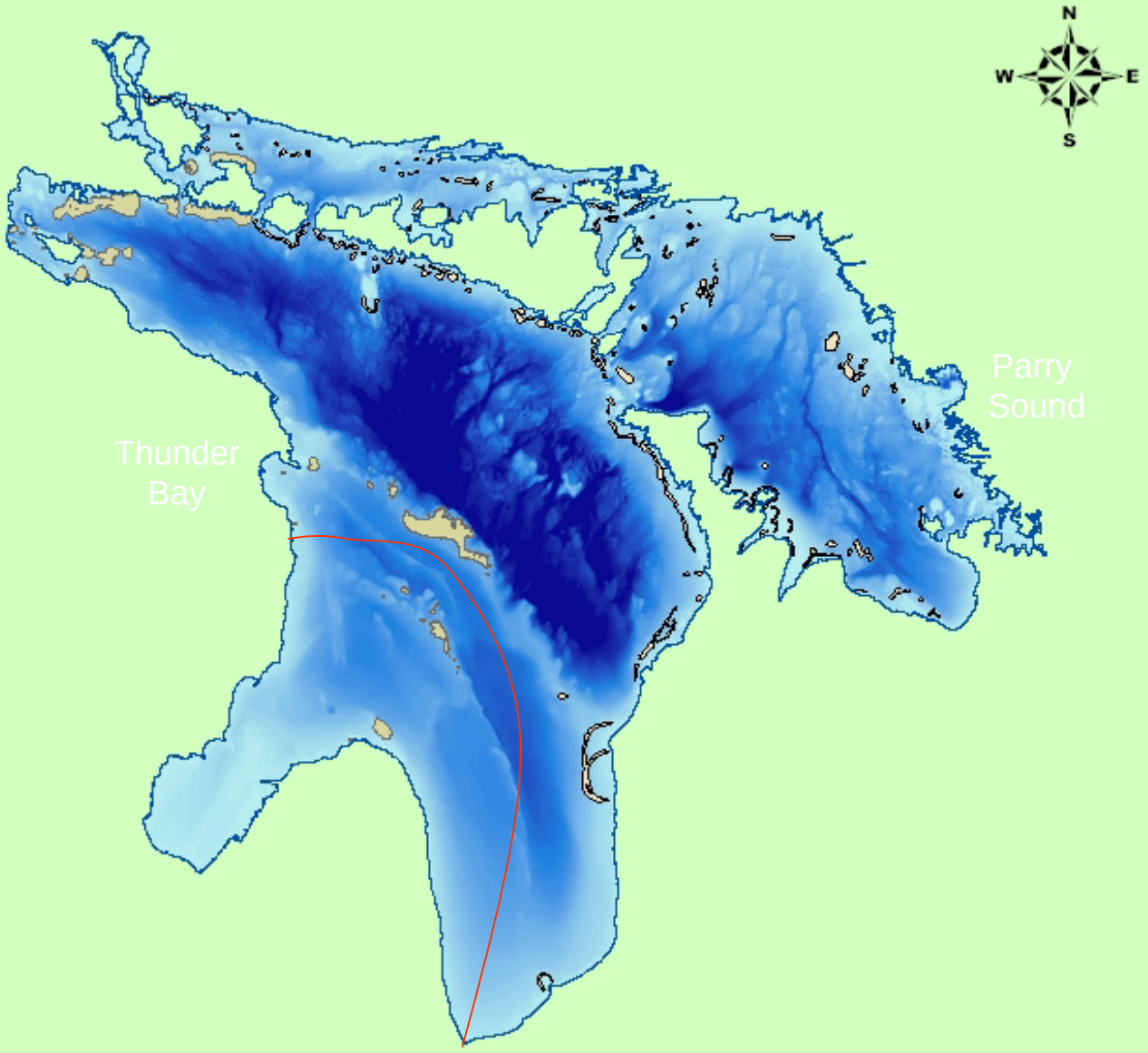
✓ Stocking **<u>has</u>** reestablished a significant biomass of (young) lake trout ;

✓ Stocking effectiveness **has not declined;**

- Significant **increase** in 1990s, units 1 & 2;
- Result of offshore stocking and improved QC?

X Adequate spawning stocks (>age 6) have **<u>not</u>** been reestablished.

Historic Lake Trout Spawning Reefs

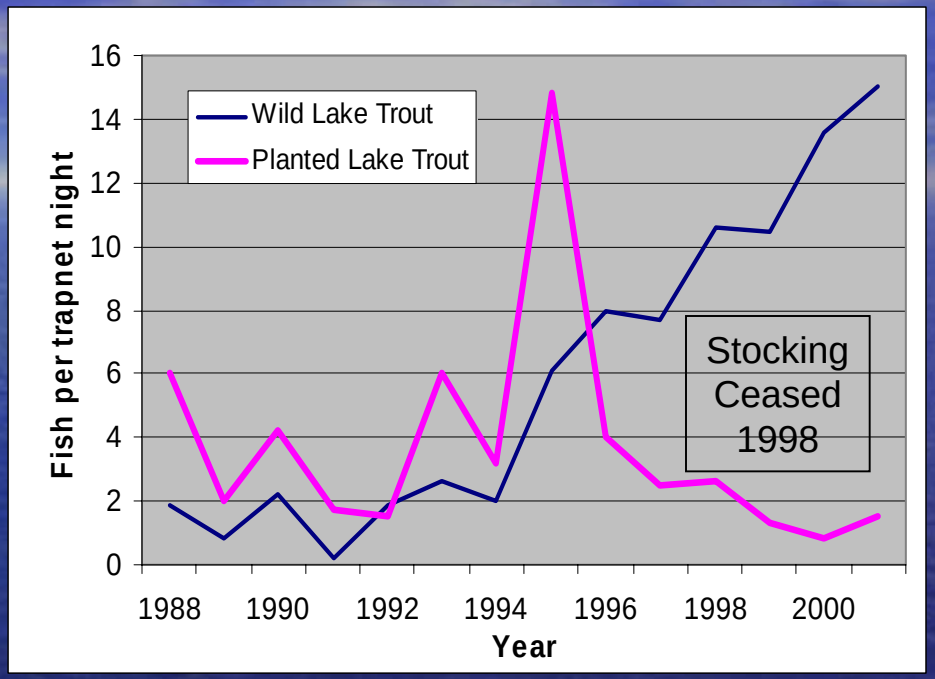



REPRODUCTION
Lake Trout

Trawl CPE, Wild Age-0 Lake Trout, Thunder Bay (Johnson and VanAmberg 1995)

Parry Sound

Composition of Catch, Mature Lake Trout, Parry Sound



Parry Sound Strategy:

- Protected, semi-isolated location;
- Historically important spawning habitat;
- Remanent stock;
- Intense (4.5/ha) stocking rate;
- Effective lamprey control;
- Effective fishing controls.

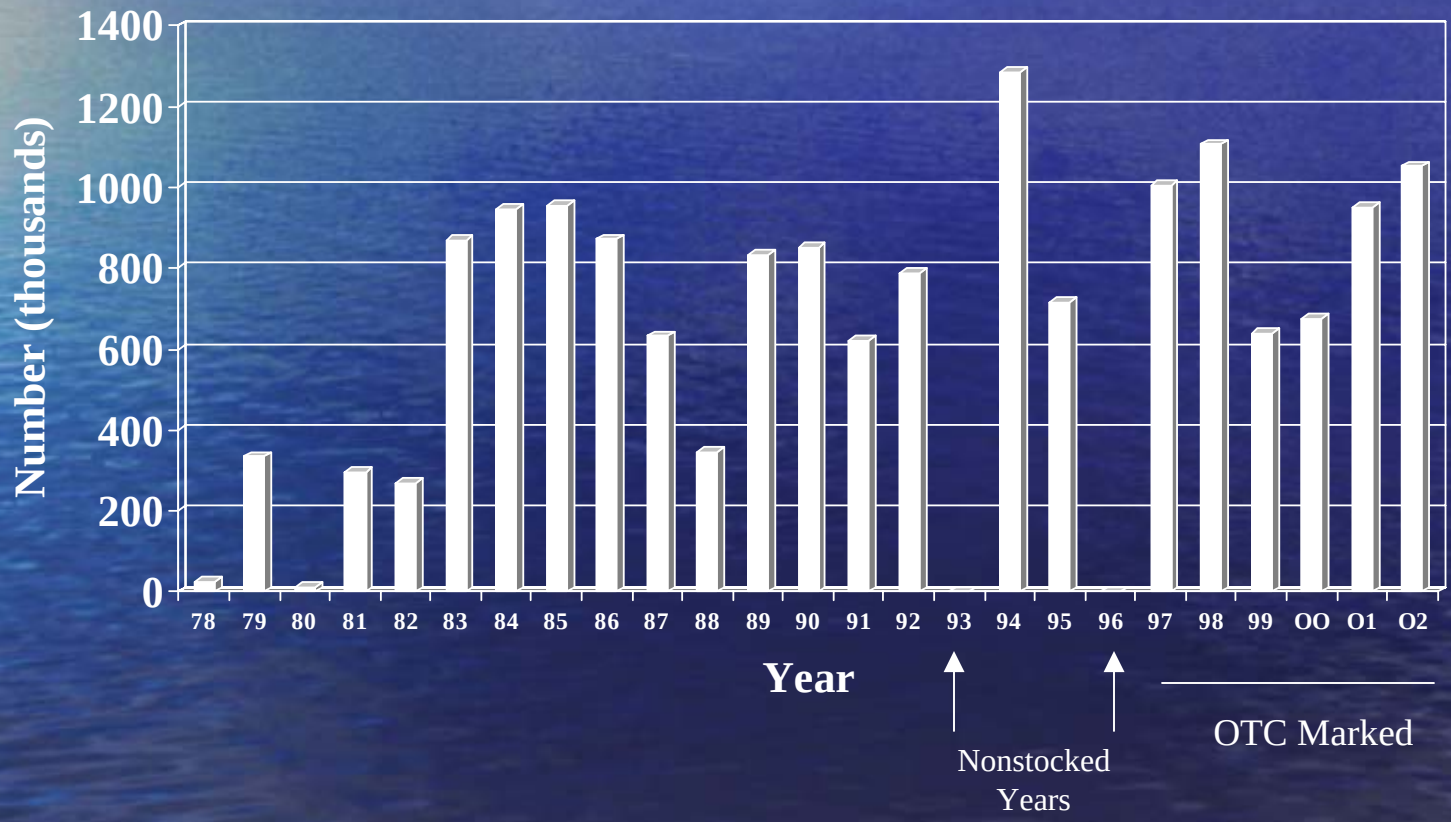
Lessons:

- Stocking effective in reestablishing stocks;
- Innovations in distribution and QC enhanced stocking effectiveness;
- Reproduction achievable only with aggressive fishing & lamprey controls;
- Invasive species problem remains source of uncertainty;

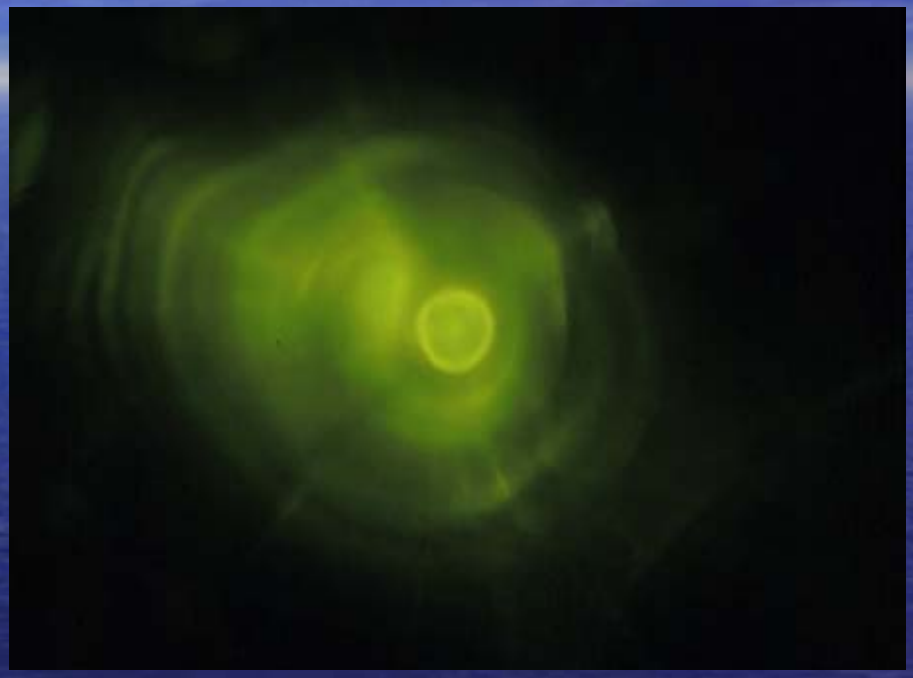
Lessons (continued):

- Focus efforts on best habitats;
- High stocking rate on prime habitats -- short-duration, ~4.5/ha.

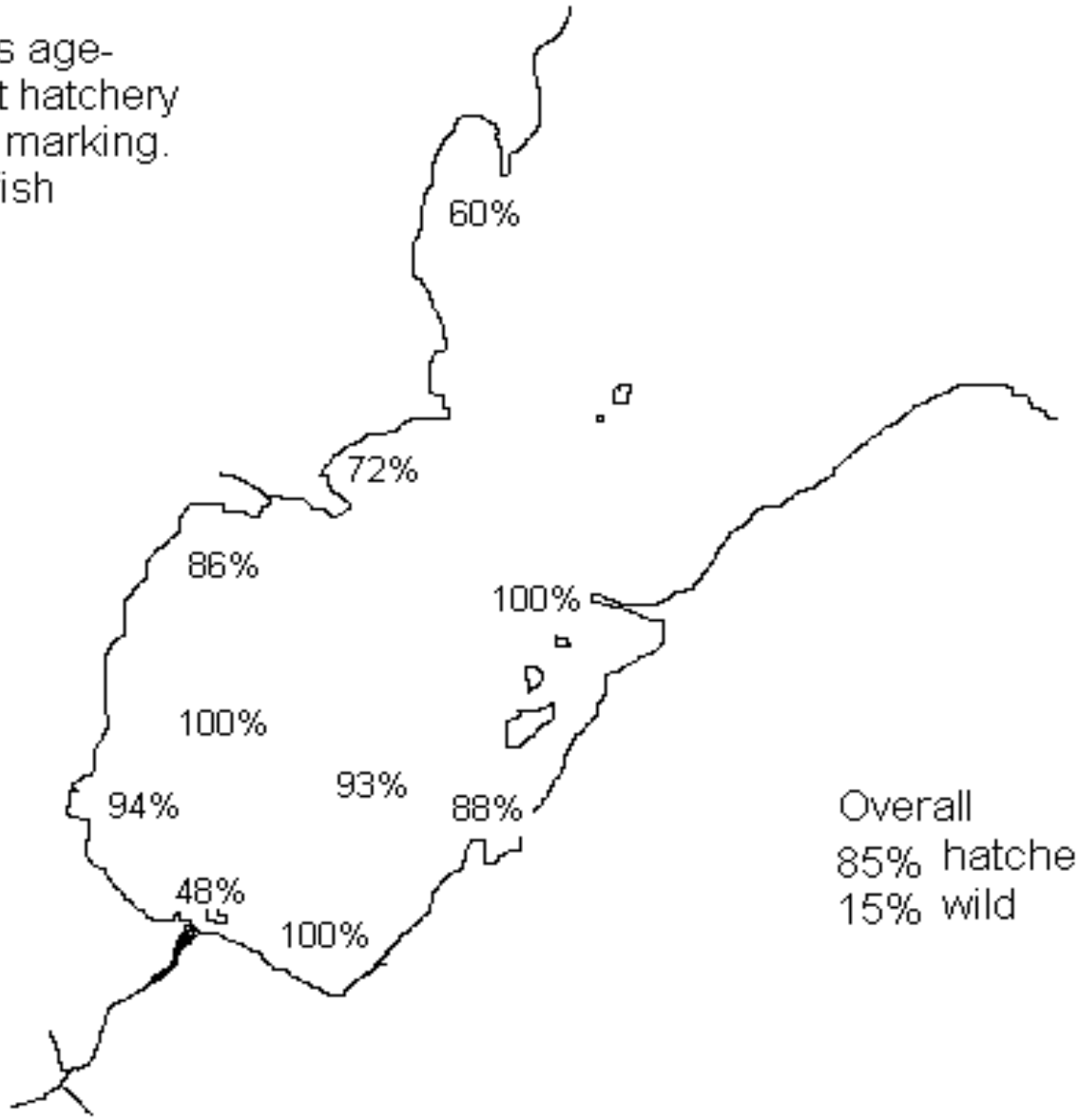
Walleye Fingerling Stocking in Saginaw Bay Since 1978




14



2002 year class age-walleye percent hatchery based on OTC marking.
N= 150 age-0 fish



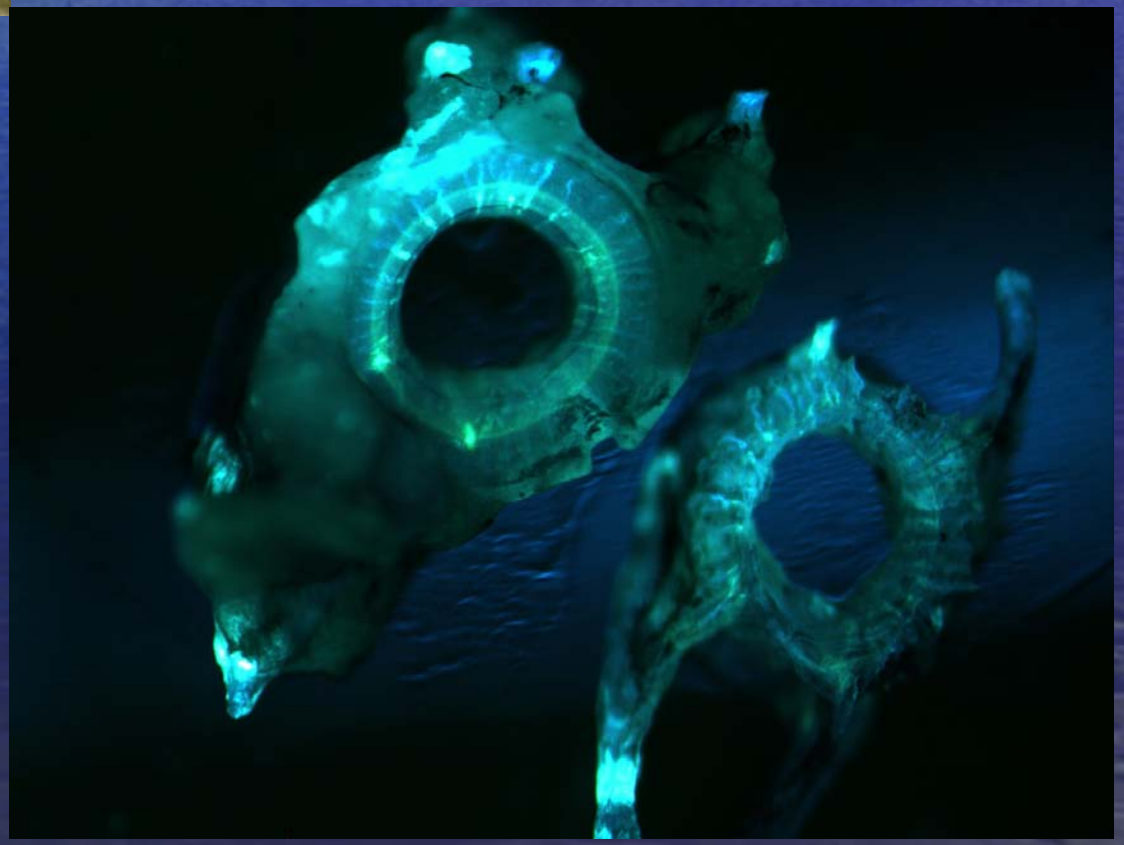
Overall
85% hatchery
15% wild

Percent Hatchery Contribution of Walleye as Measured by OTC Marking Over Six Year Classes from Saginaw Bay open water surveys and from the 2002 run at Dow Dam

Year Class	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Composite for YC	2002 Dow Run[1]
1997	81%	50%	73%	69%	---	55%	73%	67%
1998	81%	83%	92%	86%	85%		84%	93%
1999	85%	84%	---	71%			85%	67%
2000	96%	94%	94%				95%	---
2001	61%	61%					61%	---
2002	85%						85%	---

[1]Estimates from Dow run were based on very low sample sizes especially for the 97 and 99 year classes and caution should be used in interpreting these values.

Salmon Reproduction Study



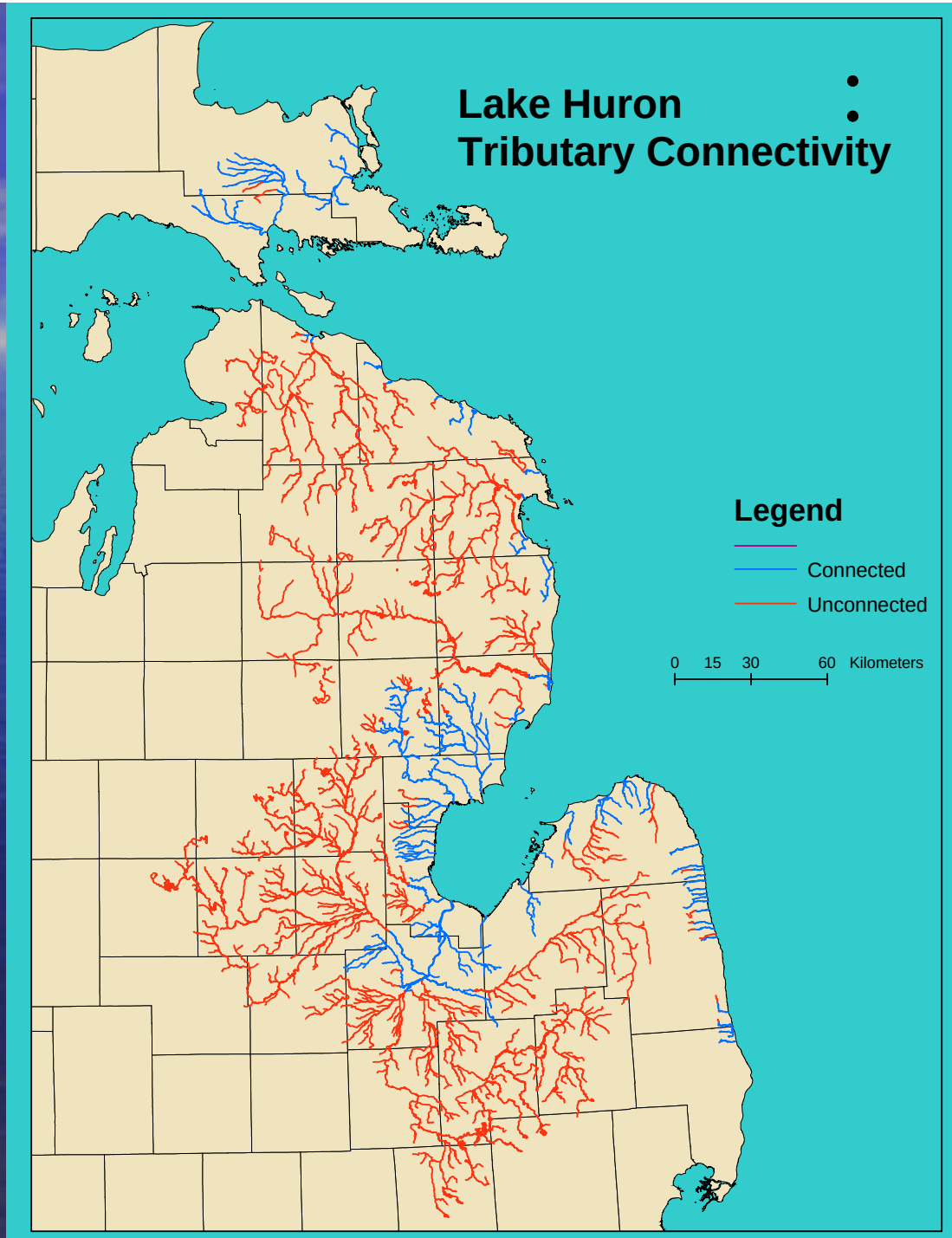
Lake Huron
Technical Committee

Lake Huron streams still assessable to Great Lakes fish for spawning:

The streams shown in blue are still assessable

Streams shown in red are blocked by dams

Only the colder streams are suitable for trout and salmon; of these, only 3% remain assessable.



Lost Connections: Great Lakes Tributaries

Historic					Present				
	Gradient class					Gradient class			
Size class	Very Low	Low	Moderate	High	Size class	Very Low	Low	Moderate	High
Coldwater									
Small	41	336	201	0	Small	10	15	0	0
Medium	320	517	347	0	Medium	0	19	1	8
Large	8	22	0	0	Large	0	0	0	0
Very Large	0	37	0	0	Very Large	0	0	0	0
Coolwater									
Small	344	451	127	0	Small	50	84	102	0
Medium	512	559	43		Medium	18	113	43	0
Large	92	135	0	0	Large	38	29	0	0
Very Large	69	50	67	0	Very Large	17	46	0	0
Warmwater									
Small	1223	168	0	0	Small	196	7	0	0
Medium	361	192	0	0	Medium	78	34	0	0
Large	20	115	0	0	Large	0	0	0	0
Very Large	602	43	17	0	Very Large	219	0	6	0

1,857 miles

53 miles

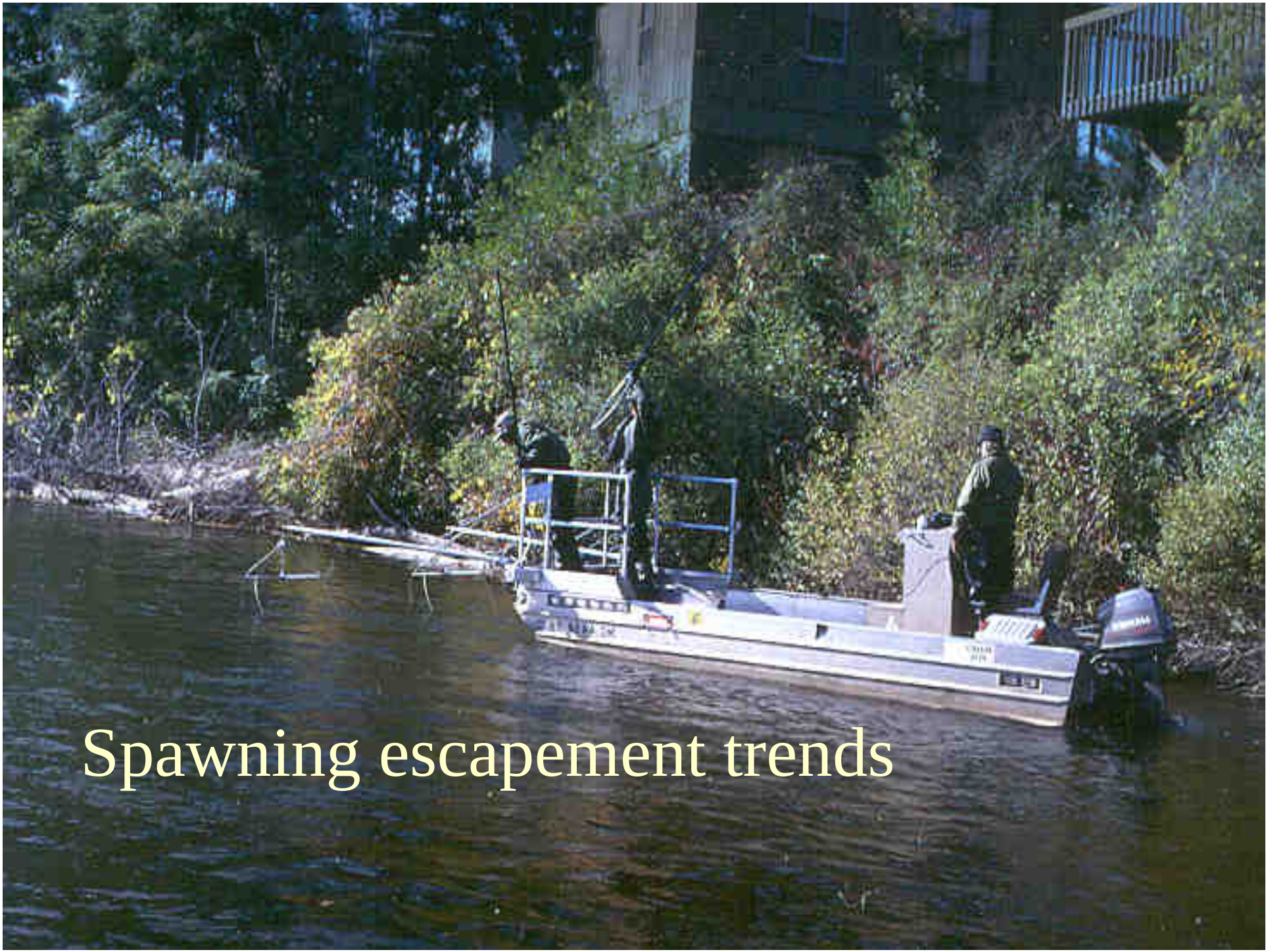
Zorn, T.G., A. Cottrill, and M.A. MacKay. In Press. Connectivity of Lake Huron Tributary Habitats. State of the Lake Report 2000.

Methods:

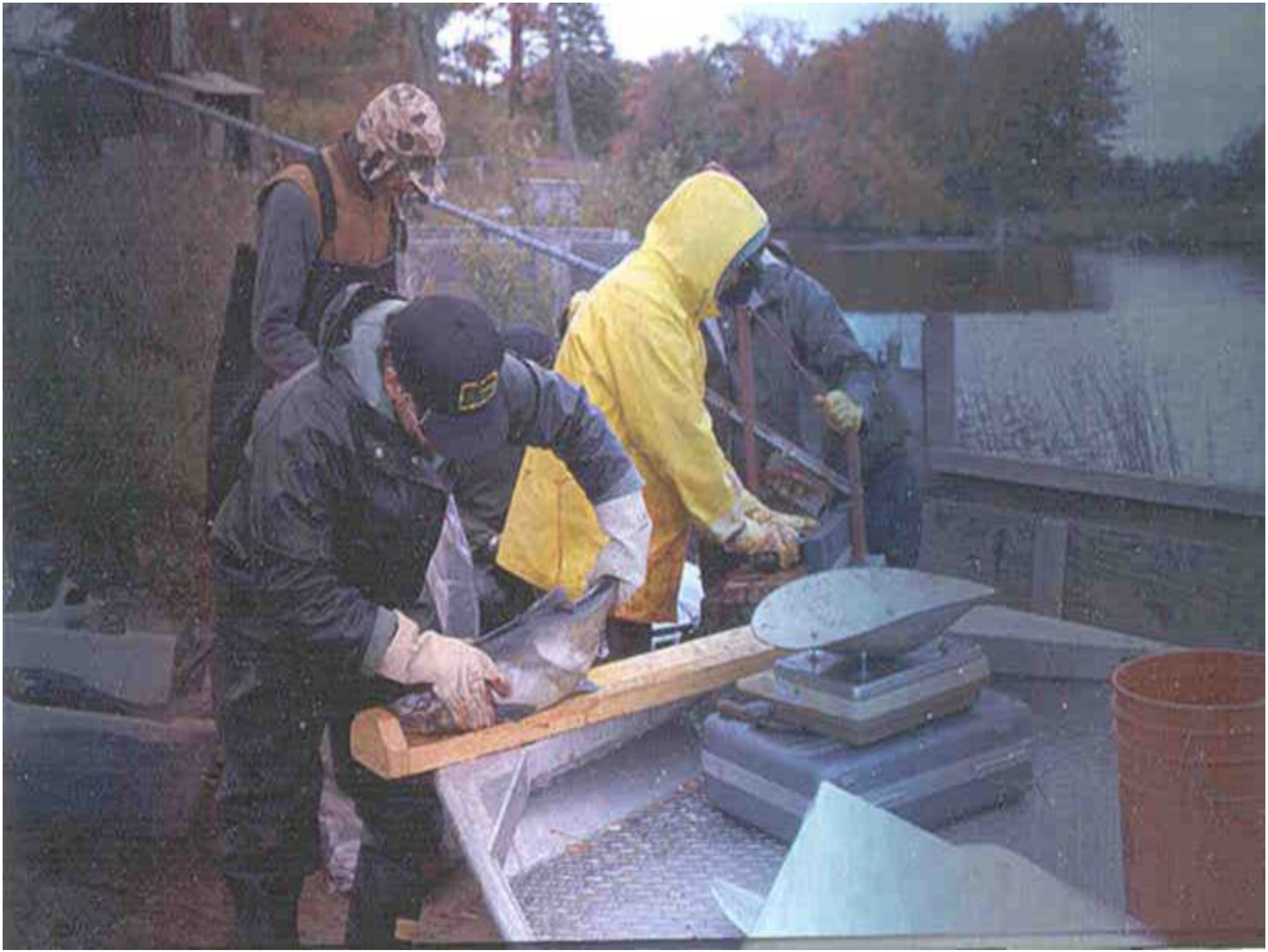

Reynolds Wrap
Reynolds Wrap
T . . . SLEEP . . .
GO FISHING


5

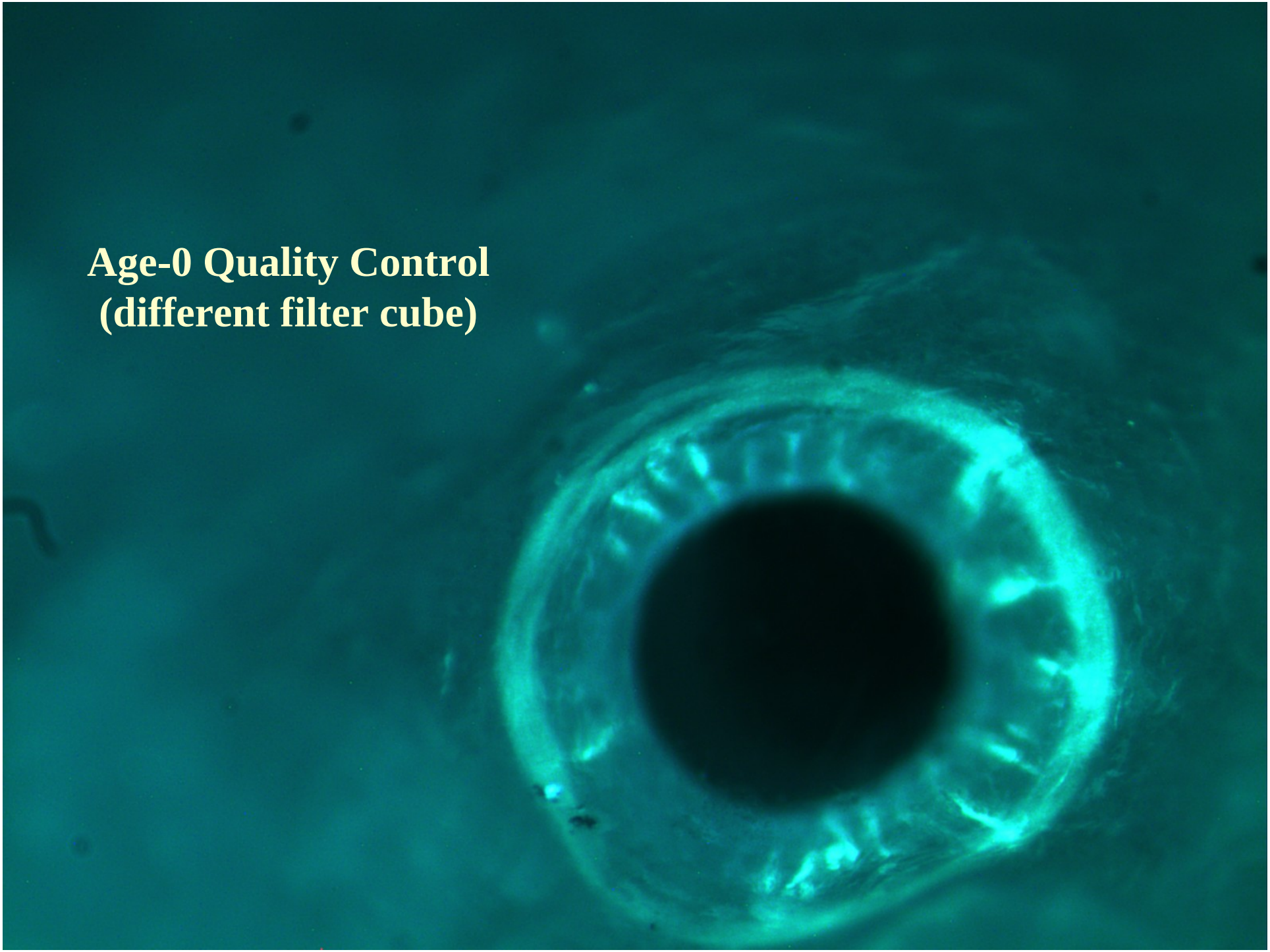

9

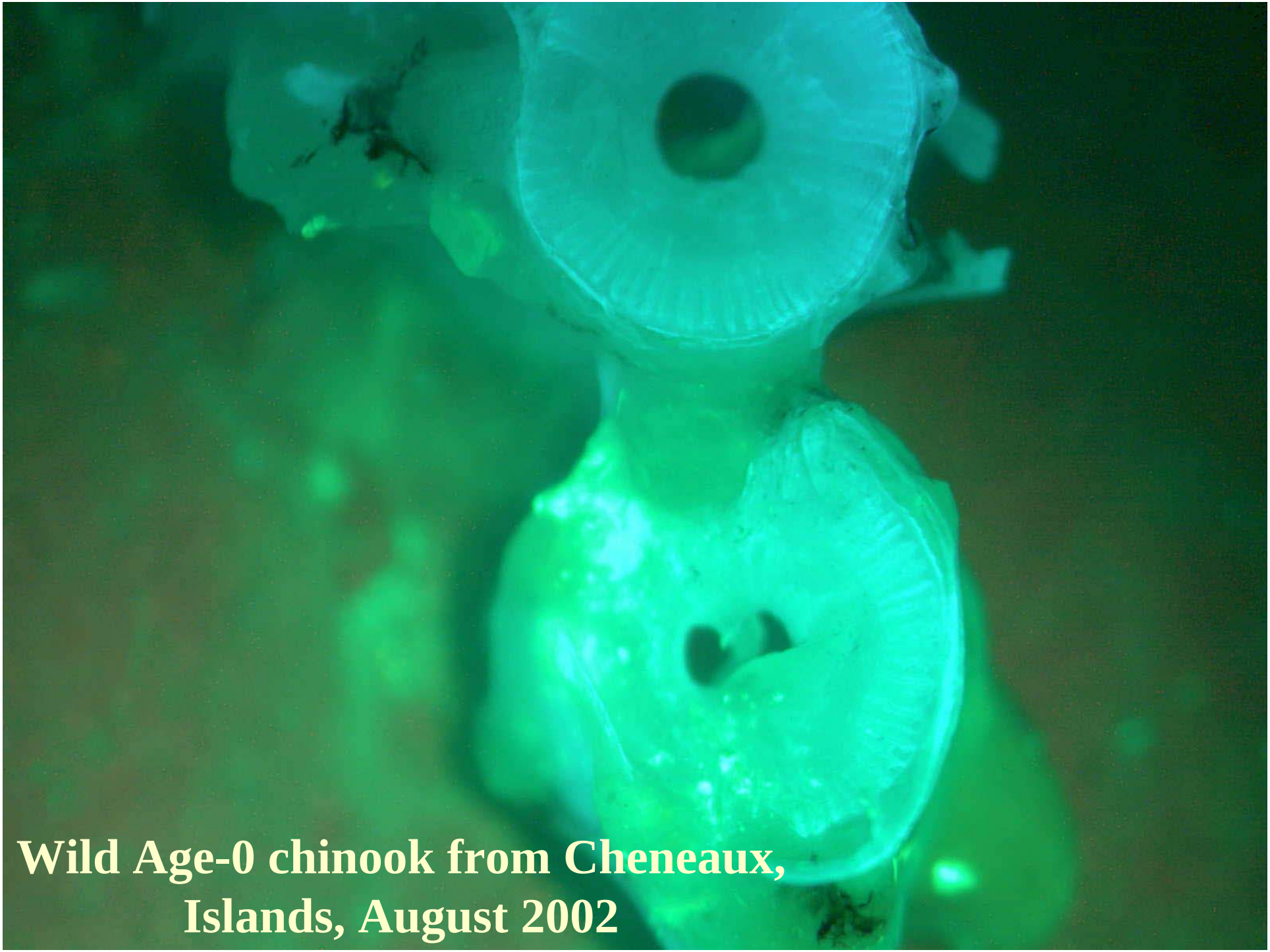


Spawning escapement trends

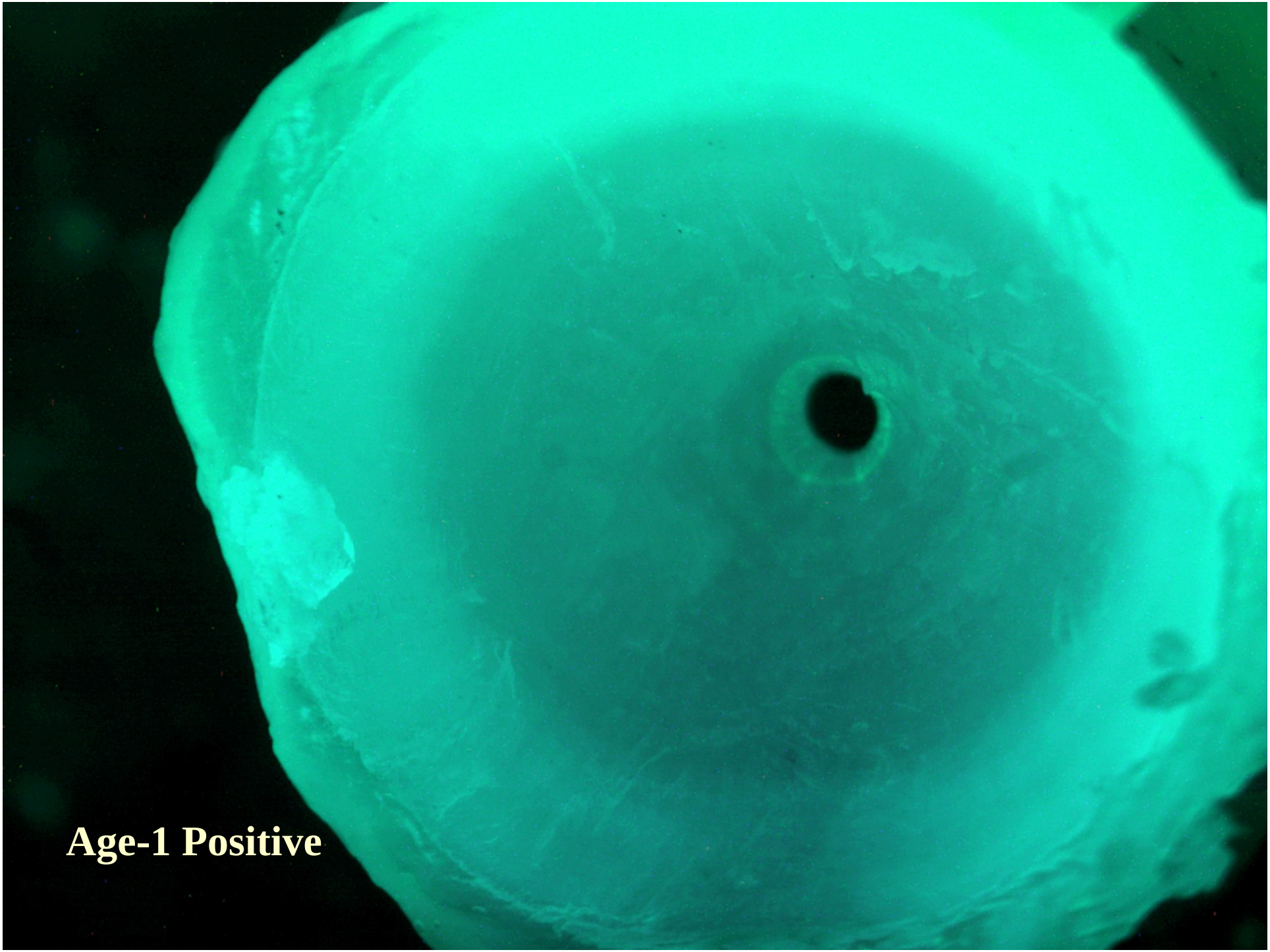


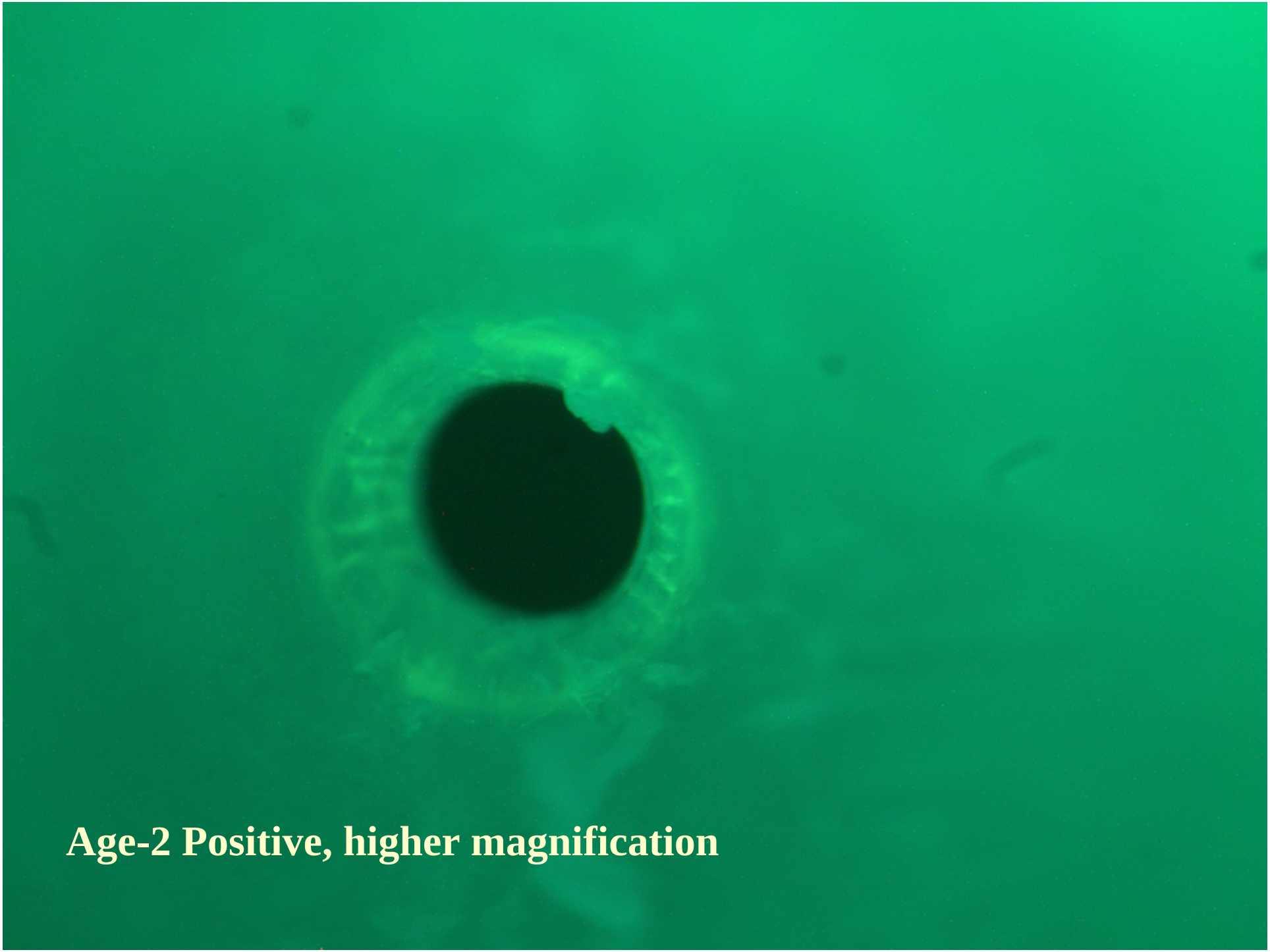

Laboratory
DELL


Age-0 Quality Control
(different filter cube)

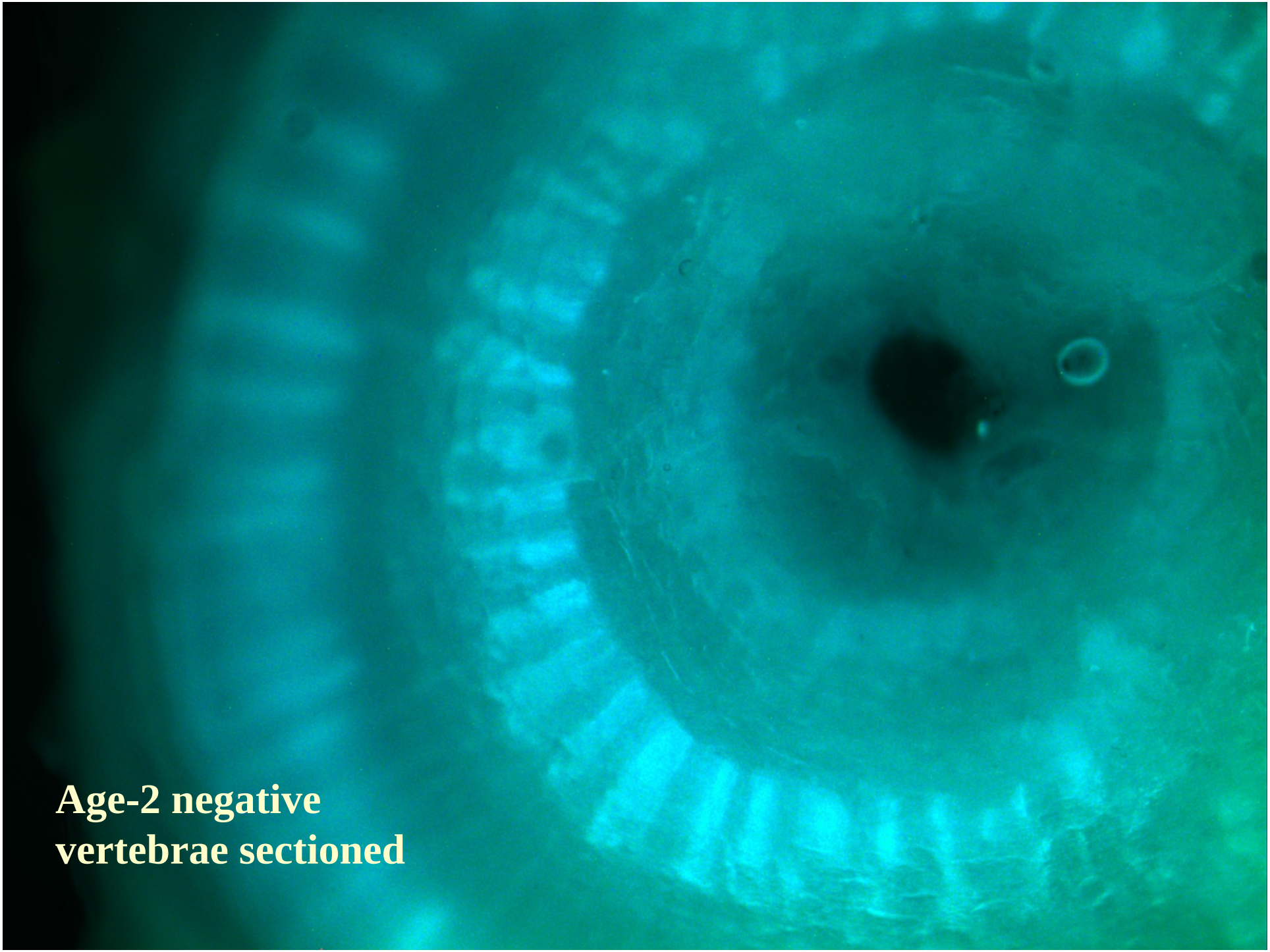


Wild Age-0 chinook from Cheneaux, Islands, August 2002


Age-1 Positive



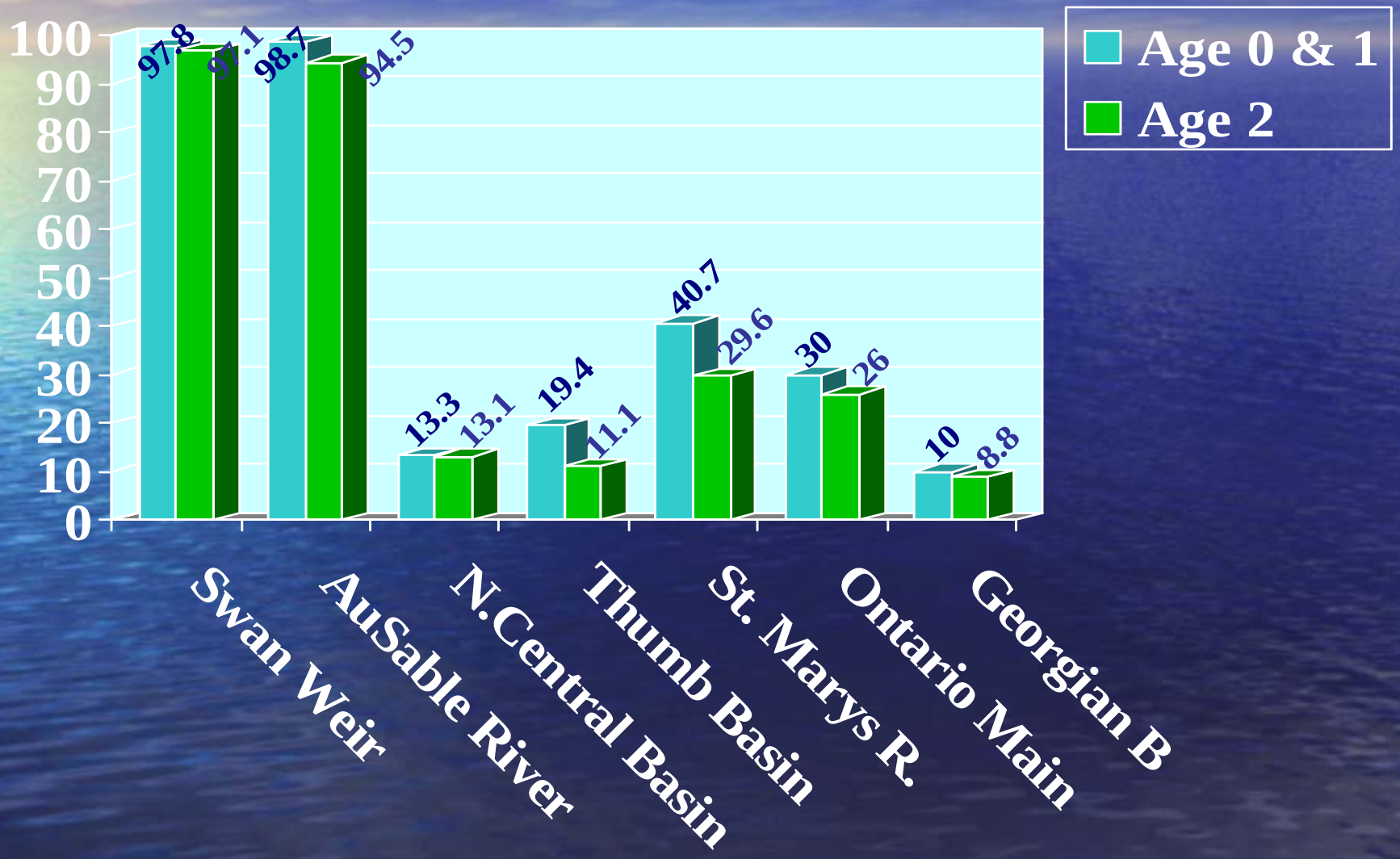
Age-2 Positive, higher magnification


Age-2 negative
vertebrae sectioned

Sample sizes: Chinook Vertebrae Lake Huron 2002

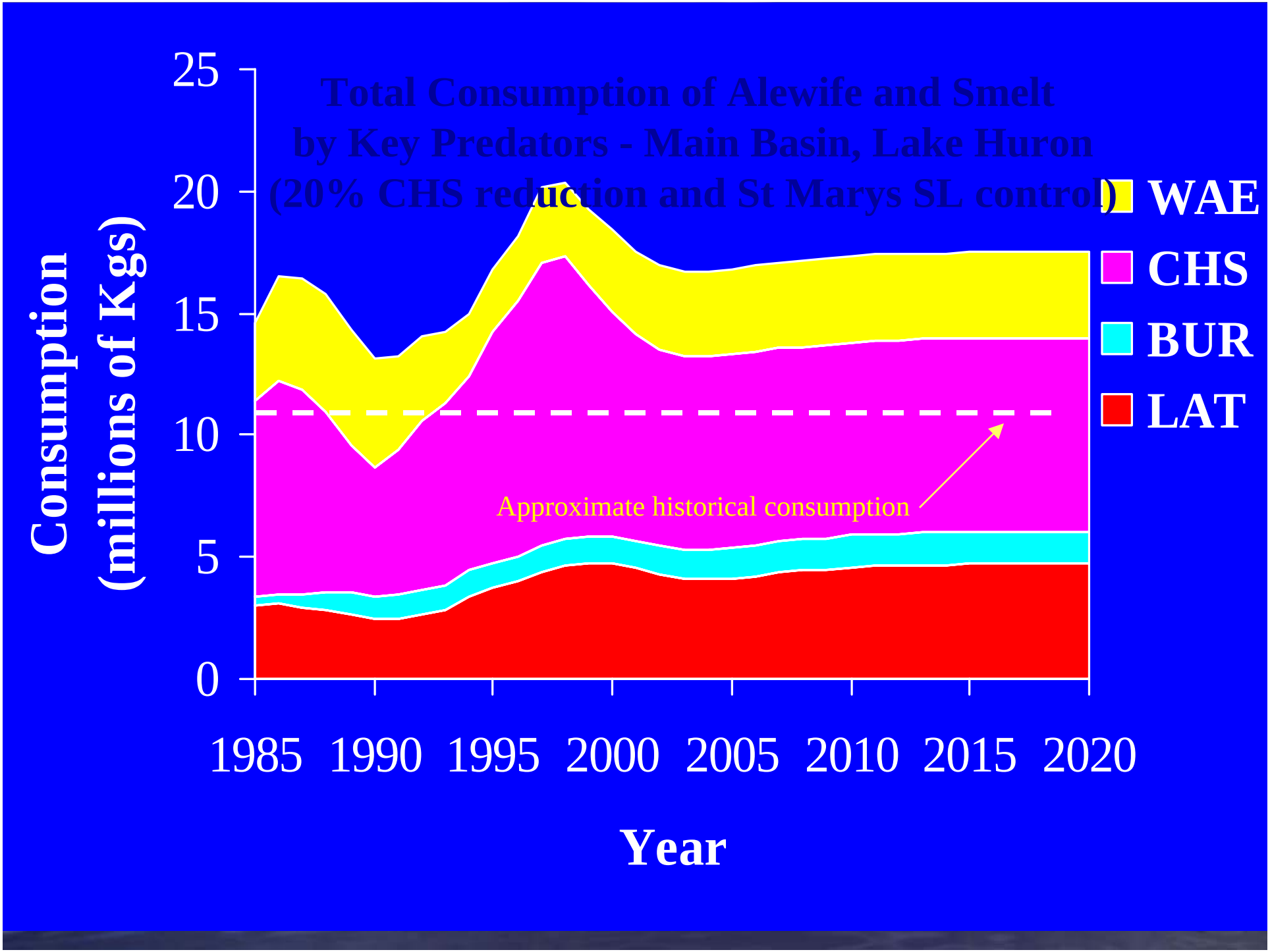
Area:	**All Ages**	**< Age-3**
Swan Weir	245	184
AuSable River (fall)	255	187
N. Central Basin	279	243
Thumb	188	144
St. Marys (LSSU, fall)	463	419
Ontario Main Basin	256	193
Georgian Bay	100	98
Total	**1,723**	**1,468**

Incidence (%) of OTC Marks, Chinook Vertebrae, by Sample Area, Lake Huron



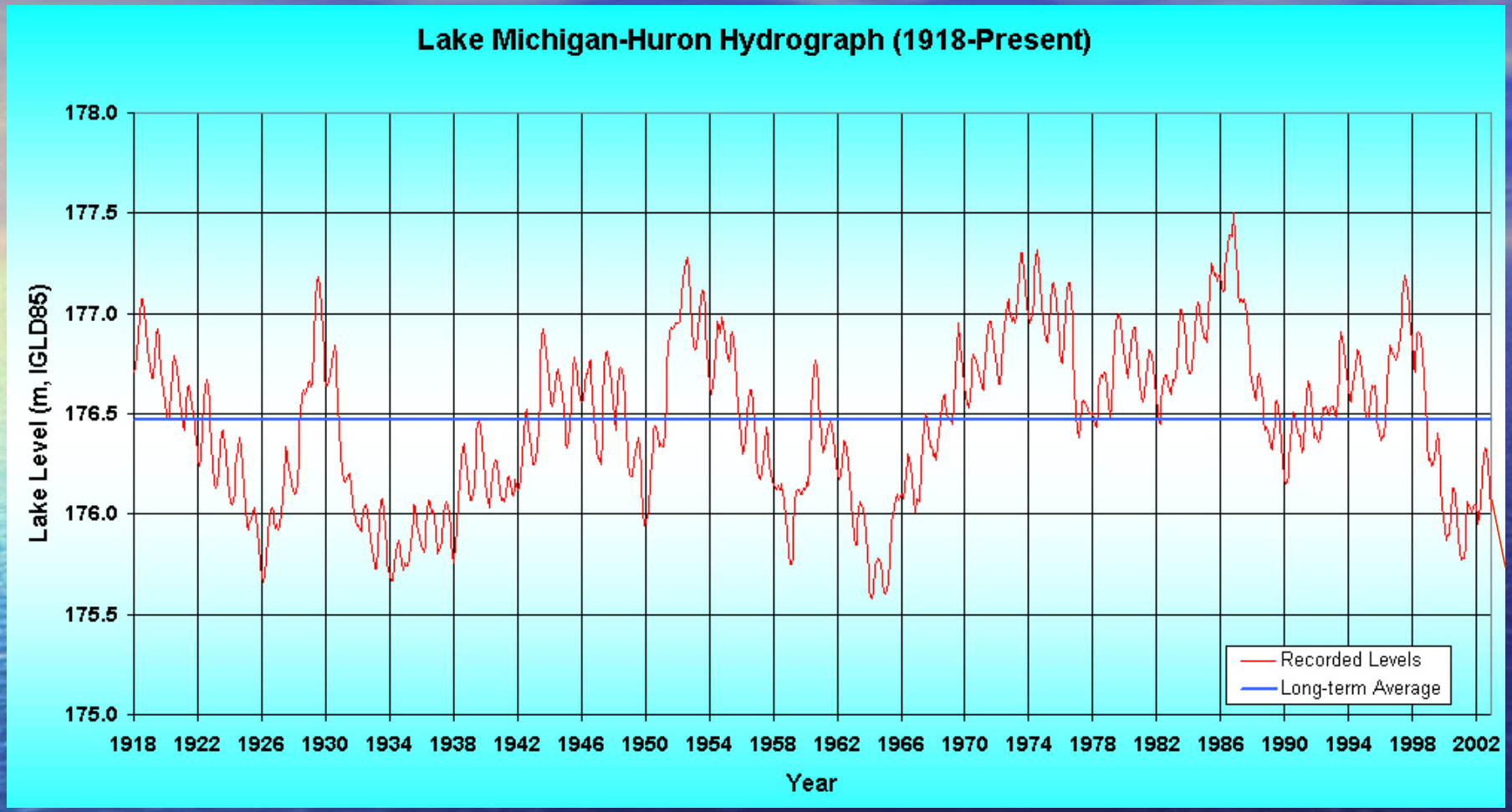
Implications of Chinook Reproduction Findings

- Appear to be at least 8 wild chinook for each stocked salmon
- Produced record harvest in 2002
- Future stocking needs?
- Implications to alewife (prey base) conditions
- Implications to size and condition of salmon and other predators


Total Consumption of Alewife and Smelt
by Key Predators - Main Basin, Lake Huron
(20% CHS reduction and St Marys SL control)
Consumption
(millions of Kgs)
25
20
15
10
5
0
1985
1990
1995
2000
2005
2010
2015
2020
Year
WAE
CHS
BUR
LAT
Approximate historical consumption

Acknowledgements:

- ***RV Chinook*** staff
- Federal Aid to Fish Restoration Project F-80-R, Study 451
- Dr. James Bence Michigan State Univ.



Great Lakes water levels have declined below the long-term average and are approaching the low levels recorded during the 1930's and 1960's

Recovering Saginaw Bay coastal wetland, June 2001, undisturbed

Disturbed Saginaw Bay coastal wetland, June 2001, recently tilled

Photos by : Joseph Haas, Field Biologist
DEQ - Geological and Land Management Division
Saginaw Bay District