Keynote: Mortality of Age-1 Lake Trout in the Great Lakes

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Lake Trout
Presentation Outline

- Background on the species
- Lessons from Great Lakes
- Lake trout life history
- Recruitment regulation
- Survey needs

Lake Trout Background

Lake charr

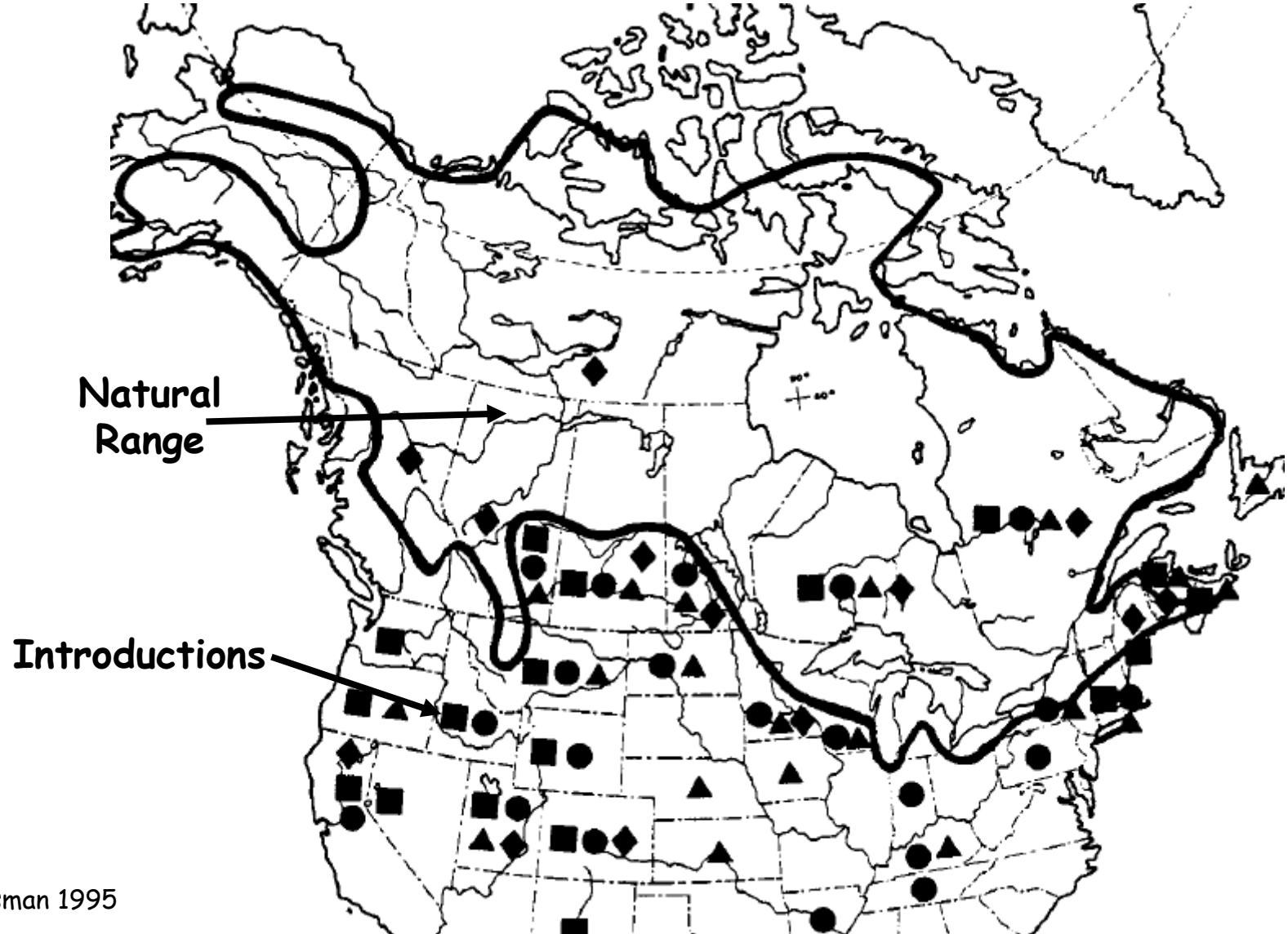
Salvelinus namaycush

Specialized benthic invertebrate feeder
620 mm, male, September 1, 2005
Great Bear Lake, Dease Arm,
Northwest Territories, Canada

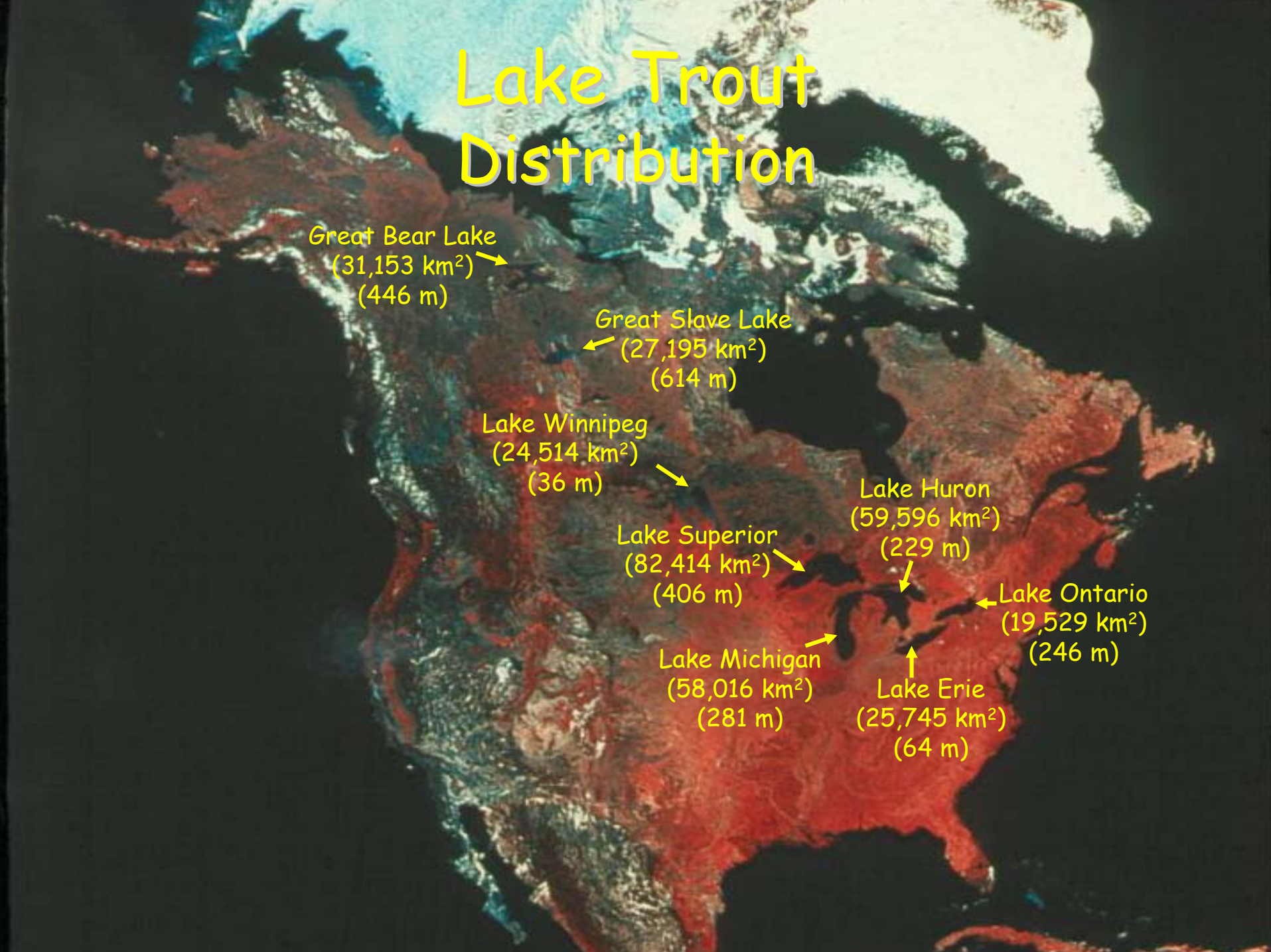
Principle investigator: Craig Blackie (Ph.D candidate)
Dr. Paul Bentzen (Professor), Dalhousie University, N.B.

Illustrator: Paul Vecsei (Ph.D candidate)
Medium: Water color pencil used wet and dry, hard graphite and burnishing techniques

Lake Trout Distribution



Crossman 1995

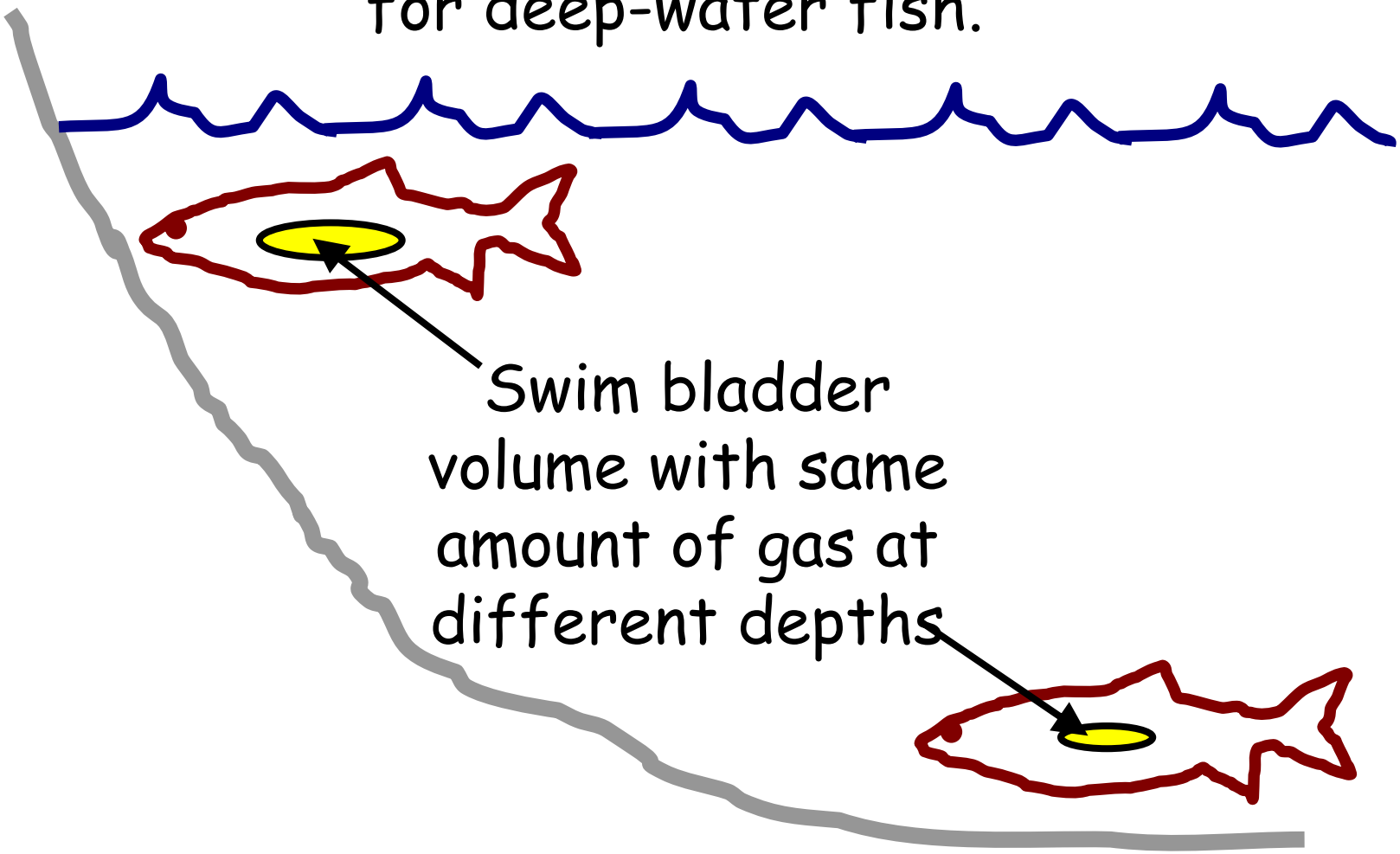

Lake Trout Distribution
Great Bear Lake
(31,153 km²)
(446 m)
Great Slave Lake
(27,195 km²)
(614 m)
Lake Winnipeg
(24,514 km²)
(36 m)
Lake Huron
(59,596 km²)
(229 m)
Lake Superior
(82,414 km²)
(406 m)
Lake Ontario
(19,529 km²)
(246 m)
Lake Michigan
(58,016 km²)
(281 m)
Lake Erie
(25,745 km²)
(64 m)

Lake Trout
Evolutionary History

Lake Trout Evolutionary History

- Lake trout readily diversify in morphology to exploit diverse habitats in large lakes of North America.
  - Shallow-water (lean) form colonized all cold lakes after glaciers receded.
  - Humper (intermediate) form evolved to exploit invertebrates (*Mysis relicta*) in deep water.
  - Siscowet (fat) form evolved to feed on deepwater ciscoes that evolved to feed on invertebrates.

Lake Trout
Evolutionary History
Habitat depth presents a physiological challenge for deep-water fish.

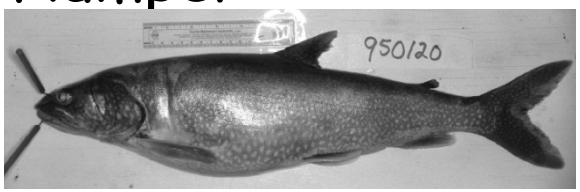


Lake Trout Evolutionary History

Phenotypic diversity in the Great Lakes

"Lean"

"Humper"



"Siscowet

These forms differ in body shape, fat content, and habitat depth.

Lake Trout
Evolutionary History

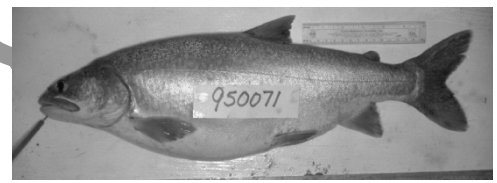
Great Slave Lake

Heavy

Light

Lake Superior

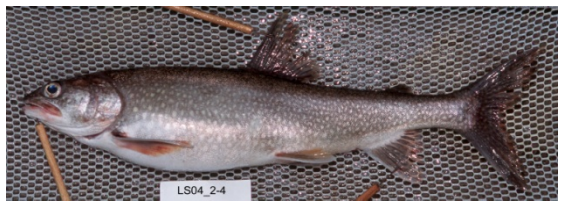
Heavy

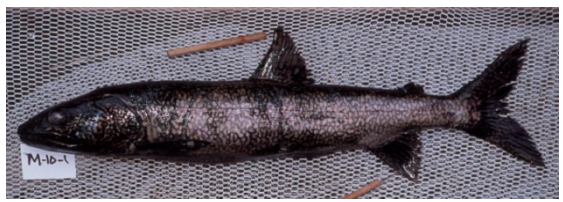


Light

Lake Trout Evolutionary History

Phenotypic diversity in North American lakes



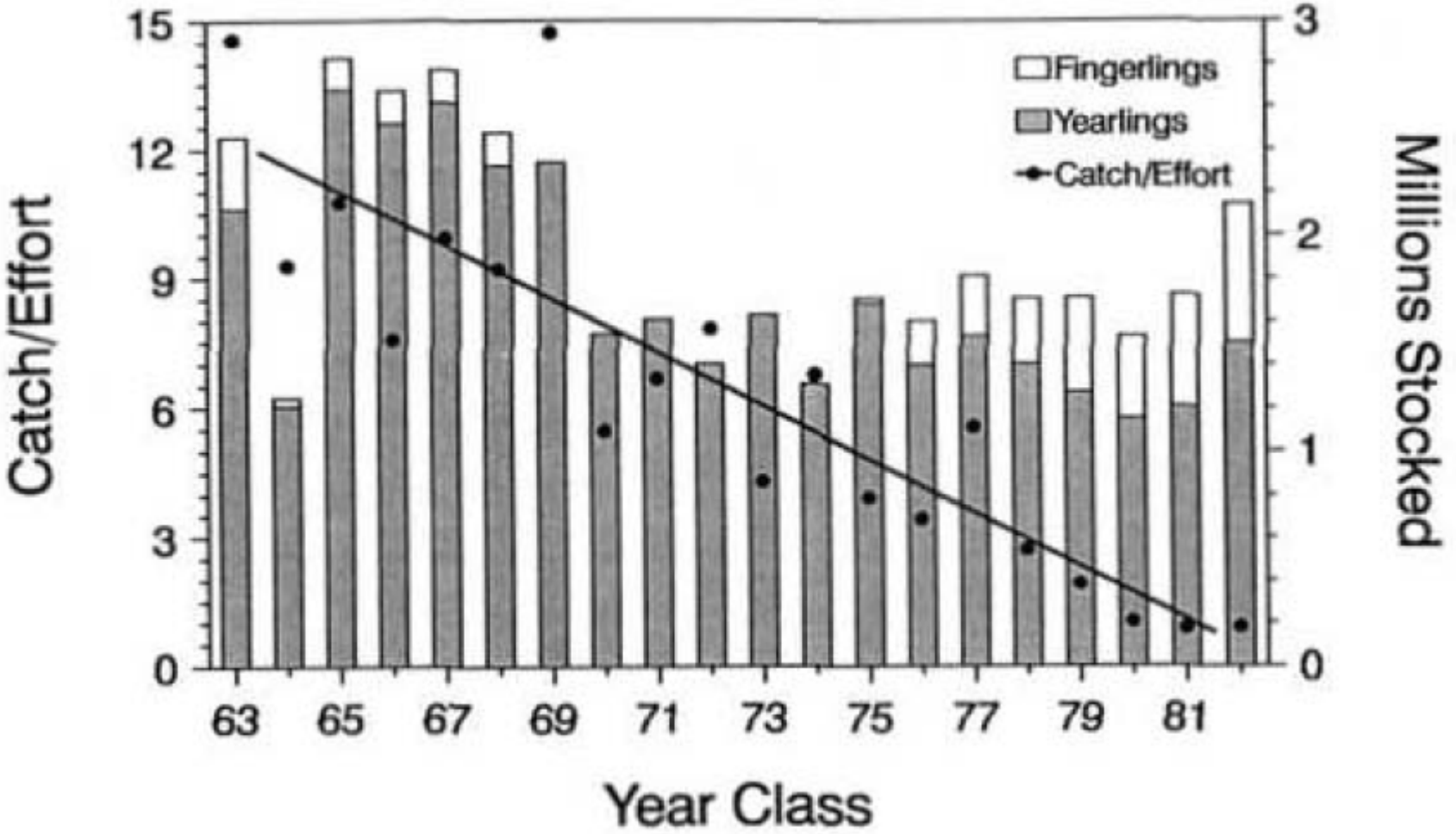


Lake Trout Background

- Lake trout are at the southern fringe of their range in the Laurentian Great Lakes.
- The Laurentian Great Lakes are notable lake trout lakes mostly due to their great depth.
- Restoration programs that ignore deepwater forms of lake trout fail to take full advantage of available habitat.


Lake Trout
Great Lakes Lessons

Lake Trout
Lake Superior Lessons



Hansen et al. 1994

Lake Trout
Lake Superior Lessons

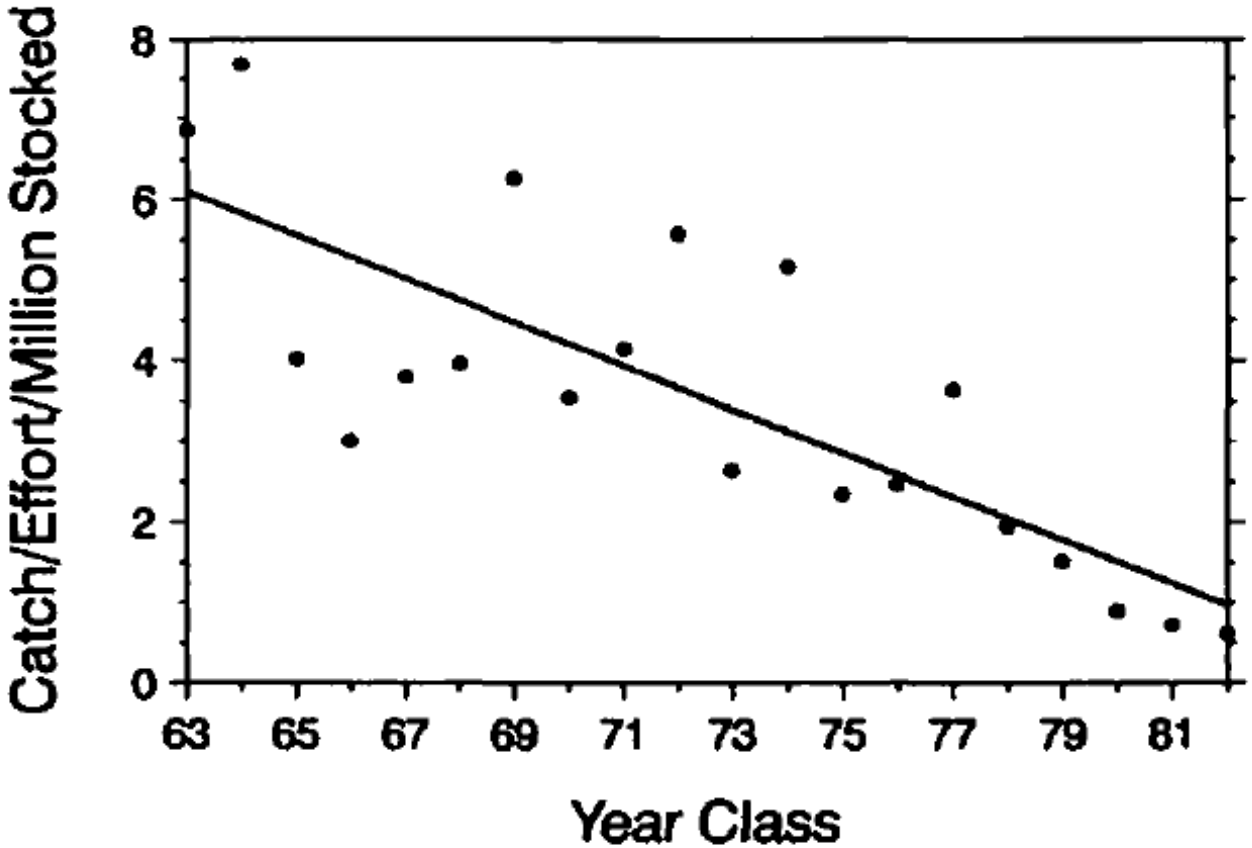
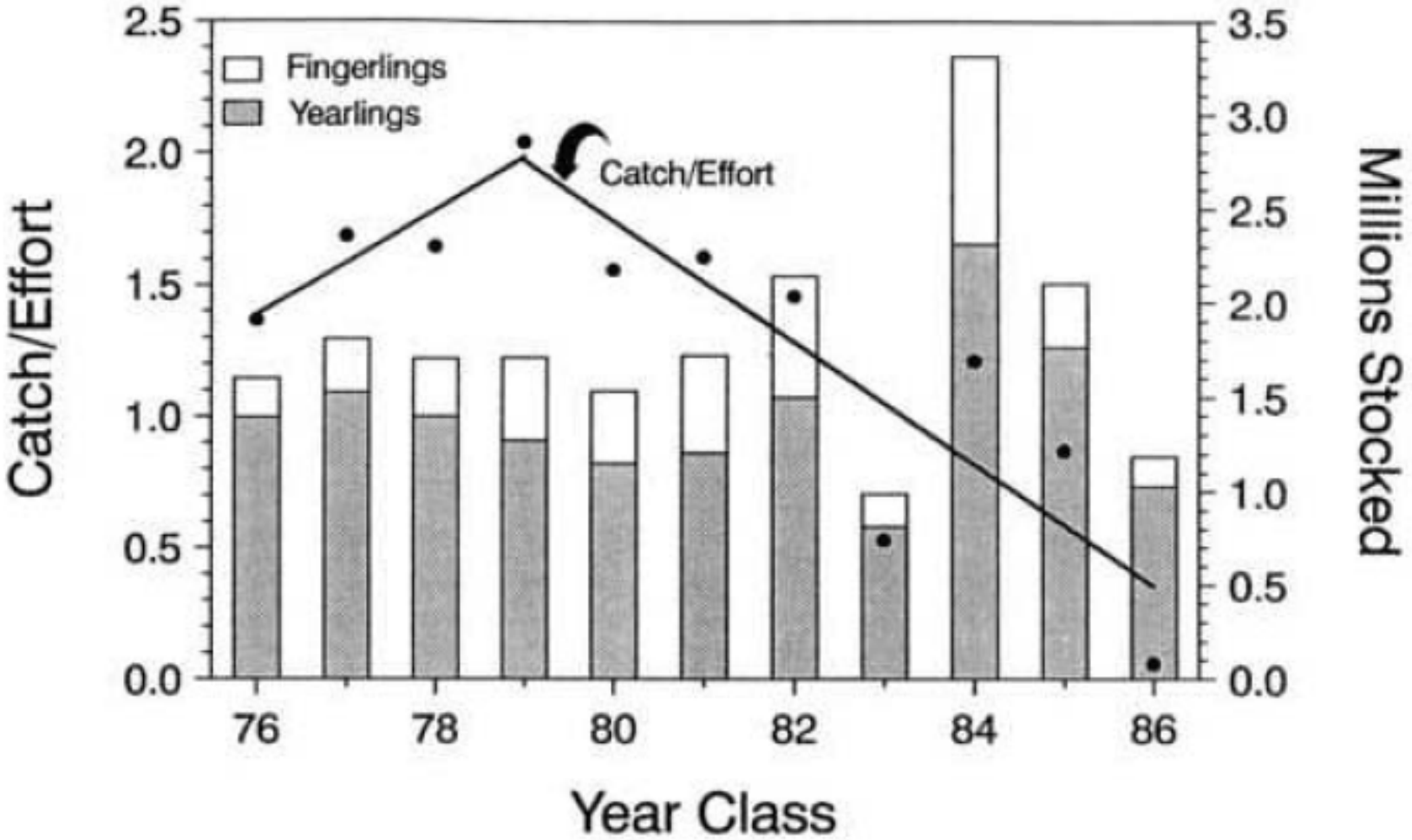


FIGURE 3.—Index of survival to age 7 (catch per effort per million fish stocked) for the 1963–1982 year-classes of lake trout stocked in U.S. waters of Lake Superior.

Hansen et al. 1994

Lake Trout
Lake Superior Lessons



Hansen et al. 1994

Lake Trout
Lake Superior Lessons

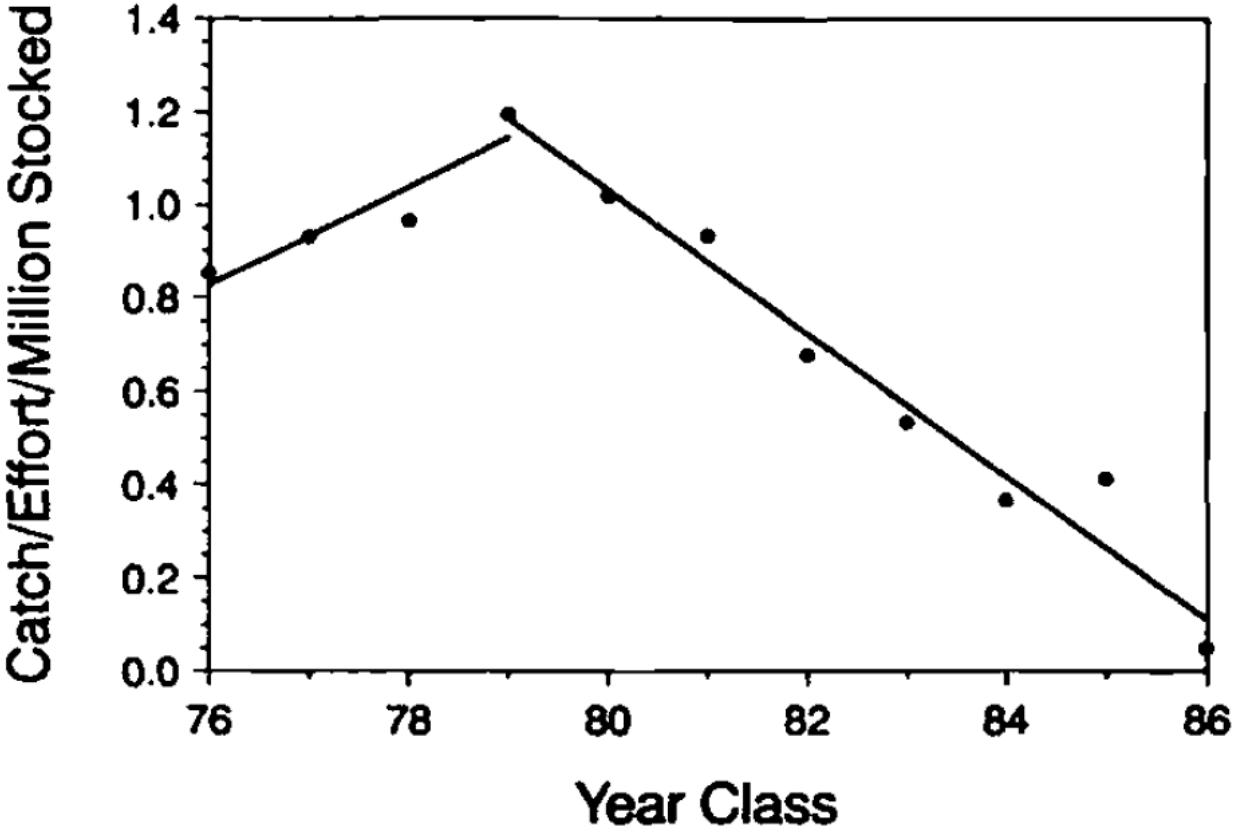


FIGURE 5.—Index of survival to ages 2–4 (catch per effort per million fish stocked) for the 1976–1986 year-classes of lake trout stocked in U.S. waters of Lake Superior.

Hansen et al. 1994

Lake Trout
Lake Superior Lessons

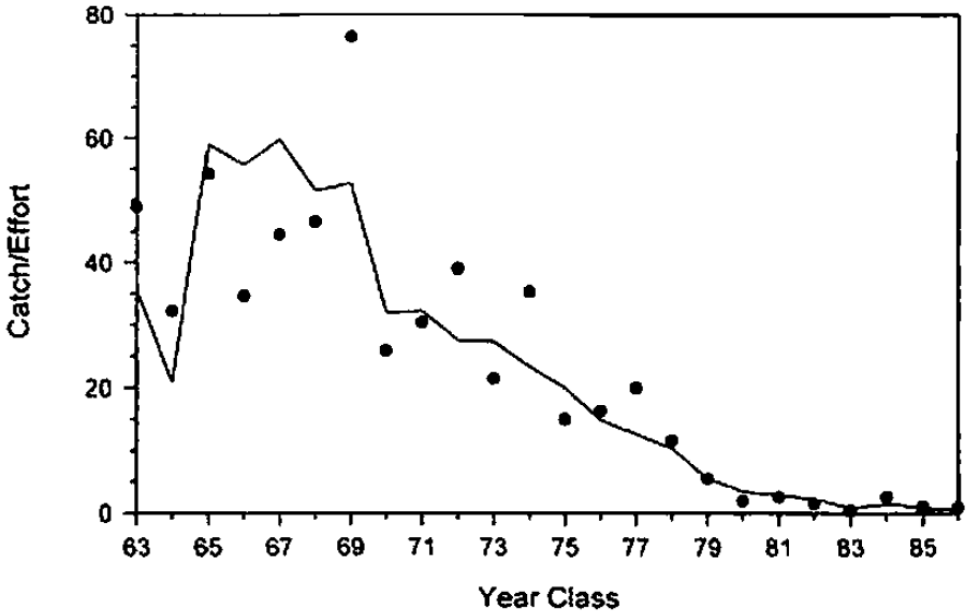


FIGURE 2.—Catch per effort (kilometer of gill net) of age-7 stocked lake trout caught in assessment fisheries (dots) and predicted from yearling stocking and commercial large-mesh gill-net fishing effort (line) in Michigan waters of Lake Superior.

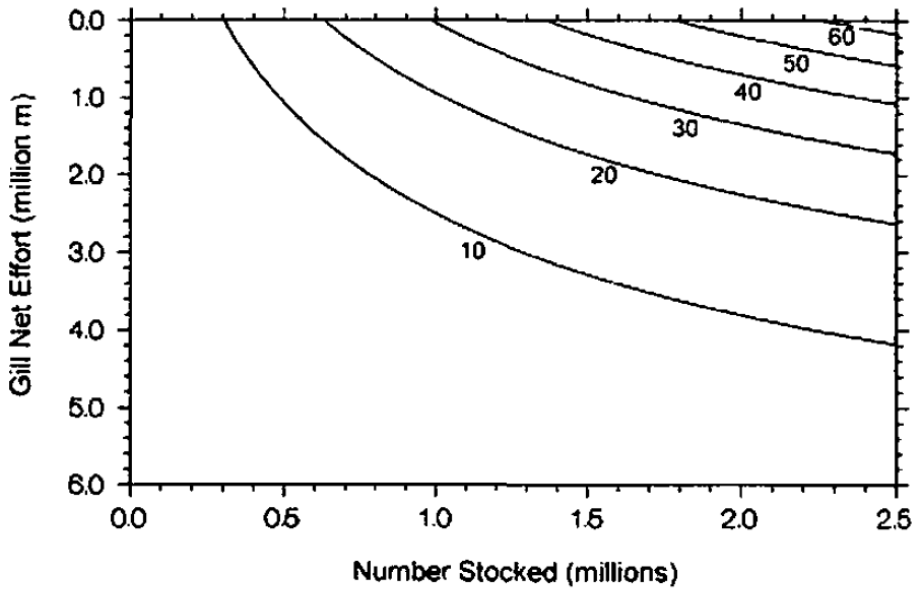


FIGURE 4.—Contours of catch per effort of age-7 stocked lake trout (numbers caught per kilometer of gill net in assessment fisheries) predicted from yearling stocking and commercial large-mesh gill-net fishing effort in Michigan waters of Lake Superior.

Hansen et al. 1996

Lake Trout
Lake Superior Lessons

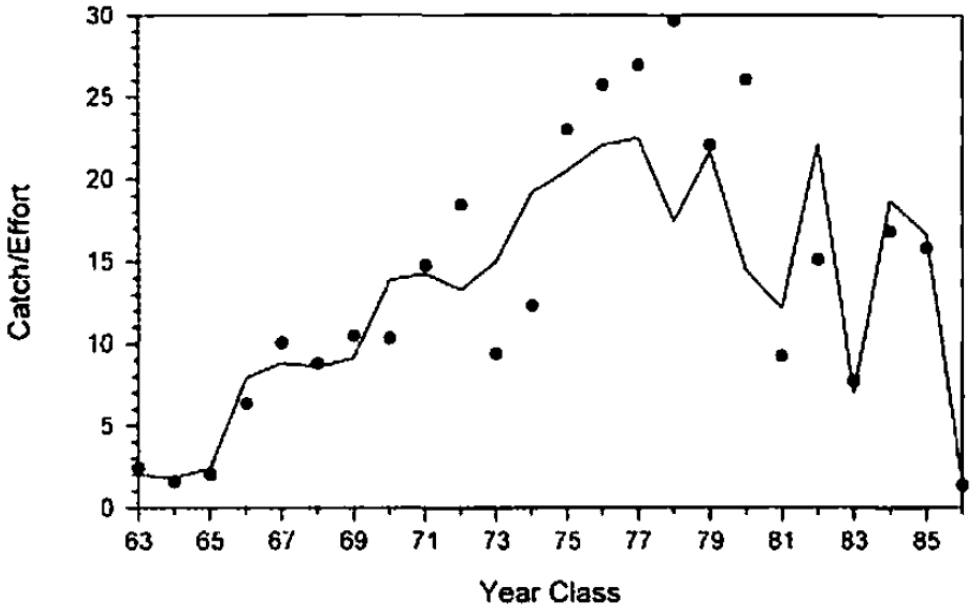


FIGURE 5.—Catch per effort (kilometer of gill net) of age-7 stocked lake trout caught in assessment fisheries (dots) and predicted from yearling stocking and wild lake trout density (line) in Minnesota waters of Lake

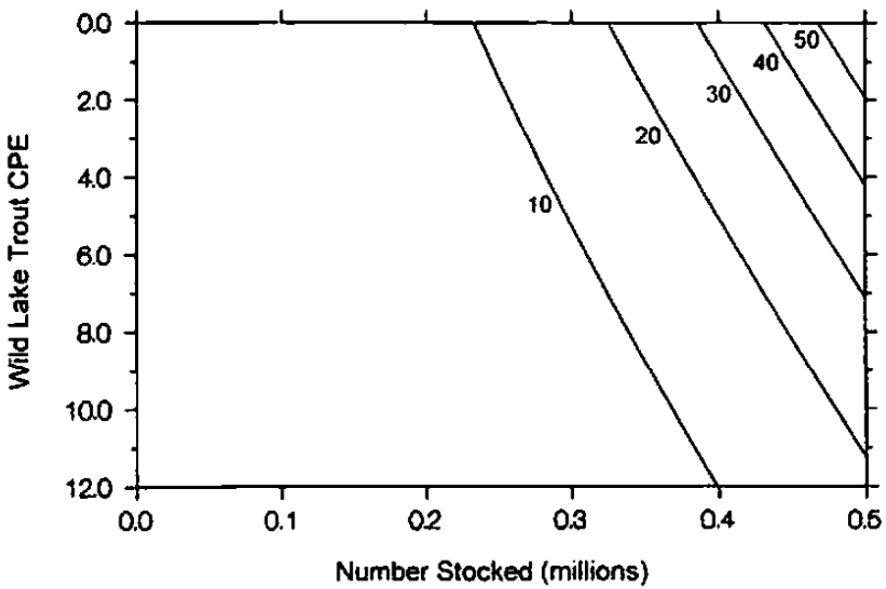


FIGURE 7.—Contours of catch per effort of age-7 stocked lake trout (numbers caught per kilometer of gill net in assessment fisheries) predicted from yearling stocking and assessment catch per effort (CPE) of wild lake trout density in Minnesota waters of Lake Superior.

Hansen et al. 1996

Lake Trout
Lake Superior Lessons

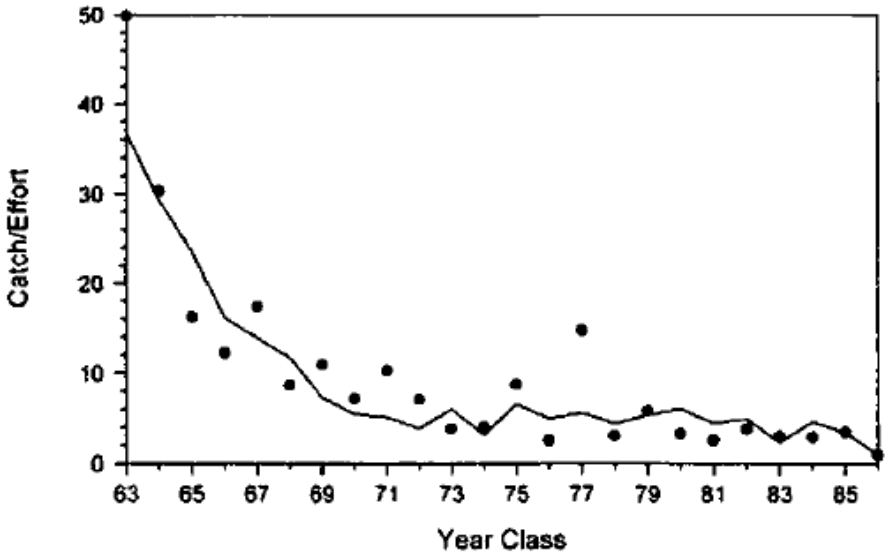


FIGURE 8.—Catch per effort (kilometer of gill net) of age-7 stocked lake trout caught in assessment fisheries (dots) and predicted from yearling stocking and commercial large-mesh gill-net fishing effort (line) in Wisconsin waters of Lake Superior.

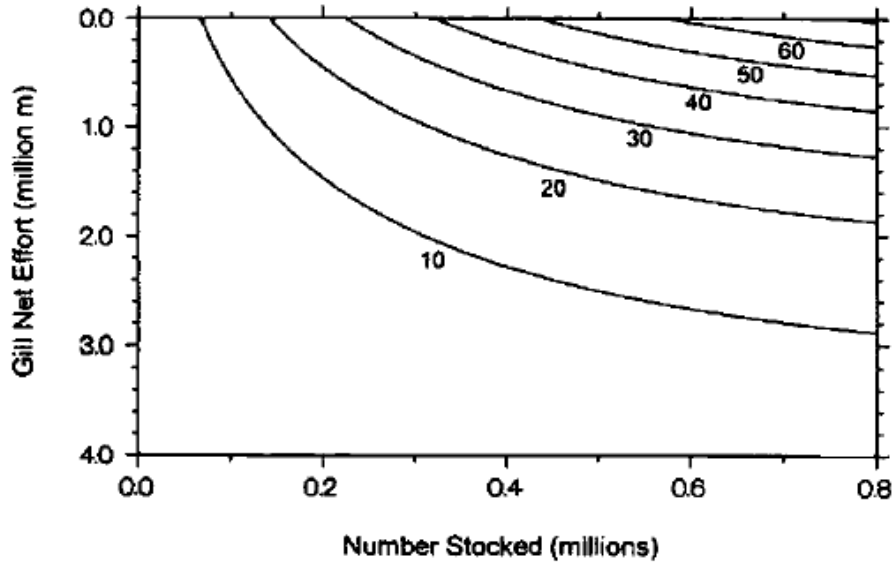


FIGURE 10.—Contours of catch per effort of age-7 stocked lake trout (numbers caught per kilometer of gill net in assessment fisheries) predicted from yearling stocking and commercial large-mesh gill-net fishing effort in Wisconsin waters of Lake Superior.

Hansen et al. 1996

Lake Trout
Lake Ontario Lessons

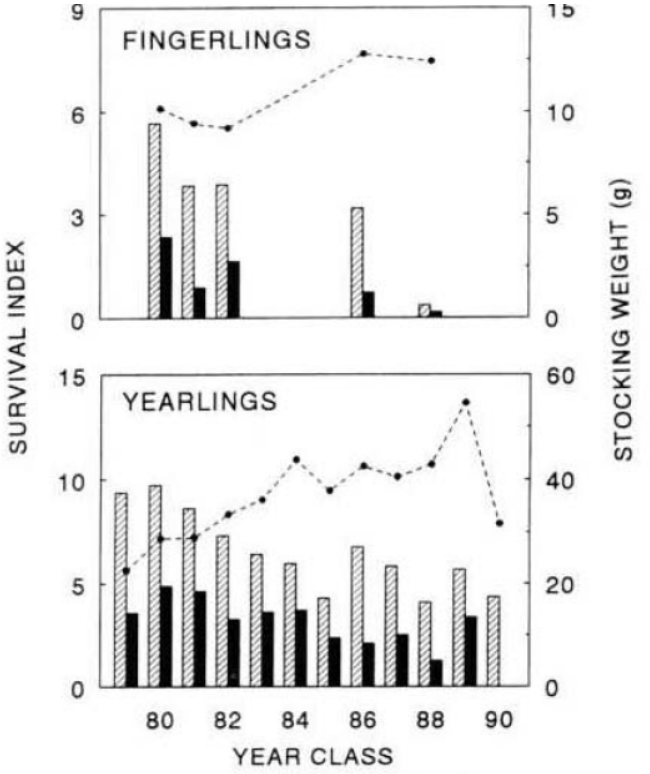


FIGURE 3.—Survival indices (bars) and mean weight at stocking (dashed line) over all stocking locations for various year-classes (1979–1990) of Lake Superior strain lake trout stocked in Lake Ontario as fingerlings and as yearlings, based on catches with trawls at age 2 (striated bars) and with gill nets at age 3 (solid bars). Survival indices were calculated as 10,000 times the number of stocked fish captured at age 2 or age 3 divided by the number of fish stocked; values given are least-squares mean estimates for each year-class over all stocking locations.

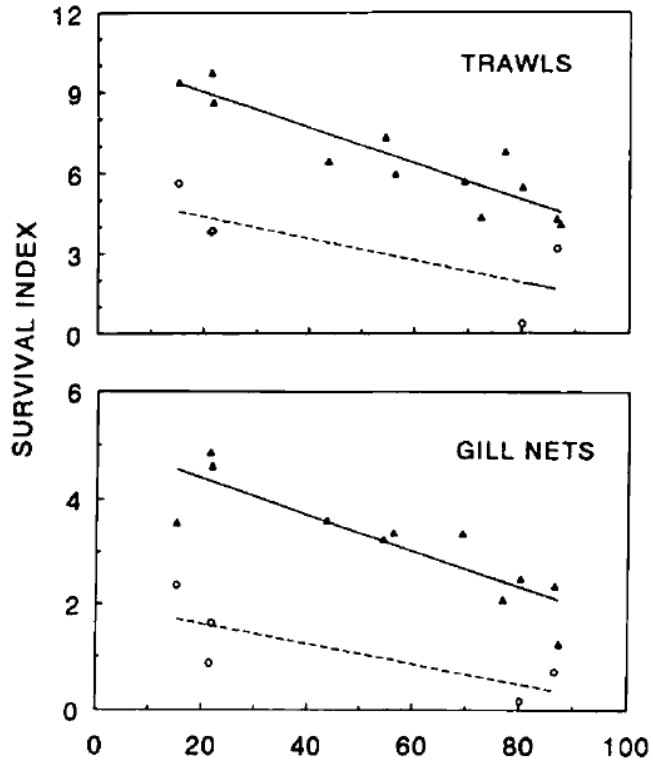


FIGURE 5.—Relation between survival indices of Lake Superior strain lake trout (1979–1990 year-classes) stocked in Lake Ontario as yearlings (triangles, solid lines) and as fingerlings (open circles, dashed lines) and abundance (gill-net catch/transect) of large (≥550 mm total length) lake trout in September in the year of stocking. Survival indices were based on catches with trawls at age 2 and with gill nets at age 3, and were calculated as in Figure 3.

Elrod et al. 1993

Lake Trout
Lake Erie Lessons

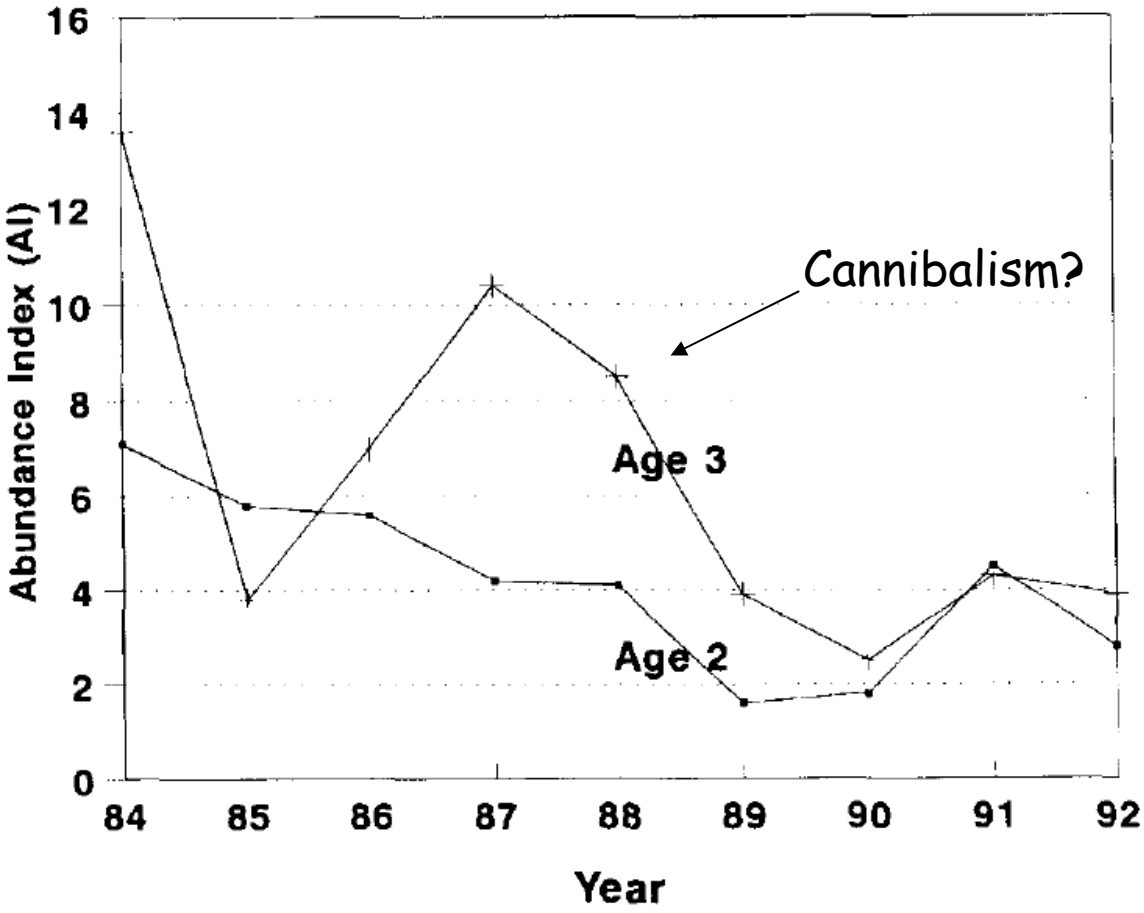
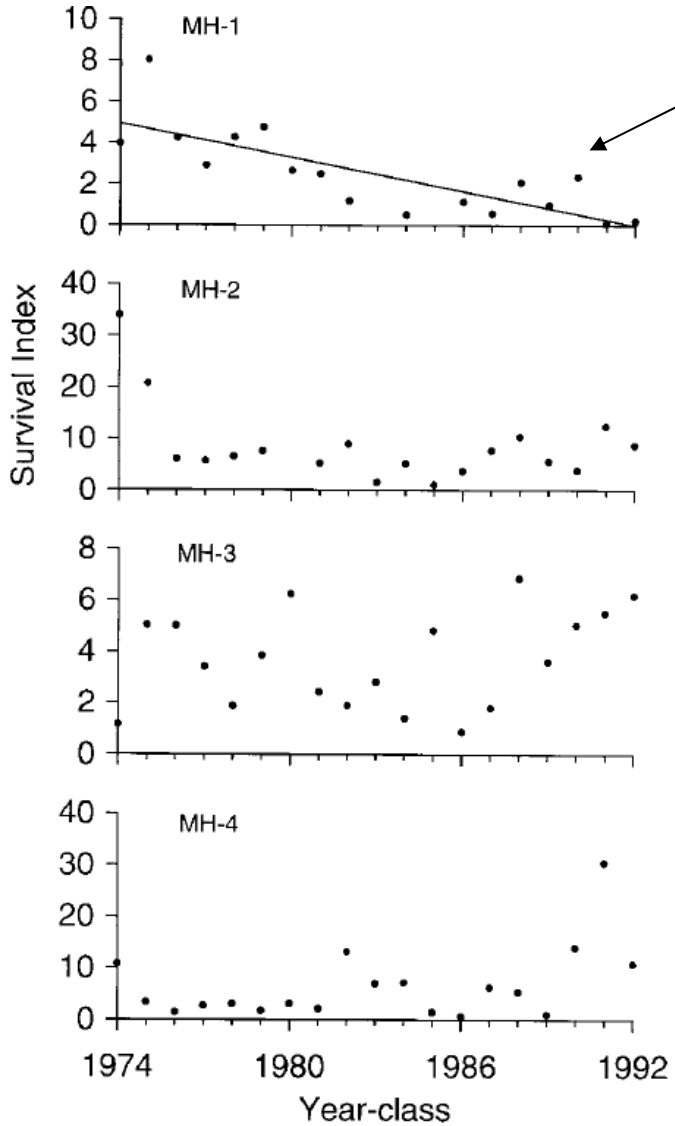


FIG. 7. Relative abundance of age 2 and 3 lake trout from eastern basin Lake Erie, 1984–1992.

Cornelius et al. 1995

Lake Trout
Lake Huron Lessons



Sea lamprey predation?

Wilberg et al. 2002

Lake Trout
Great Lakes Lessons

- Survival of stocked lake trout must decline as population density increases.
- In lakes where survival of stocked lake trout has not declined, density must be low.

Lake Trout
Life History

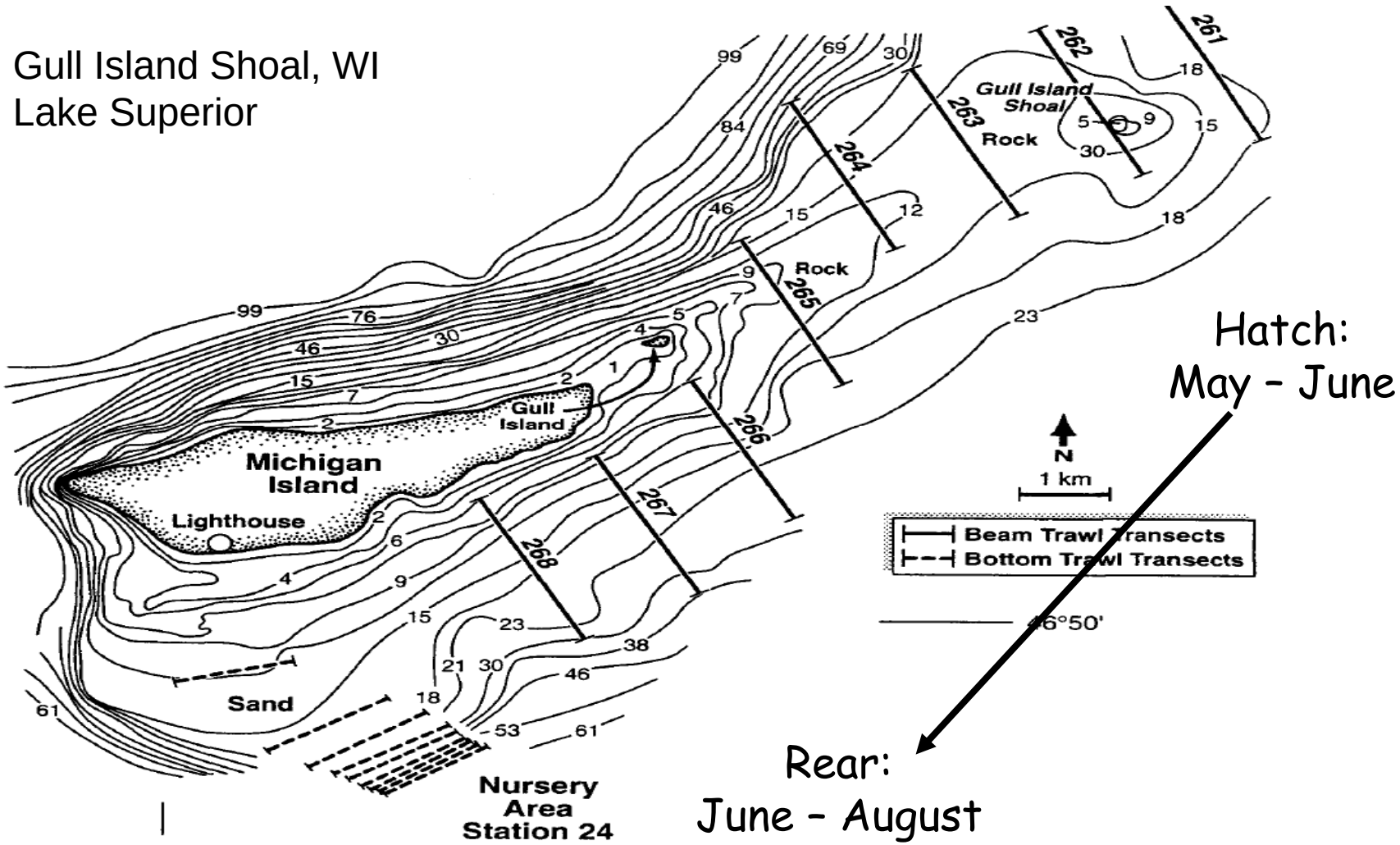
Lake Trout Reproduction

- Spawning:
  - Season = late September – late November.
  - Substrate = gravel, rubble, or boulders.
  - Depth = <1 (small lakes) – 61 m (large lakes).
  - Temperature = 10°C (5 – 15°C).
- Hatching:
  - Incubation = 2 (rivers) – 7 months (Superior).
  - Season = November (rivers) – May-July (Superior).
  - Hatching size = 21.7 mm (20.2 – 23.1 mm).
  - Movement = soon migrate to deep water.

Martin and Olver 1980

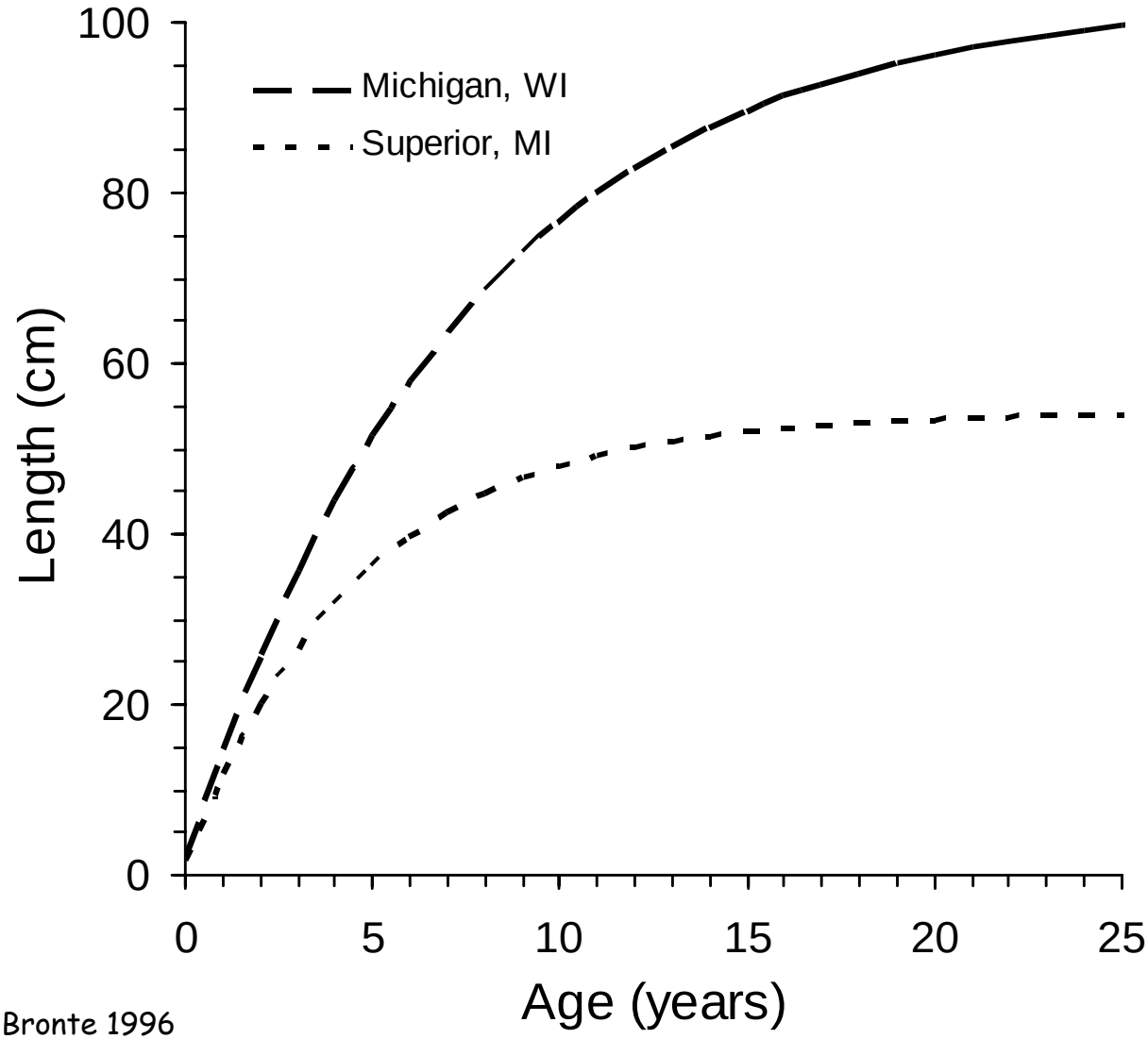
Lake Trout Reproduction

Gull Island Shoal, WI
Lake Superior



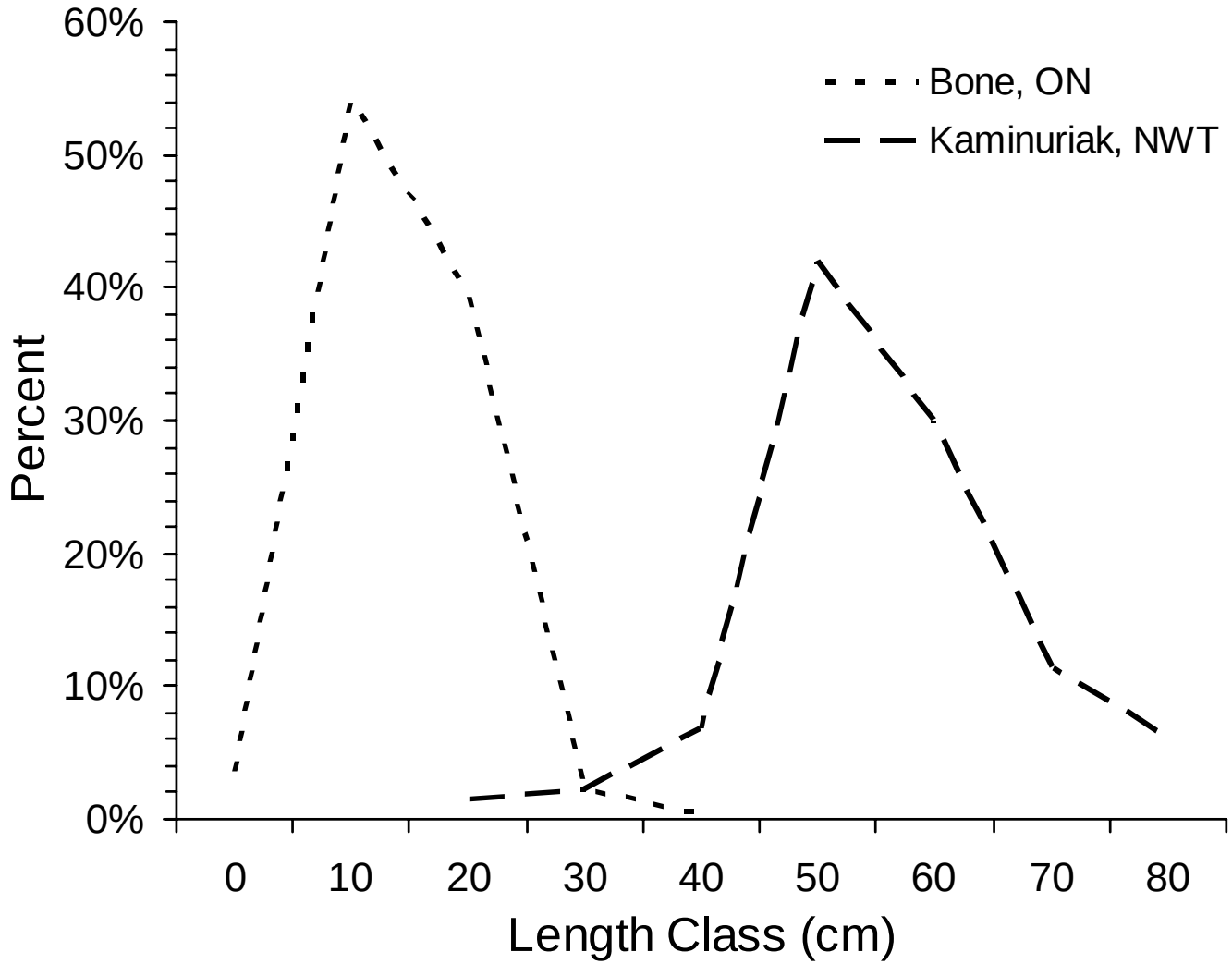
Bronte et al. 1995

Lake Trout Growth



McKee et al. 2004
Burnham-Curtis and Bronte 1996

Lake Trout
Size Structure



Martin and Olver 1980

Lake Trout
Maturity

- Age:
  - Minimum: 42 cm (Lake Tahoe, CA-NV)
  - Maximum: 55 cm (Lake Kaminuriak, NWT)
- Size:
  - Minimum: 4 years (Lake Tahoe, CA-NV)
  - Maximum: 19 years (Lake Kaminuriak, NWT)

Martin and Olver 1980

Lake Trout Fecundity

- Eggs per female:
  - Fewest = 411 (humper, Lake Superior)
  - Average = 5,000 (all, North America)
  - Most = 21,500 (lean, Big Trout Lake, ON)
- Eggs per kg:
  - Lowest = 1,023 (siscowet, Lake Superior)
  - Average = 1,500 (all, North America)
  - Highest = 1,872 (lean, Swan Lake, Alberta)

Martin and Olver 1980

Lake Trout
Longevity

- Age:
  - 62 years (Lake Kaminuriak, NWT)
  - 53 years (Great Bear Lake, NWT)
- Size:
  - Largest reported = 54.5 kg, 120 lb (Superior)
  - All world record = 46.3 kg, 102 lb (Athabasca, SA)
  - IGFA world angling = 32.7 kg, 72 lb (Great Bear)
  - Unofficial angling = 39.5 kg, 87 lb (Bennett, YK)

Martin and Olver 1980
IGFA 2007

Lake Trout
Abundance (Density)

- Numbers:
  - Fewest = 0.87/ha (Cold Stream Pont, ME)
  - Average = 4.35/ha (15 lakes, NA)
  - Most = 14.21/ha (Alluring Lake, ON)
- Biomass:
  - Lowest = 1.12 kg/ha (Indian Lake, QB)
  - Average = 2.90 kg/ha (8 lakes, NA)
  - Highest = 5.46 kg/ha (Cayuga Lake, NY)

Martin and Olver 1980

Lake Trout
Survival (Mortality)

- Natural:
  - Average = 18% (much higher if lampreys).
  - Range = 10–36% (much higher if lampreys).
- Fishing:
  - Highest = 45% (Superior prior to lamprey).
  - Populations decline if harvest > 0.50 kg/ha.
- Total:
  - Populations are sustainable if $A < 50\%$.
  - Most populations decline if $A > 50\%$.

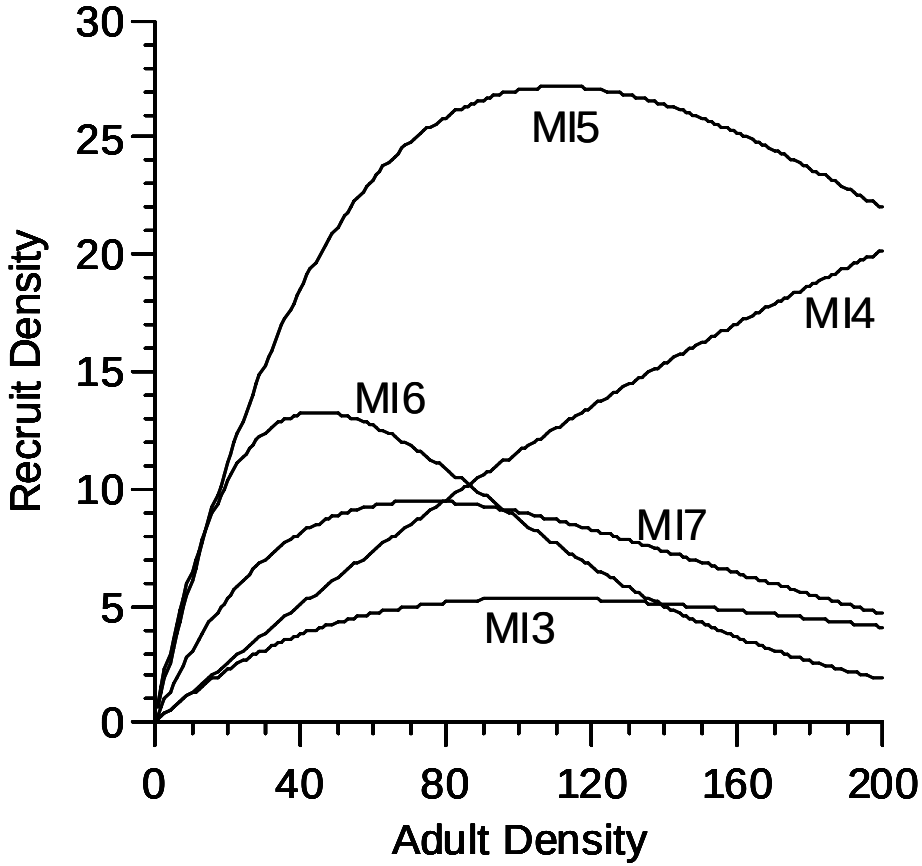
Healey 1978

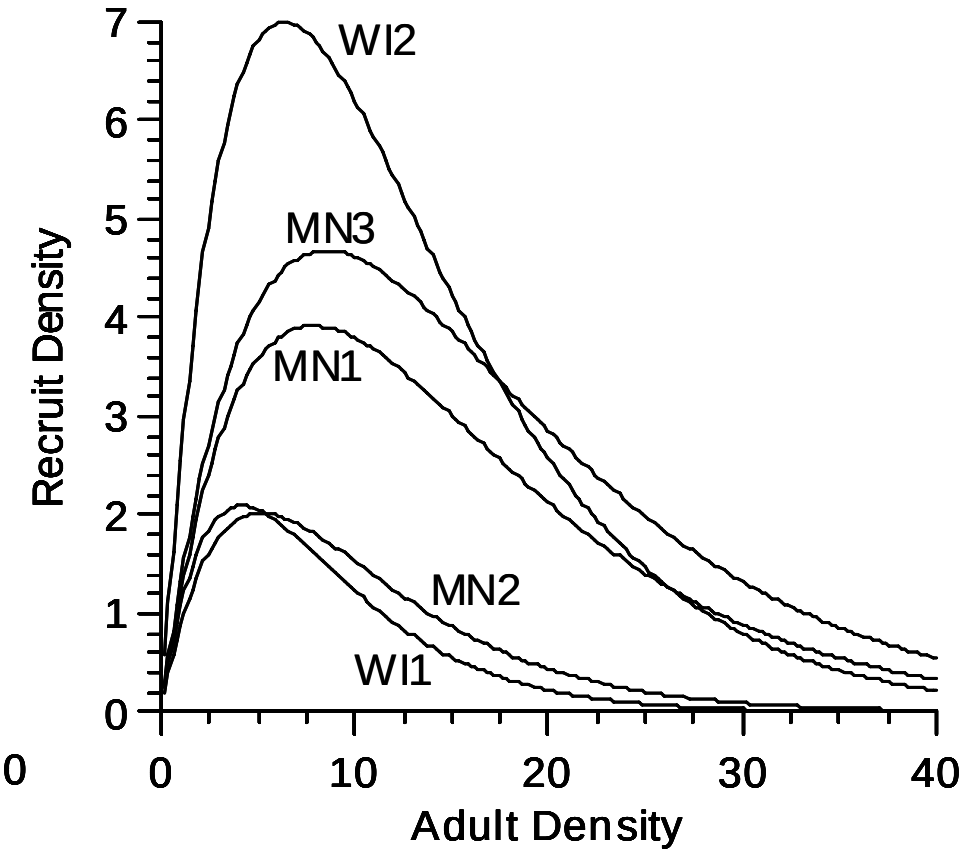
Lake Trout
Life History

- Lake trout are remarkably plastic in their life history attributes (adaptable).
- Lake trout are long-lived and late-maturing, which makes them vulnerable to over-fishing.
- Fishing and sea lamprey mortality will often impede recovery programs in the Great Lakes.

Lake Trout Recruitment Regulation

Lake Trout
Recruitment Regulation

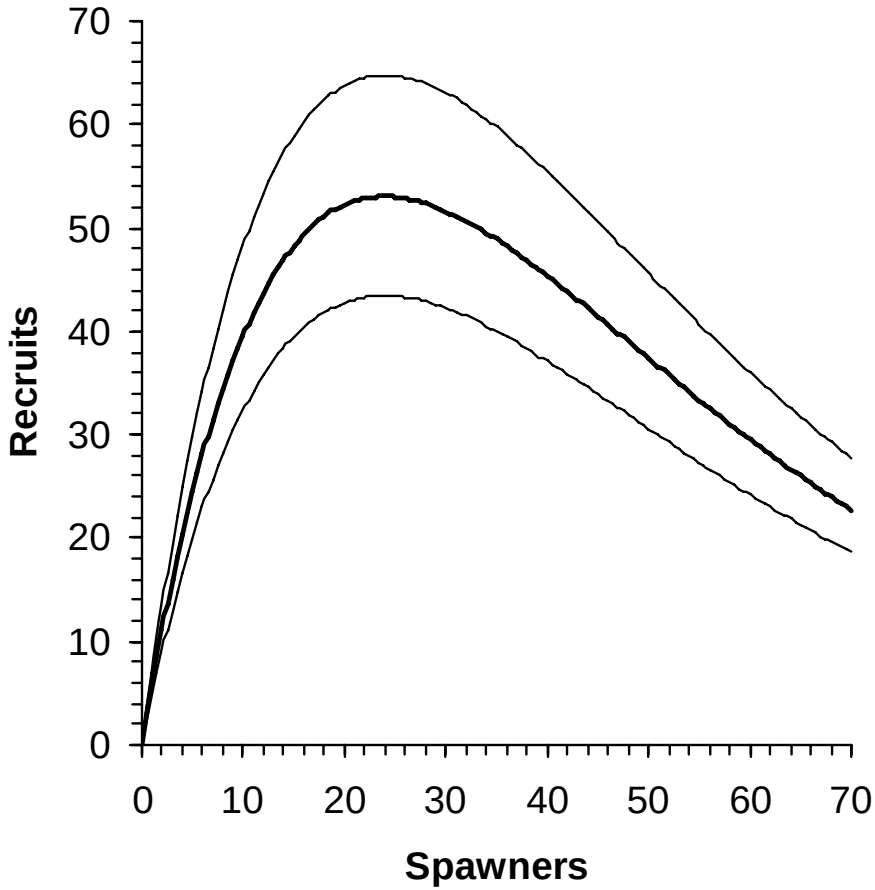




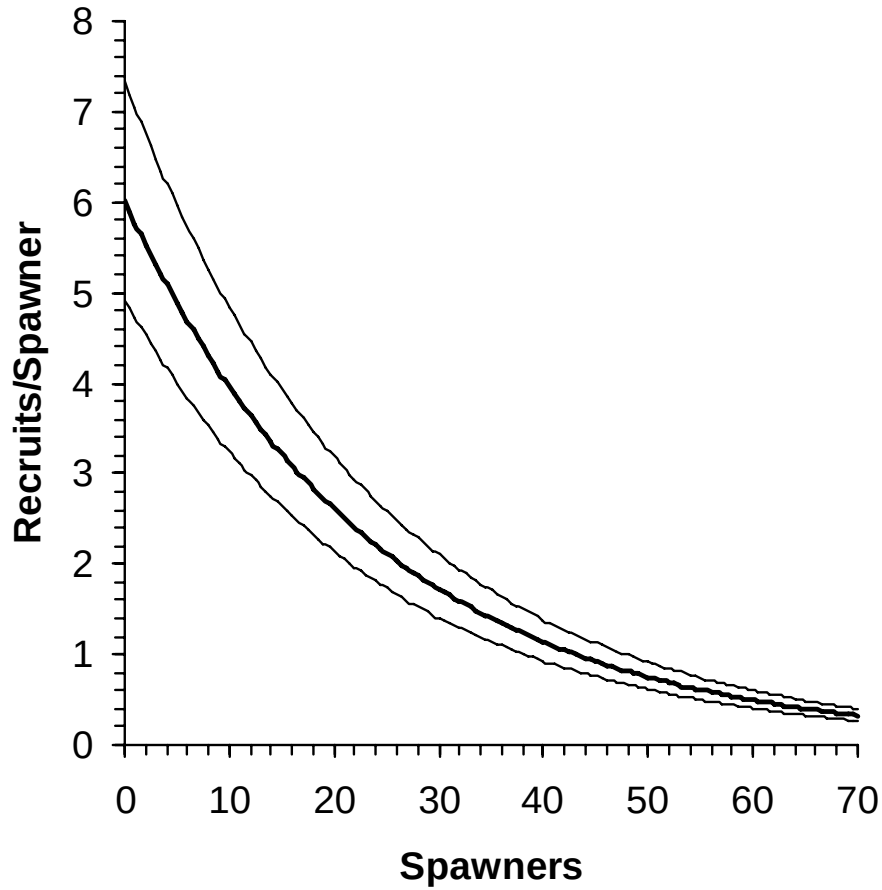
Richards et al. 2004
Corradin et al. 2008

Lake Trout Recruitment Regulation

$$N_{j=0} = \alpha N_{j=8+} e^{-\beta N_{j=8+}} e^{\varepsilon}$$



$$N_{j=0} / N_{j=8+} = \alpha e^{-\beta N_{j=8+}} e^{\varepsilon}$$



Myers et al. 1999

Lake Trout Recruitment Regulation

- Potential Mechanisms (RESTORE themes):
  - Genetics (Burnham-Curtis et al. 1995).
  - Spawning habitat (Marsden et al. 1995).
  - Stock size (Selgeby et al. 1995).
  - Biotic interactions (Jones et al. 1995).
  - Ecology and evolution (Eshenroder et al. 1995).
  - Toxic substances (Zint et al. 1995).

Healey 1978

Lake Trout Recruitment Regulation

- Genetic diversity.
  - Loss of genetic diversity constrains the future of rehabilitation programs, so conserve what's left.
  - Some genetic strains seem better able to survive sea lamprey predation, so match strains to habitat.
  - Lean lake trout are the focus of rehabilitation programs, but why ignore other forms?
  - *Diversify lake trout forms to maximize use of deep water habitat!*

Healey 1978

Lake Trout Recruitment Regulation

- Spawning habitat.
  - When present, lake trout reproduce (e.g. western lakes; many areas of inshore Lake Superior).
  - When absent, lake trout fail to reproduce (e.g. many areas of Superior, Huron, and Michigan).
  - Stocking early life stages on offshore reefs will overcome lack of imprinting (Bronte et al. 2002).
  - *Failure in some areas is simply a mismatch of life history stages to available spawning habitat!*

Healey 1978

Lake Trout
Recruitment Regulation

- Stock size.
  - Early survival is likely limited by cannibalism as a natural feature of population rehabilitation.
  - Survival to adulthood is limited by fishing and sea lamprey mortality in most Great Lakes.
  - *Adult stock size and recruitment is limited by ineffective regulation of mortality!*

Healey 1978

Lake Trout Recruitment Regulation

- Biotic interactions.
  - Lake trout proliferate wherever predators are absent (Lake Superior, western lakes).
  - Native predators may be stronger regulators of lake trout survival at low lake trout density.
  - Non-native predators (e.g. alewife) are most likely to limit survival of lake trout eggs or fry.
  - Non-native prey (e.g. alewife) may limit early survival of lake trout (EMS).
  - *The alewife is bad for lake trout restoration!*

Healey 1978

Lake Trout Recruitment Regulation

- Ecology and evolution.
  - Young lake trout avoid living near their parents by moving into deep water.
  - Young lake trout rely on large-bodied invertebrate prey in large lakes (e.g. *Mysis relicta*).
  - Deepwater habitat with abundant large-bodied prey favors high early survival of lake trout.
  - *Early survival of stocked lake trout should be very high in the Great Lakes!*

Healey 1978

Lake Trout Recruitment Regulation

- Toxic substances.
  - "Exposure to toxic substances has the possibility of limiting early survival of lake trout."
  - "The greatest witch hunt of the 1970s, and we've yet to burn a witch (Jim Kitchell, pers. comm.)."
  - *Toxic substances are not likely limiting early survival of lake trout in the Great Lakes!*

Healey 1978

Lake Trout
Recruitment Regulation

- Diversify lake trout forms to maximize use of available deepwater habitat.
- Match life history stages to the location of spawning habitat when stocking.
- Control fishing mortality to maximize adult survival and abundance.
- Suppress alewife populations by over-stocking chinook salmon.

Lake Trout Survey Needs

Lake Trout
Survey Purpose

- Lake trout are late maturing and long lived, so are vulnerable to recruitment over-fishing (e.g. Great Lakes).
- Stock assessment must be designed to detect recruitment over-fishing and to estimate the harvestable surplus.
- Stock assessment must *also* be designed to evaluate progress toward rehabilitation or restoration goals.

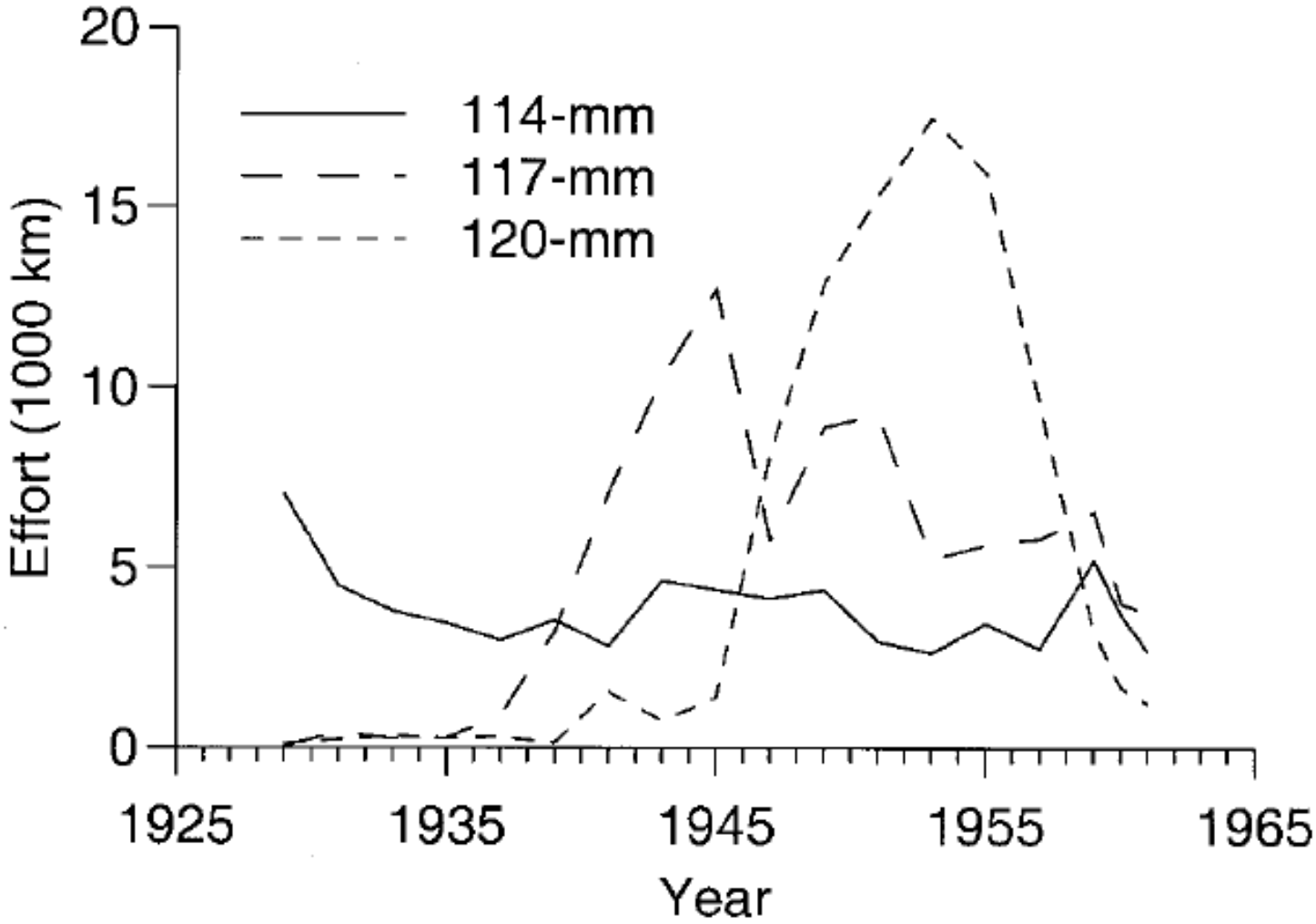
Lake Trout
Survey Types

- Fishery dependent surveys provide subjective index of fishery attributes.
- Fishery independent surveys provide objective index of stock status.
- Stock assessment is more powerful if both survey types are employed!

Lake Trout
Survey Types

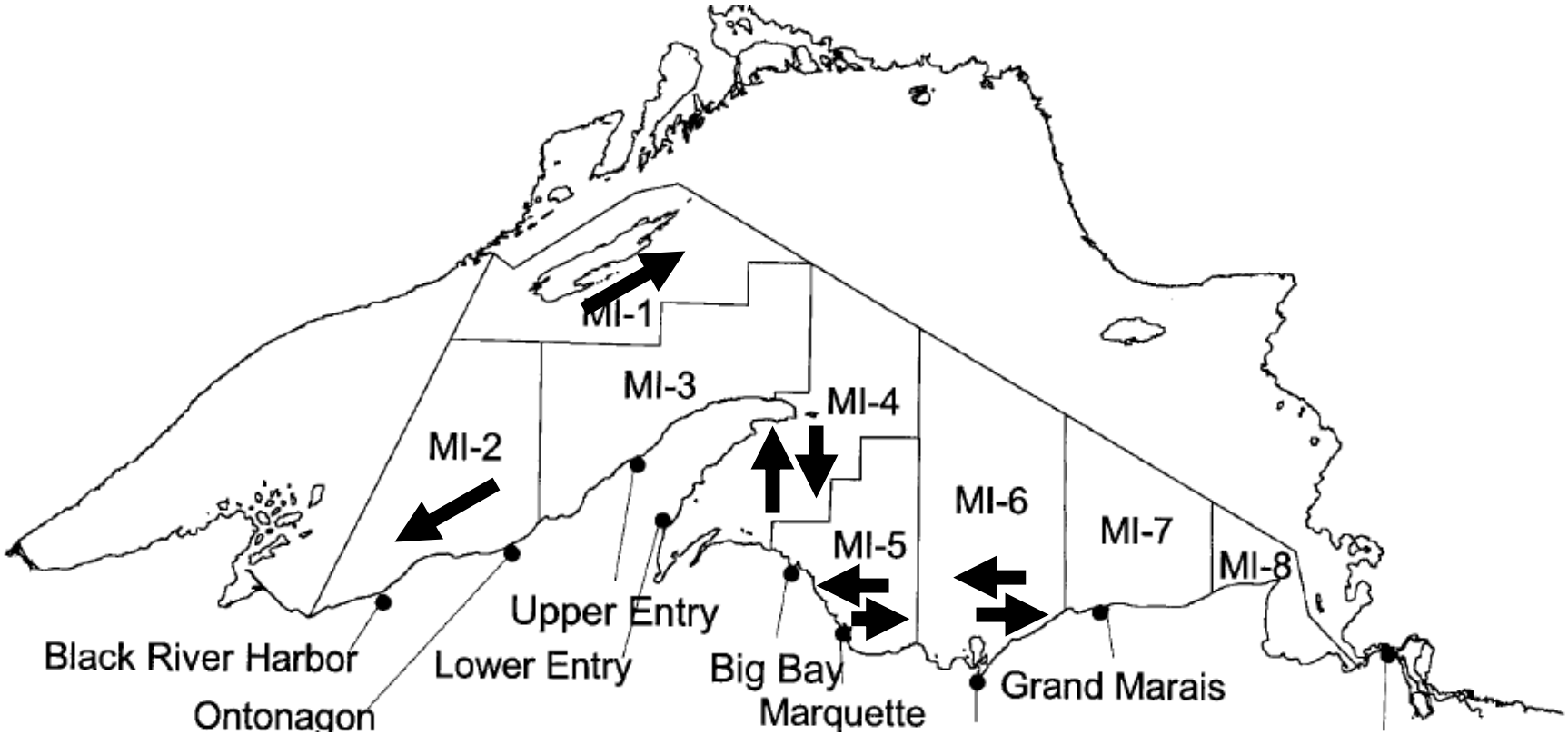
- Fishery dependent surveys:
  - Fishery attributes (effort and catch) must accurately reflect fishing locations!
  - Accuracy of reporting is muddled by external factors (IRS, mistrust of management agency).
  - Incorporate on-board monitoring to provide objective feedback on accuracy!

Lake Trout
Survey Types



Wilberg et al. 2004

Lake Trout
Survey Types

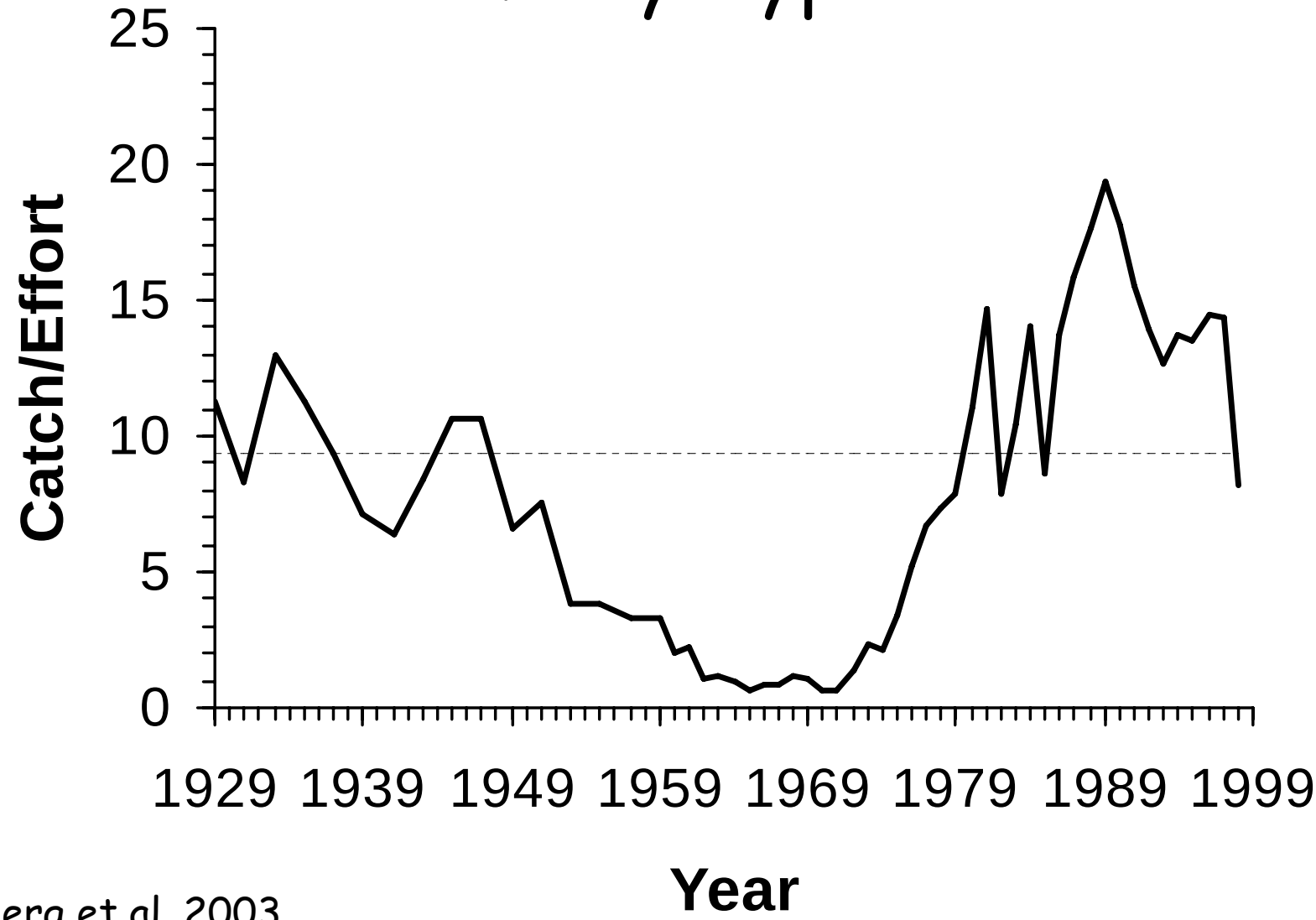


Wilberg et al. 2004

Lake Trout
Survey Types

- Fishery independent surveys:
  - Sampling stations, fixed or random, are not targeted for high catch/effort!
  - Catch/effort reflects underlying trends in stock abundance (assumption).

Lake Trout
Survey Types



Wilberg et al. 2003

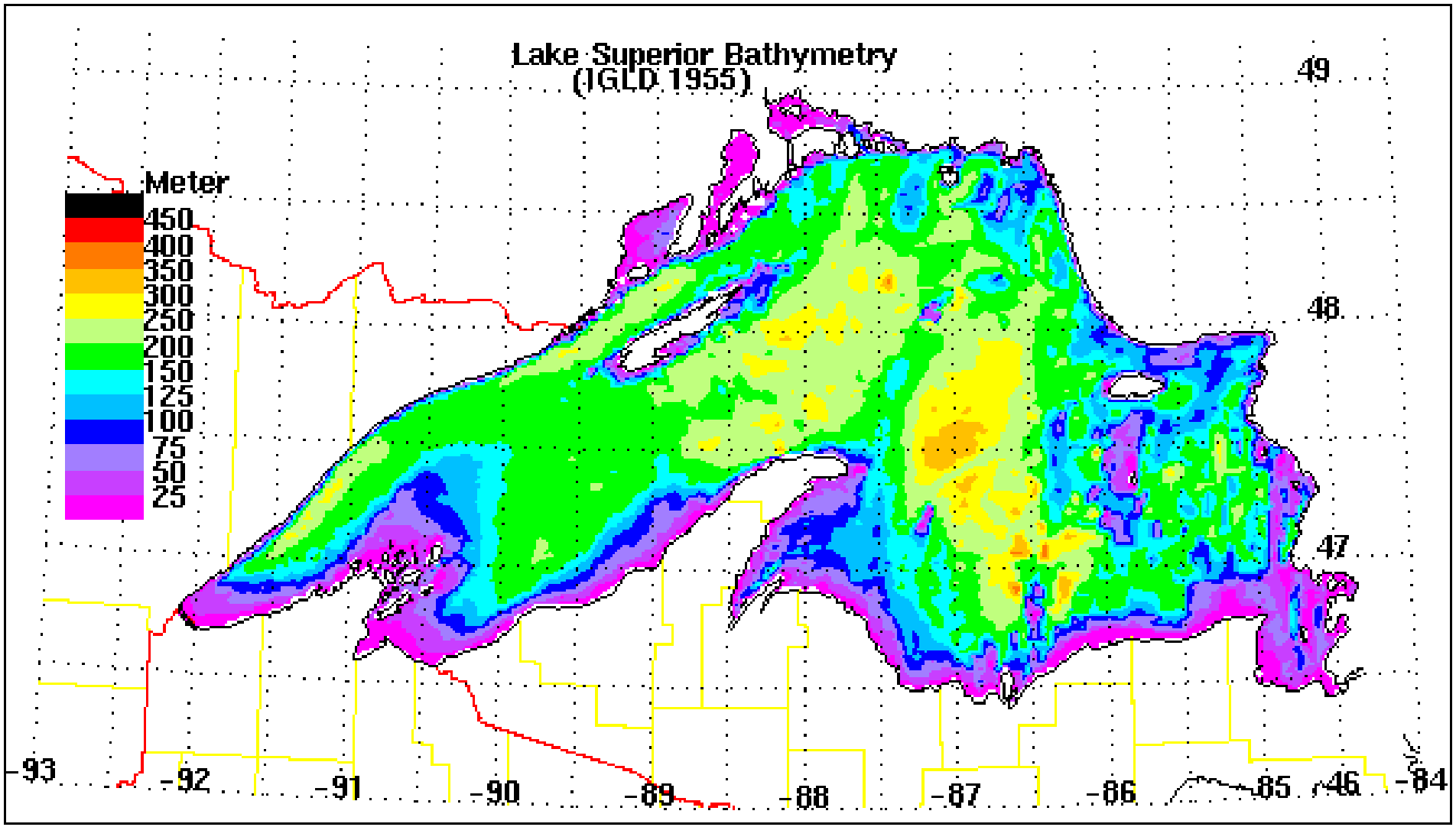
Lake Trout
Survey Designs

- Spatial scale must match the spatial dynamics of the stock or stocks.
  - In large lakes, multiple stocks likely exist that each require assessment.
- Temporal scale must relate to value of the stock or stocks.
  - For large lakes, uniqueness of systems require that assessments be annual.

Lake Trout
Survey Designs

- Large complex stocks are unique, so are generally not sampled randomly.
  - Assessments should be distributed to sample the full range of each stock.
  - Assessments should be conducted annually because costs are justified by value.
- Example: Lake Superior.

Lake Trout
Survey Designs



Lake Trout
Survey Designs

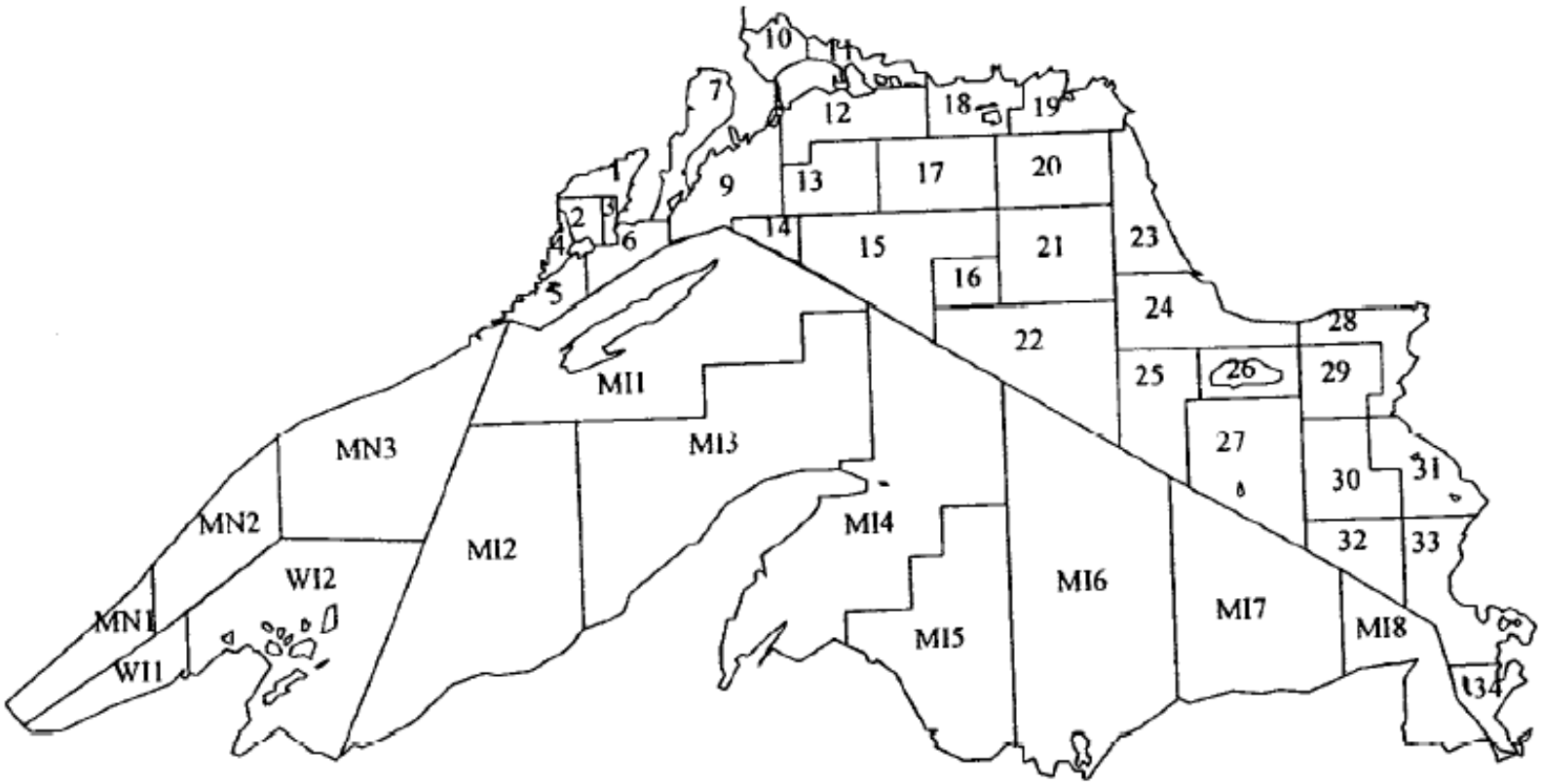
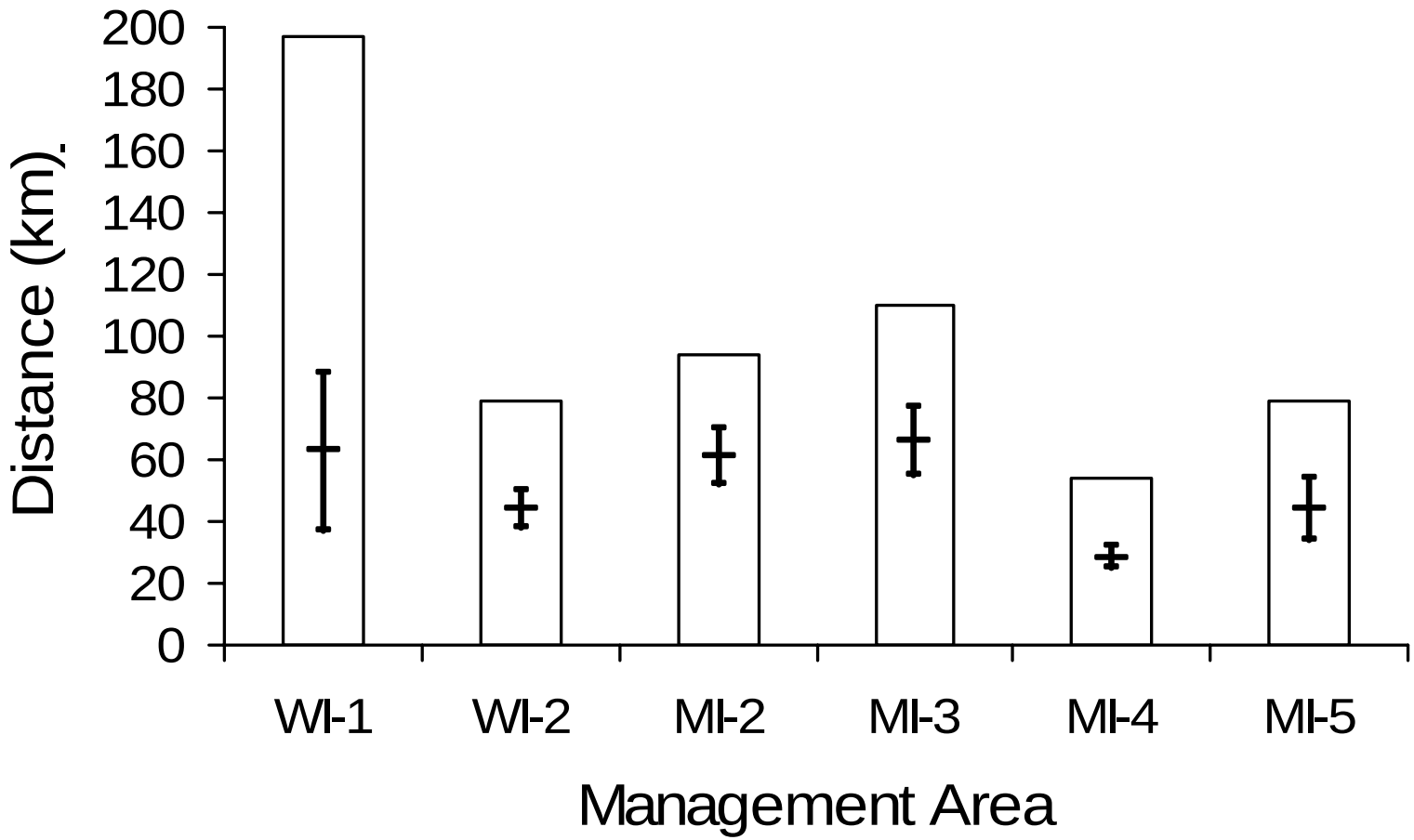


Fig 1. Lake Superior lake trout-management areas.

Lake Trout
Survey Designs



Kapuscinski et al. 2005

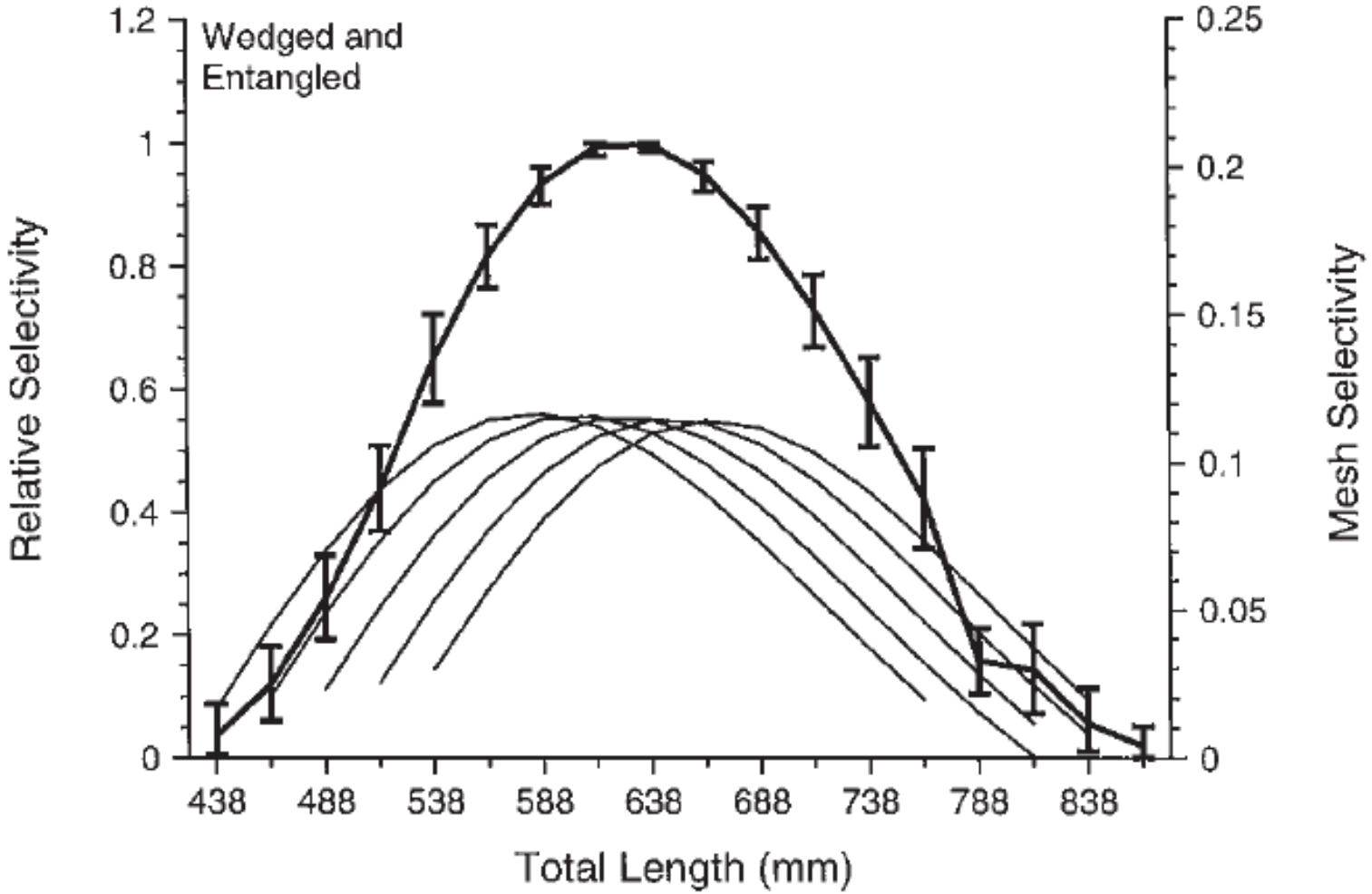
Lake Trout Survey Designs

- Index sampling.
  - Management areas within lakes treated as distinct stocks.
  - Sampling sites within areas are at fixed index locations.
- Annual sampling.
  - All index sites in each management area are sampled each year.
  - Sites distributed throughout depth range of lean lake trout (≤ 40 fathoms).

Lake Trout
Survey Methods

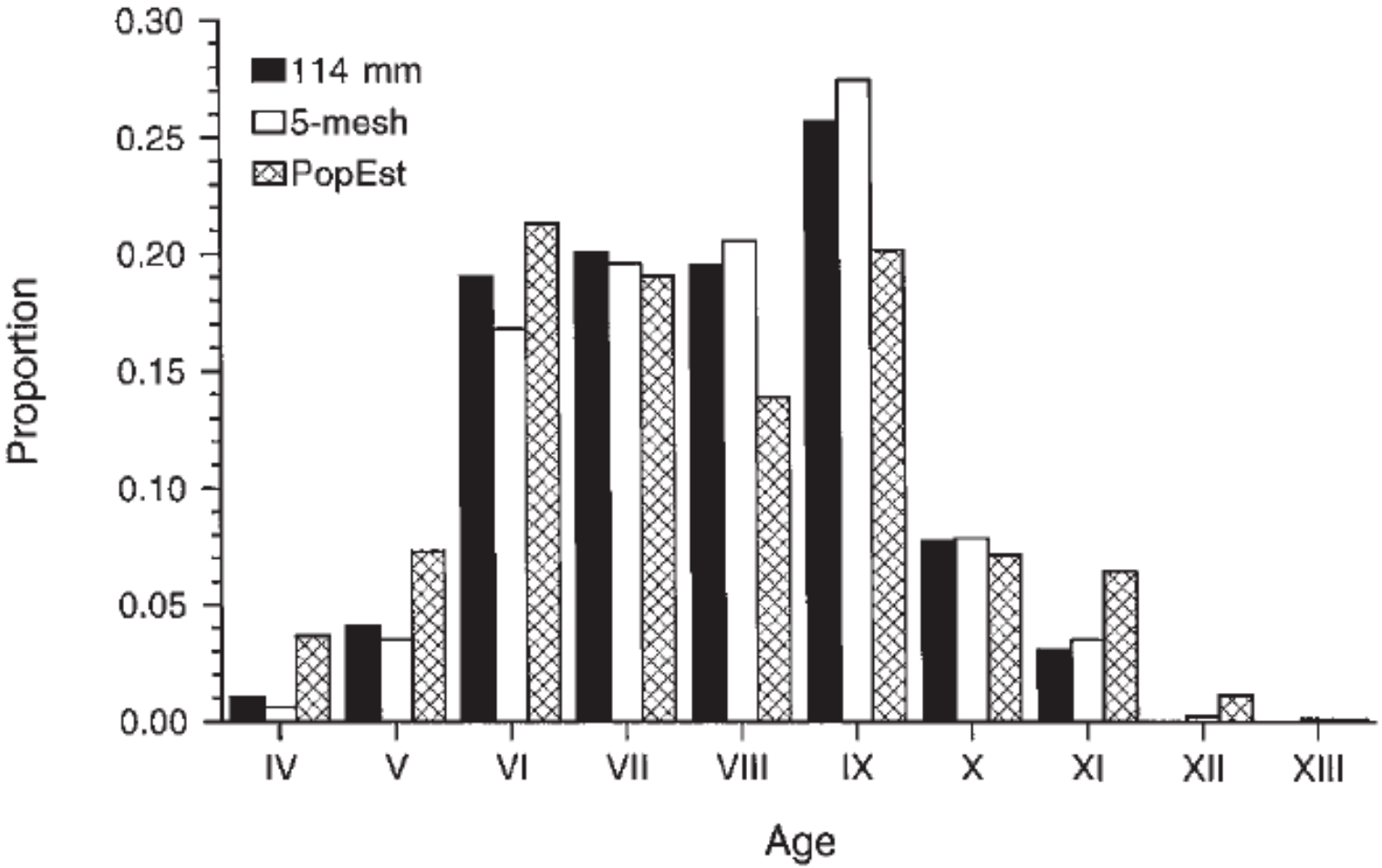
- Example: Lake Superior.
  - Index adult abundance from catches in spring in 114-mm gillnets (age composition).
  - Index recruitment from catches in summer in 51- and 64-mm gillnets (age composition).
  - Mandatory reporting of commercial fishing effort and harvest (on-board monitoring).
  - Creel surveys of recreational fishing effort (counts) and catch rates (interviews).
  - Index fish community and lake trout recruitment with trawling survey.

Lake Trout
Survey Methods



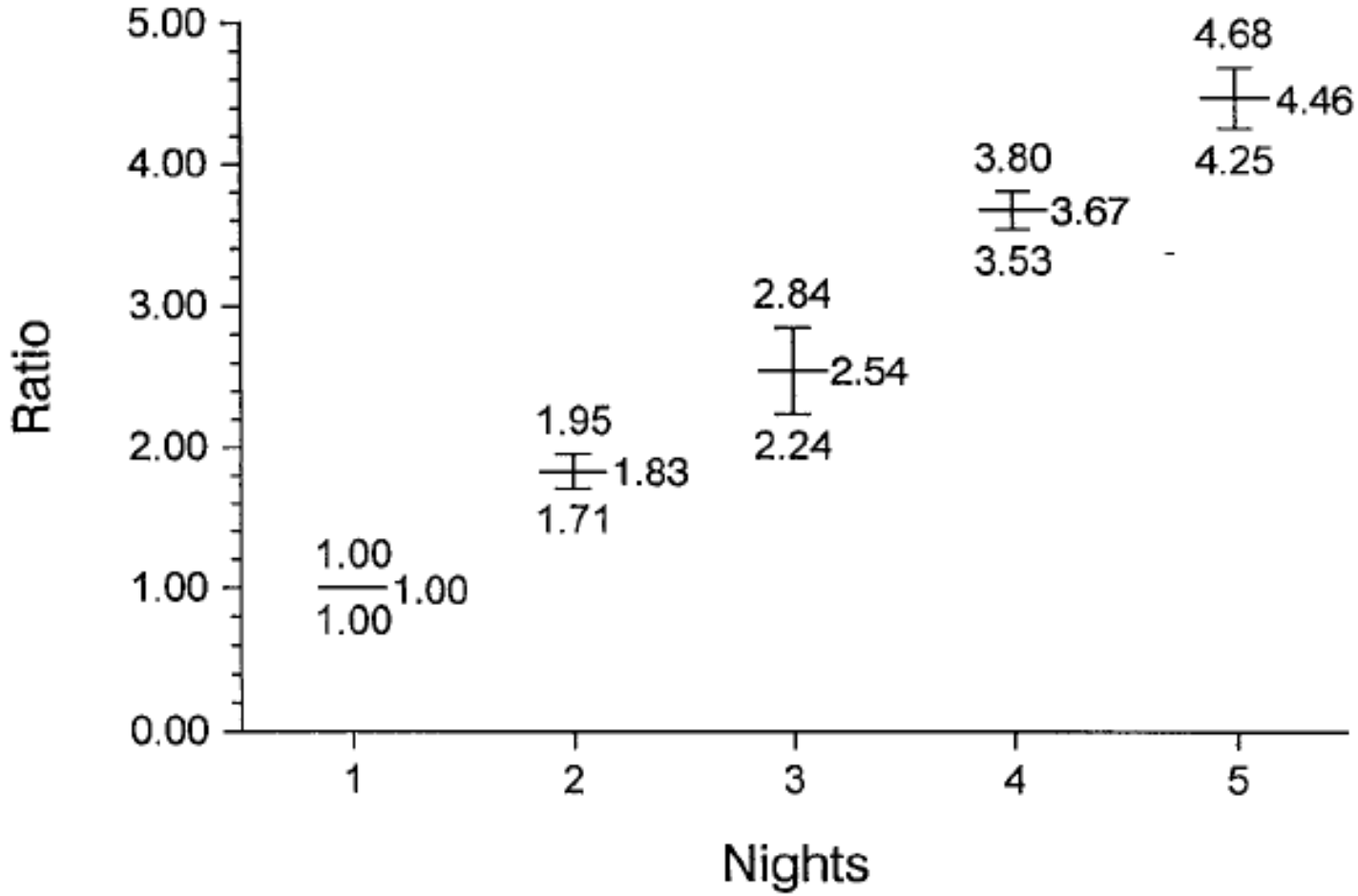
Hansen et al. 1997

Lake Trout
Survey Methods



Hansen et al. 1997

Lake Trout
Survey Methods



Hansen et al. 1998

Lake Trout
Survey Methods

- Surveys used in the Laurentian Great Lakes are generally more spatially and temporally comprehensive than in other lakes.
- However, must still study catchability and selectivity of the gear to understand how the gear reflects population attributes!
- Stock assessment methods (SCAA) enable the estimation of gear efficiency and selectivity while estimating population attributes.


The End!
Questions?
Cabela's
GORE-TEX