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Synoptic Assessment of Lake Whitefish Population Indicators for Sustainable Great Slave Lake Fisheries

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Great Slave Lake Advisory Committee Meeting
Nov 6-7, 2018, Hay River, NWT

Canada

Outline

- **Biological characteristics**
  - ✓ Life history
  - ✓ Spatiotemporal dynamics
  - ✓ Fisheries production
- **Ecological traits**
  - ✓ Trophic properties
  - ✓ Intrinsic vulnerability
- **Socio-ecological drivers**
  - ✓ Subsistence harvest
  - ✓ Indigenous participation
  - ✓ Expert knowledge bank
  - ✓ Bayesian Belief Network (BBN)
- **Acknowledgements**

- Great Slave Lake (GSL): Arctic Great Lake
- 9th largest lake
- The deepest lake in North America

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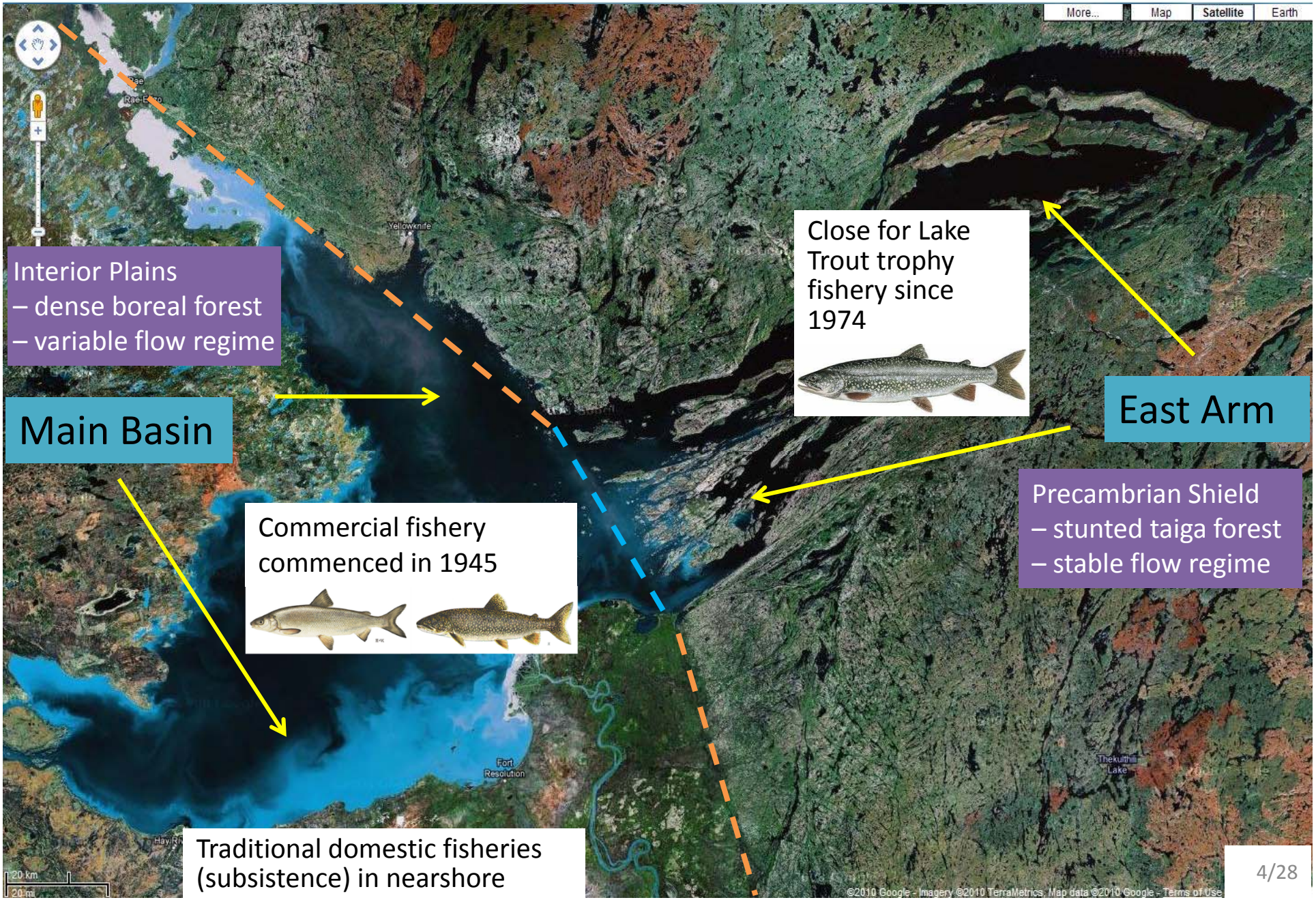


Interior Plains
– dense boreal forest
– variable flow regime

Main Basin

Commercial fishery commenced in 1945

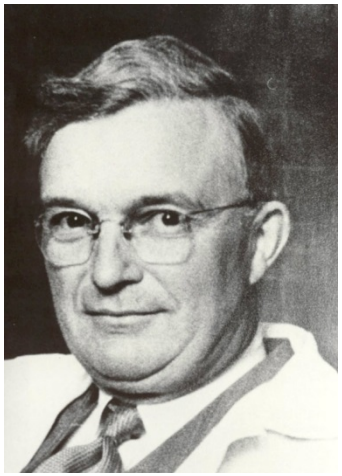
Close for Lake Trout trophy fishery since 1974

East Arm

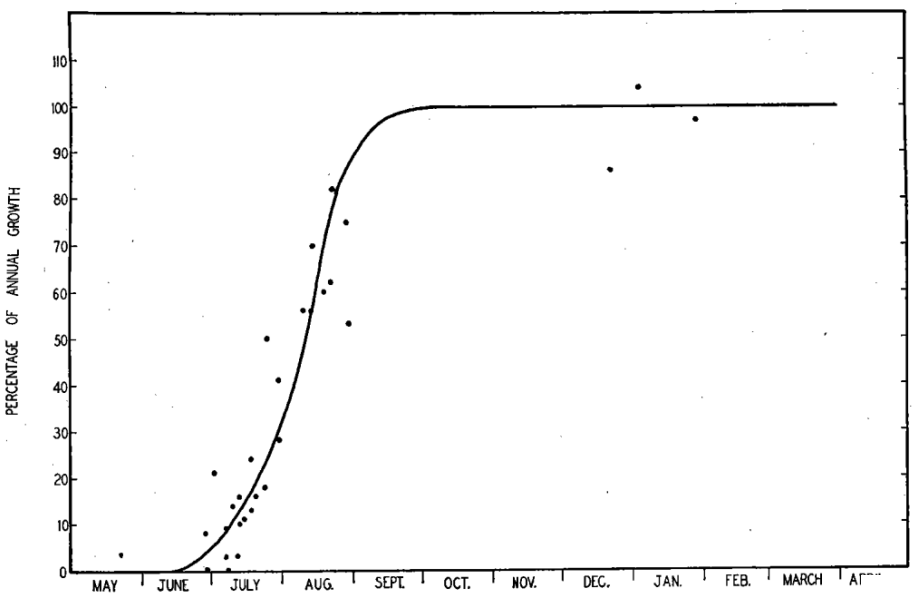
Precambrian Shield
– stunted taiga forest
– stable flow regime

Traditional domestic fisheries (subsistence) in nearshore

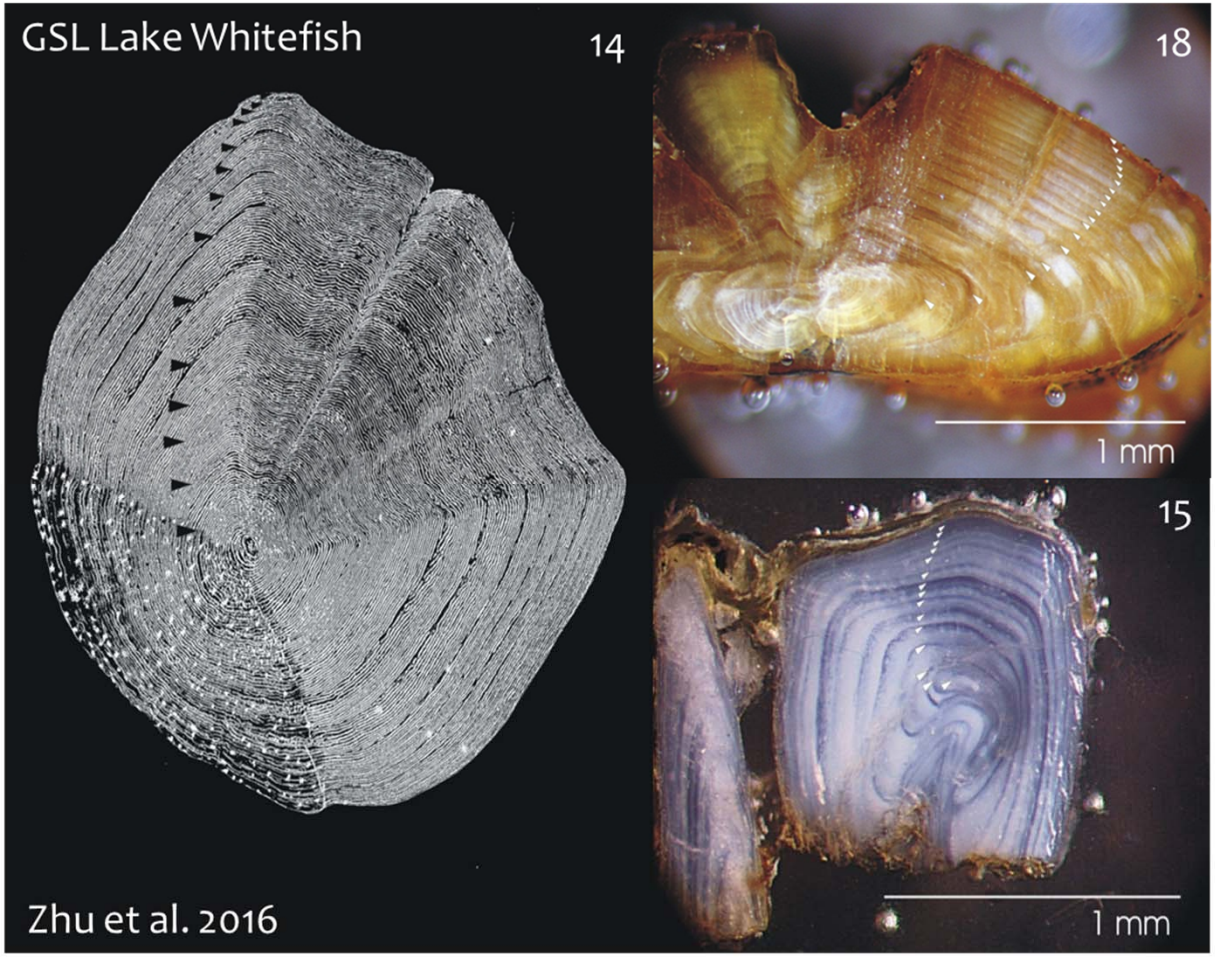
Biological Characteristics—Life History



- Donald Rawson (U. SasK.) in 1947-49 pioneered the GSL fish production studies → incepted GSL commercial fisheries.
- W.A. Kennedy (U. Toronto), in 1950-53, conducted studies of growth, mortality and reproduction of Lake Whitefish in GSL → basis of fishing quota.
- M.C. Healey (DFO), in 1975-78, reviewed mortality, growth, reproduction and stock size of unexploited and exploited Lake Whitefish→
  - ✓ Growth ~ Exploitation (+)
  - ✓ Growth ~ Mortality (-)
  - ✓ Maturation ~ Exploitation (-)



Age and Growth



- Divergence between scale and otolith ages is delayed by 5–6 years relative to more southerly populations;
- Fin rays do not offer a suitable nonlethal alternative for ageing older Lake Whitefish (>11 years).

Zhu et al. 2015. North American Journal of Fisheries Management 35:262–270

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Spatiotemporal Dynamics

Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans
Canadian Science Advisory Secretariat (CSAS)
Research Document 2015/038
Central and Arctic Region

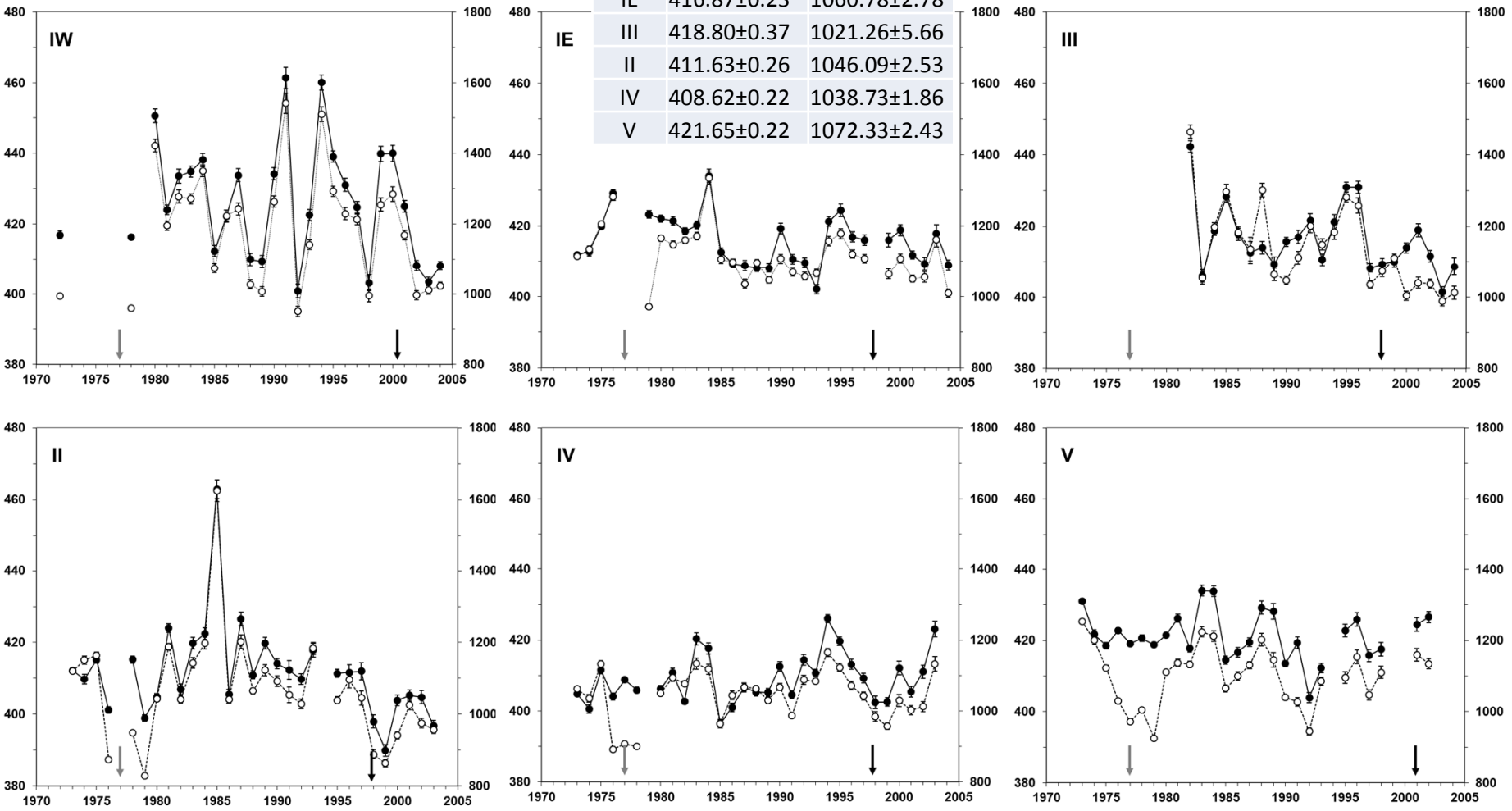
http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2015/2015_038-eng.html

Hierarchical modelling of spatiotemporal dynamics of biological characteristics of Lake Whitefish, *Coregonus clupeaformis* (Mitchill), in Great Slave Lake, Northwest Territories, Canada, 1972–2004

Xinhua Zhu[1], A. Chris Day[1], W. E. Fred Taptuna[2], Theresa J. Carmichael[1], and Ross F. Tallman[1]

- Significant differences in the length and weight over years and management areas

Area	FK_Len	RD_WT
IW	426.11±0.33	1072.66±4.04
IE	416.87±0.23	1060.78±2.78
III	418.80±0.37	1021.26±5.66
II	411.63±0.26	1046.09±2.53
IV	408.62±0.22	1038.73±1.86
V	421.65±0.22	1072.33±2.43



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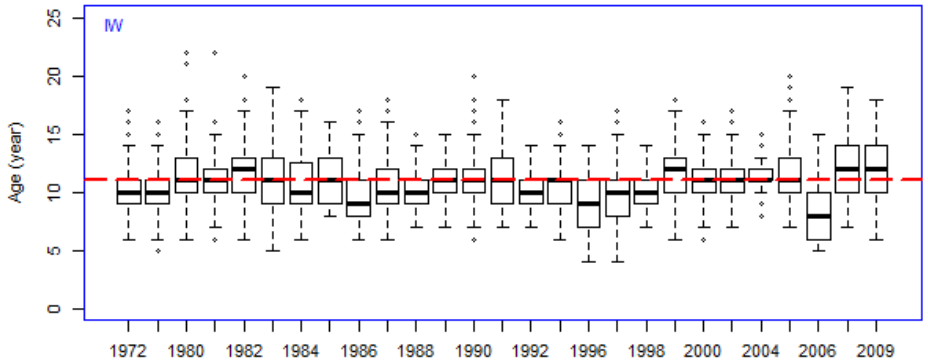
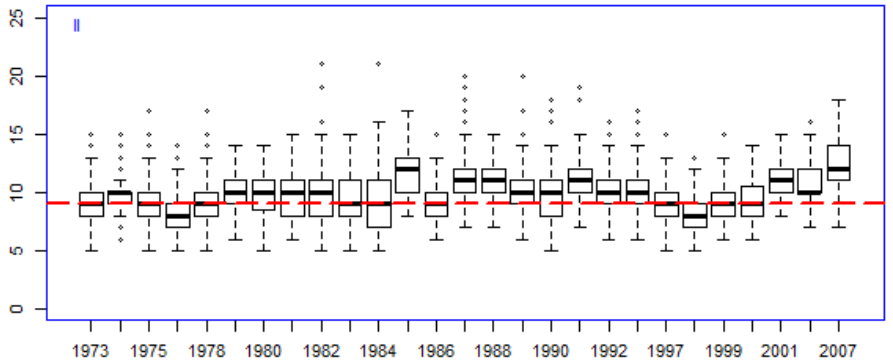
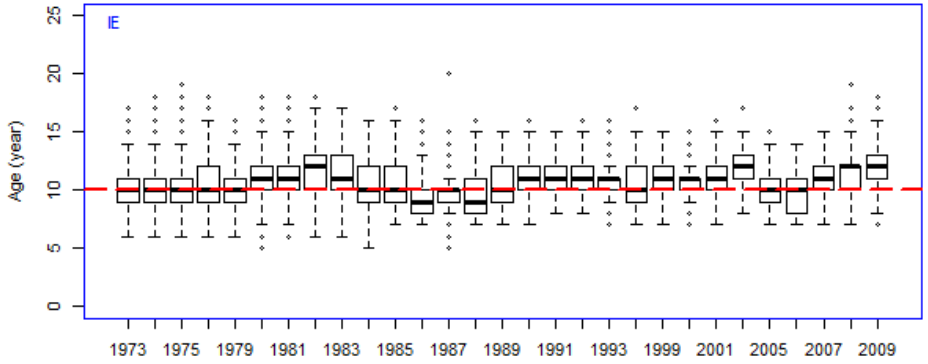
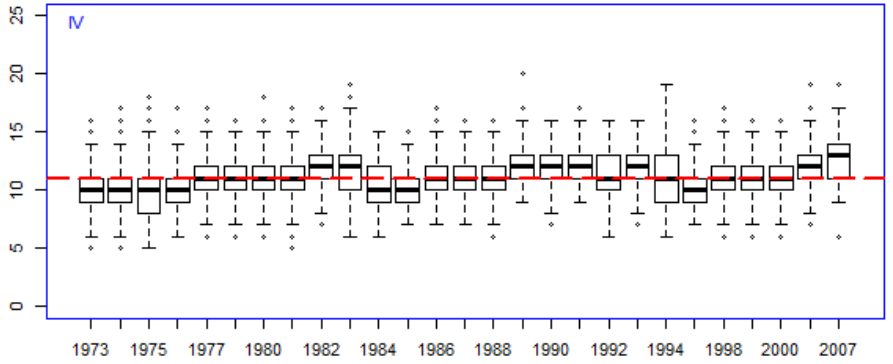
Spatiotemporal Dynamics

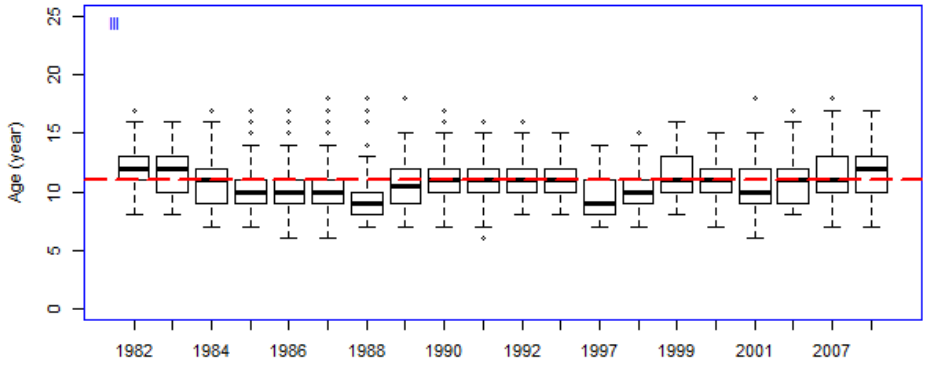
Area	Age
IW	11.29±0.02
IE	11.17±0.02
III	11.54±0.03
II	10.17±0.02
IV	11.37±0.02
V	12.18±0.02

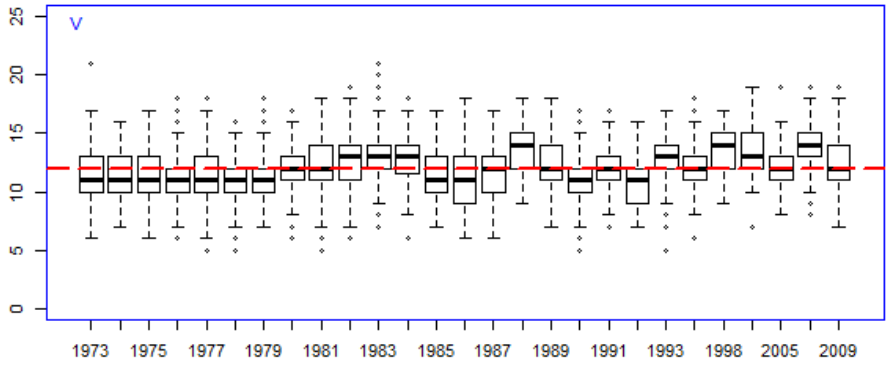












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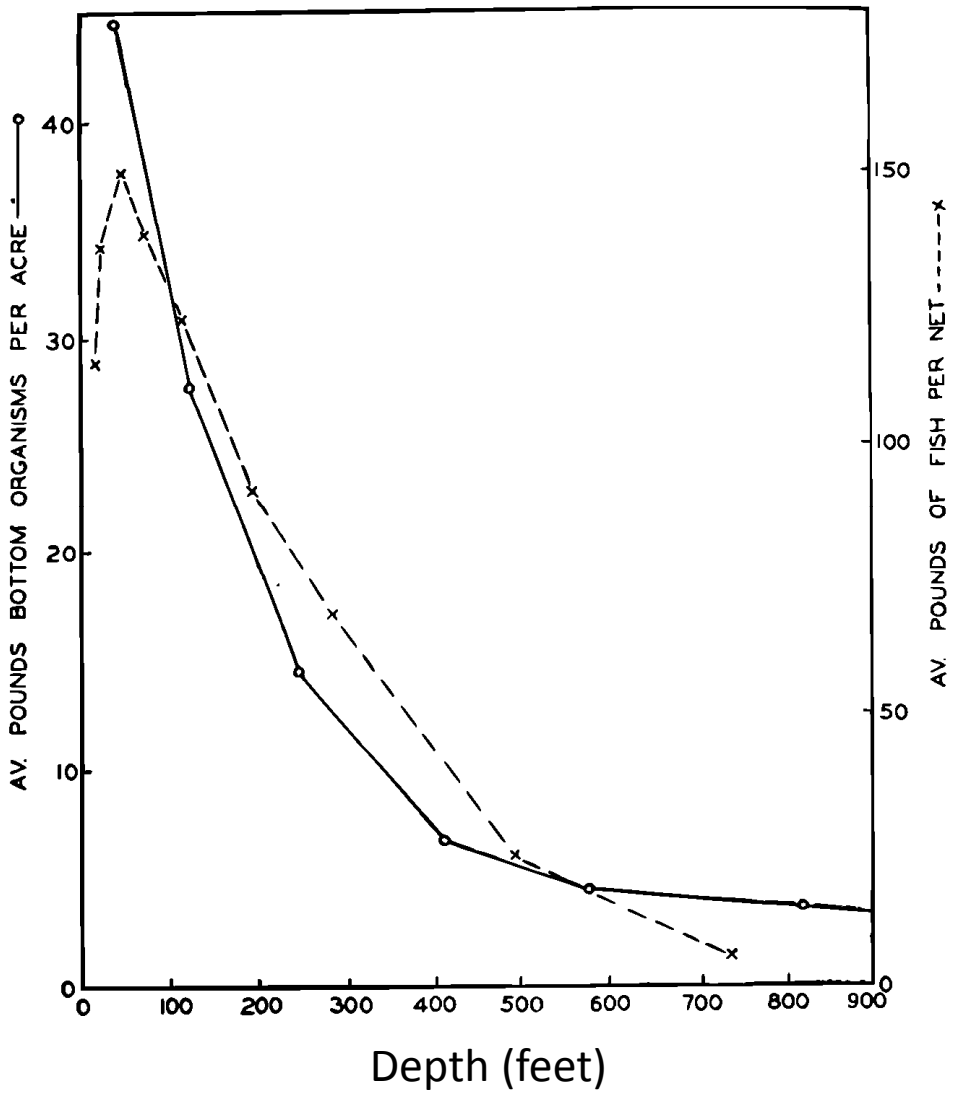
journal homepage: www.elsevier.com/locate/jglr

Modeling spatiotemporal variabilities of length-at-age growth characteristics for slow-growing subarctic populations of Lake Whitefish, using hierarchical Bayesian statistics

Xinhua Zhu *, Ross F. Tallman, Kimberly L. Howland, Theresa J. Carmichael

smaller and slower-growing fish were mainly distributed in deep waters, while larger and faster-growing fish inhabited shallow waters.

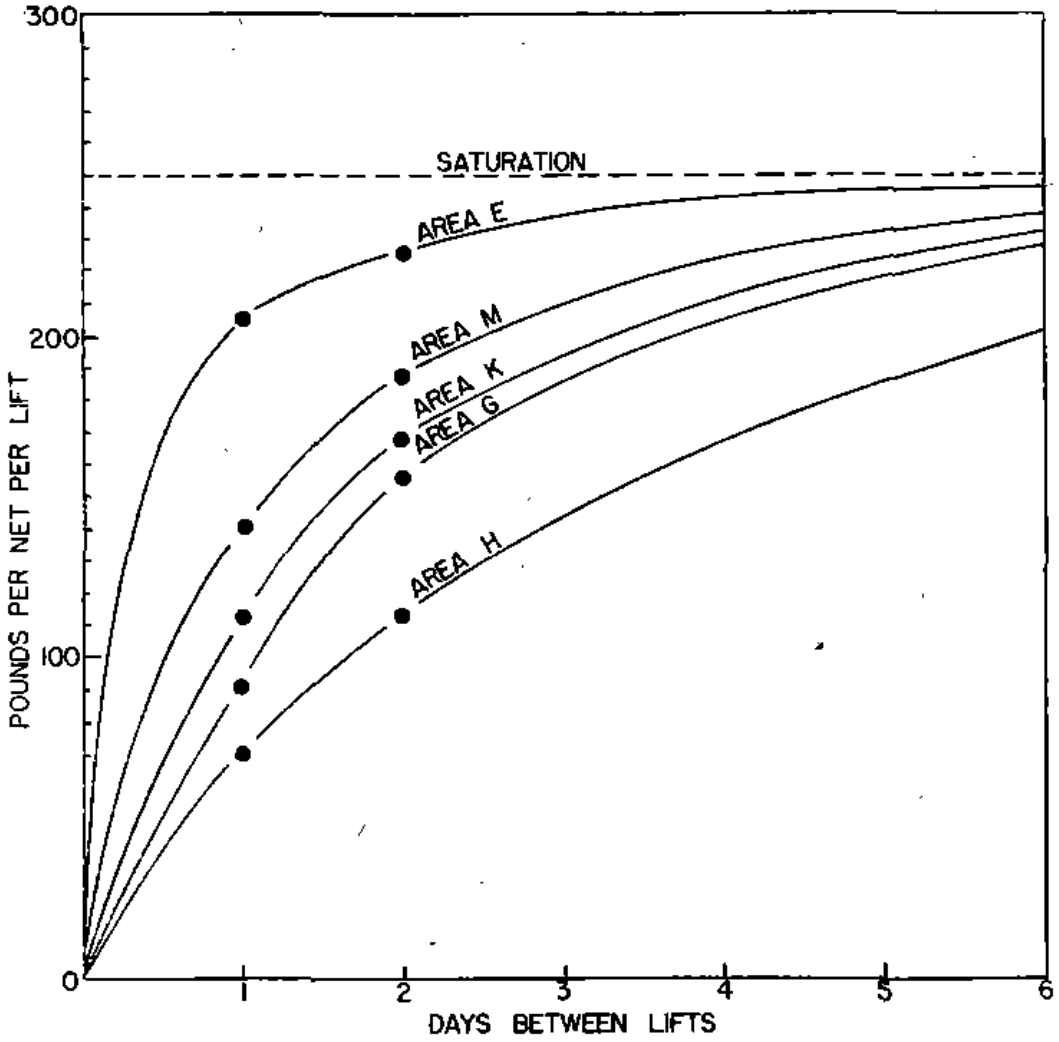
Fisheries Production



Rawson (1947) reported:

- Bottom organisms and fish production decrease with increasing depth, and
- There is a significant correlation between bottom organisms and fish production in GSL.

Fisheries Production (cont.)



Kennedy (1951) documented that the greater the catch per net was made in nets that are cleared daily; the less will be the relative increase in catch per net when they cleared every two days.

Fisheries Production (cont.)

- Rawson (1949). TAFS 77: 81-92.

A biological survey of Great Slave Lake was begun in 1944 in order to estimate its capacity for fish production before commercial fishing began. This great inland lake of 10,500 square miles was found to have a fairly heavy population of desirable fish with lake trout, lake whitefish, and ciscoes predominating. Physical, chemical, and biological evidence suggested a capacity for sustained production not unlike that of the upper Great Lakes and Lake Nipigon. A first estimate of 3 to 5 million pounds per year was made in December 1944. Commercial fishing began in 1945 and has now increased to a point where production is 3.7 million pounds per year. General biological studies extended over 4 years, and a continuing program has been established to follow the effects of fishing on the fish population. This lake affords a unique opportunity for the scientific investigation of a large fishery and for the conservation of an important natural resource.

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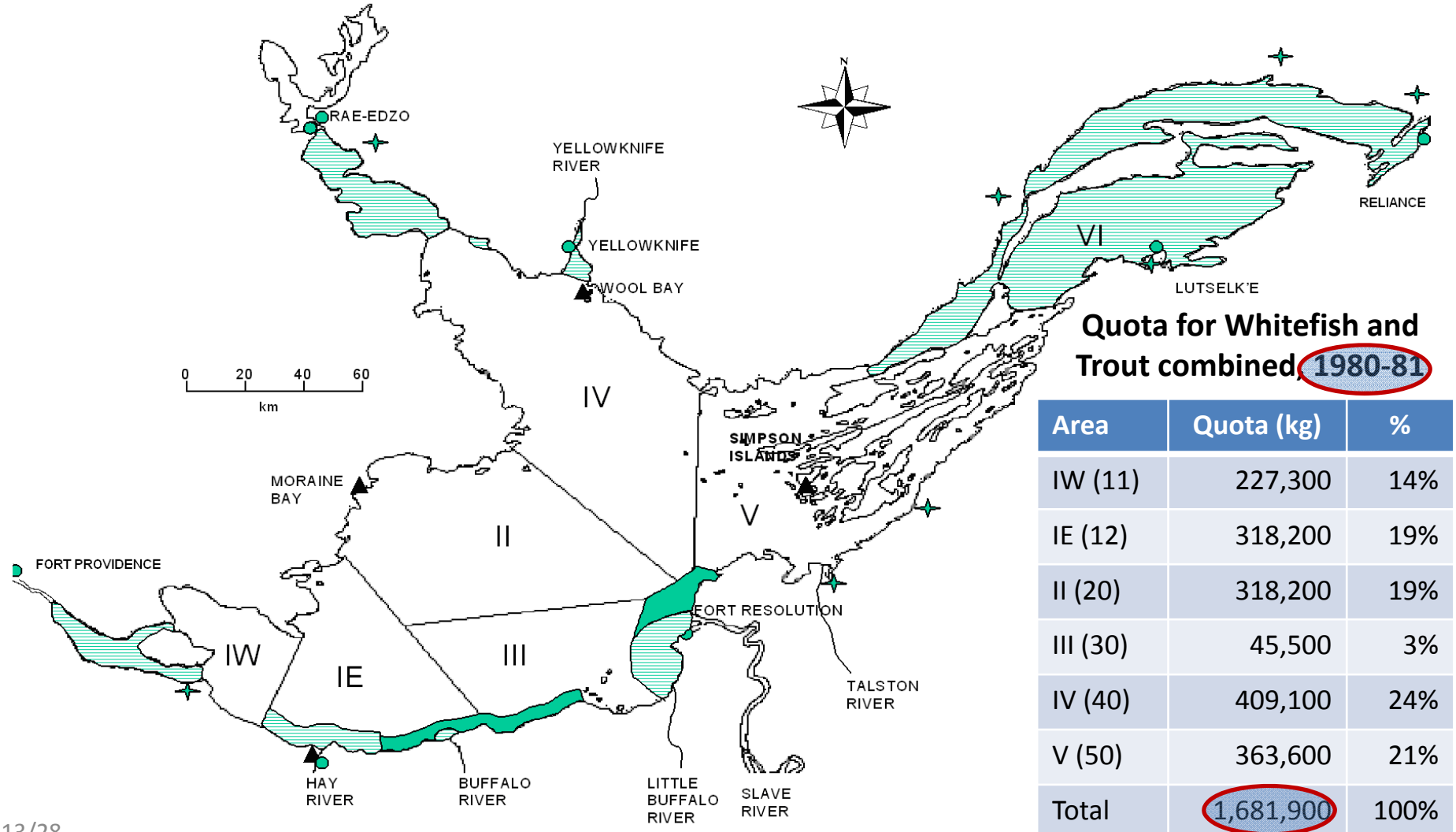
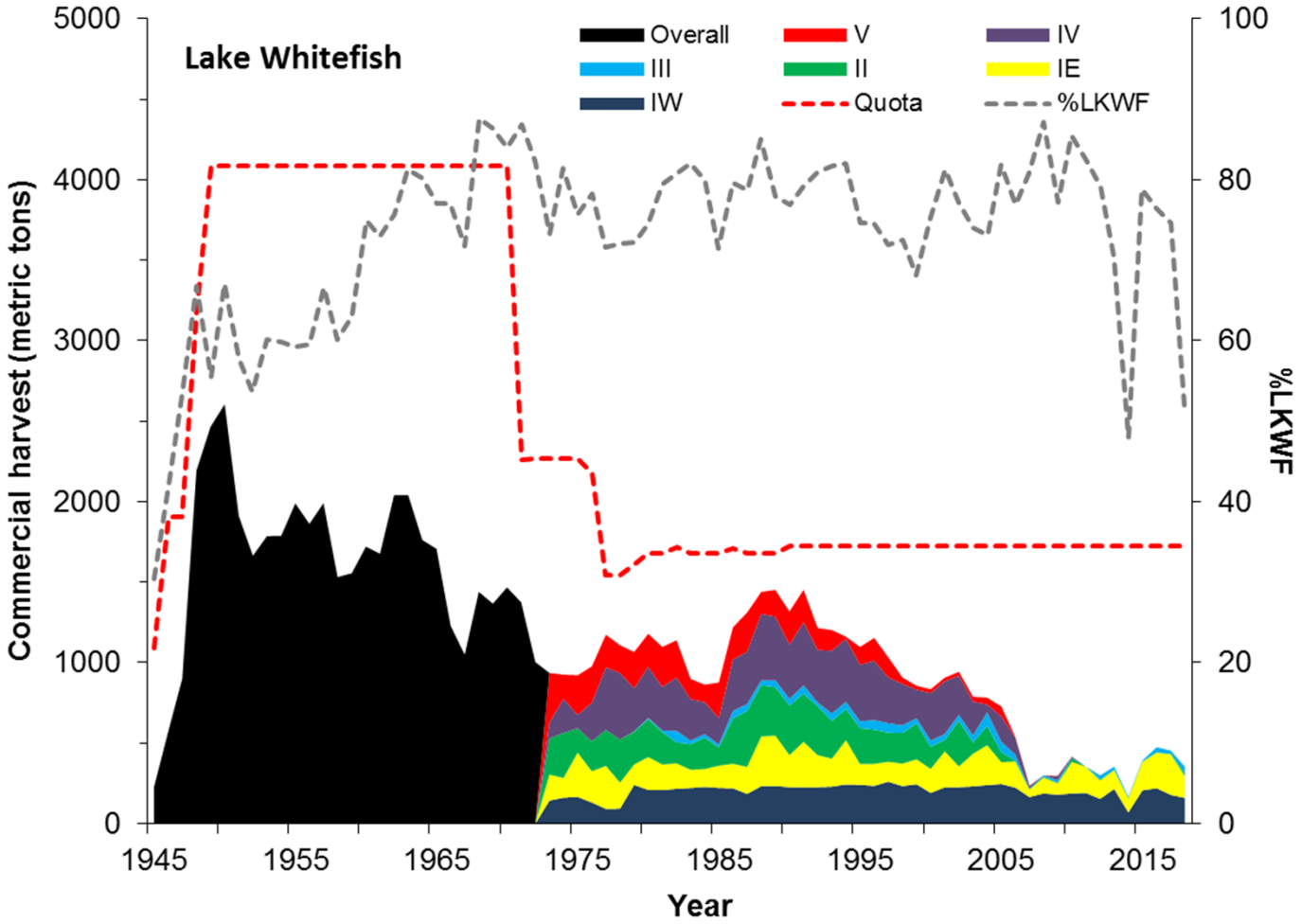
GSL Fisheries Management Regime



Quota for Whitefish and Trout combined, 1980-81

Area	Quota (kg)	%
IW (11)	227,300	14%
IE (12)	318,200	19%
II (20)	318,200	19%
III (30)	45,500	3%
IV (40)	409,100	24%
V (50)	363,600	21%
Total	1,681,900	100%

GSL Commercial Fisheries



- Lake Whitefish are the target species sought by commercial fisheries, accounted for ~80%
- Since 2000, commercial harvest main came from the western basin, unproportione d catch

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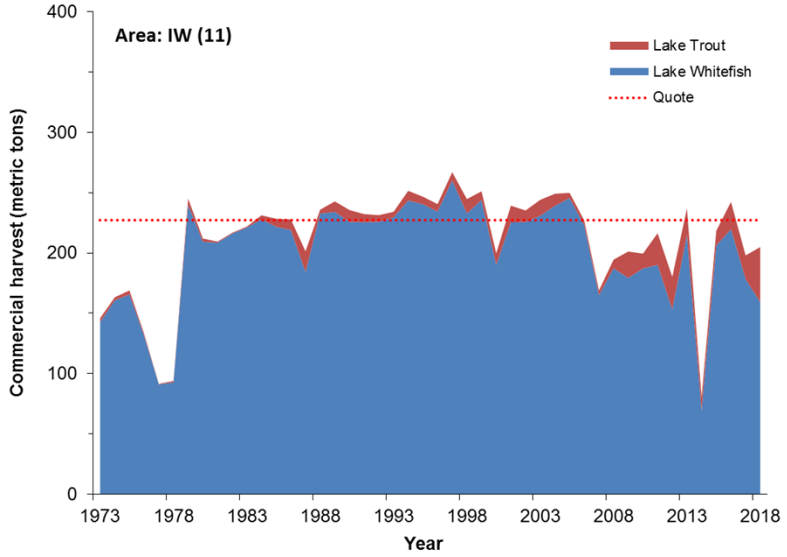
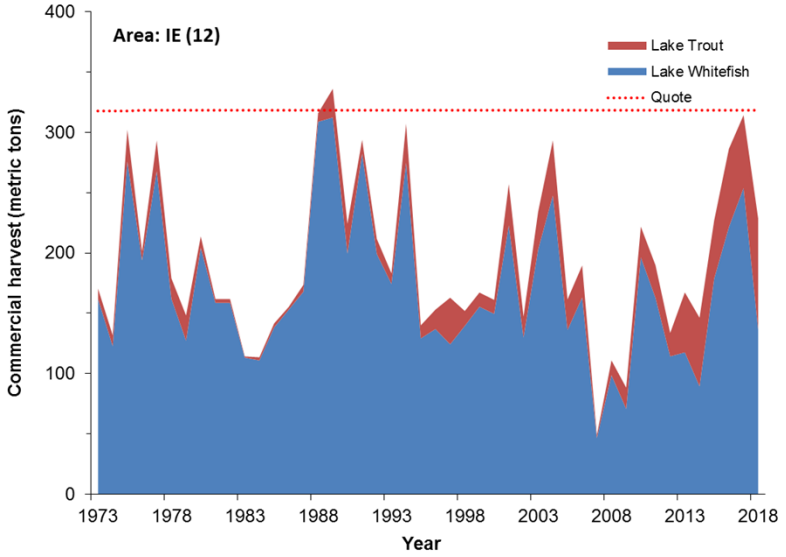
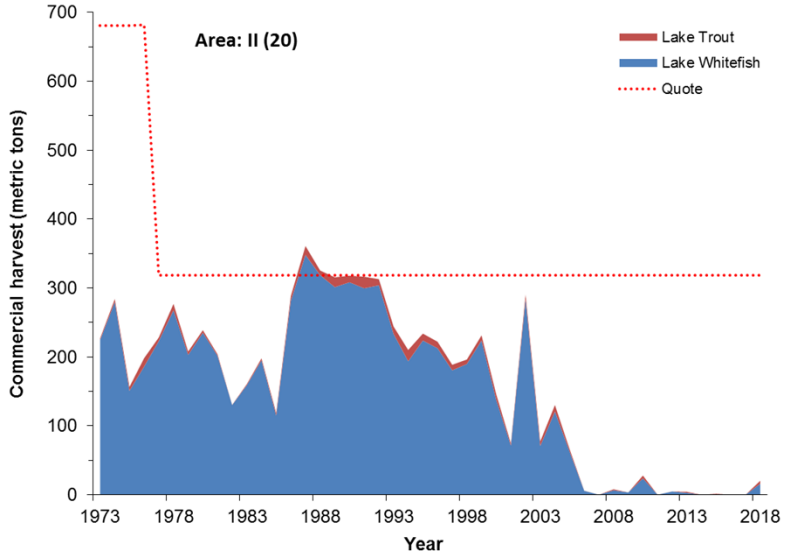
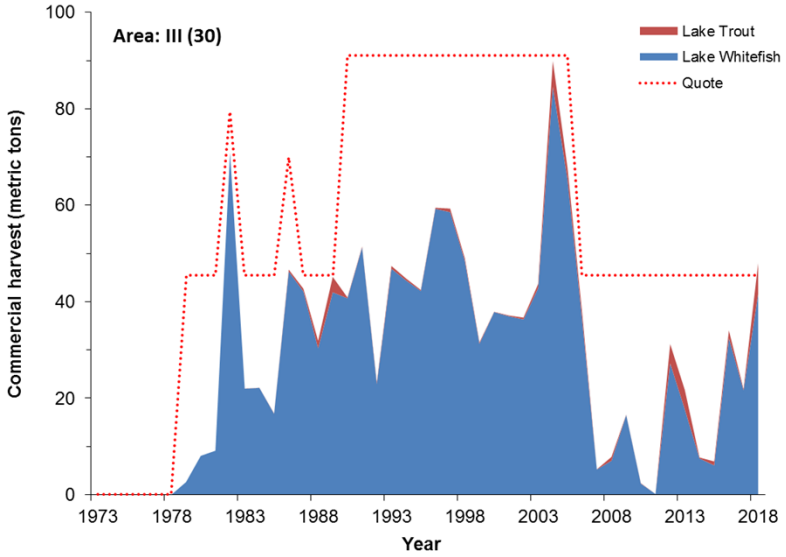
GSL Commercial Fisheries







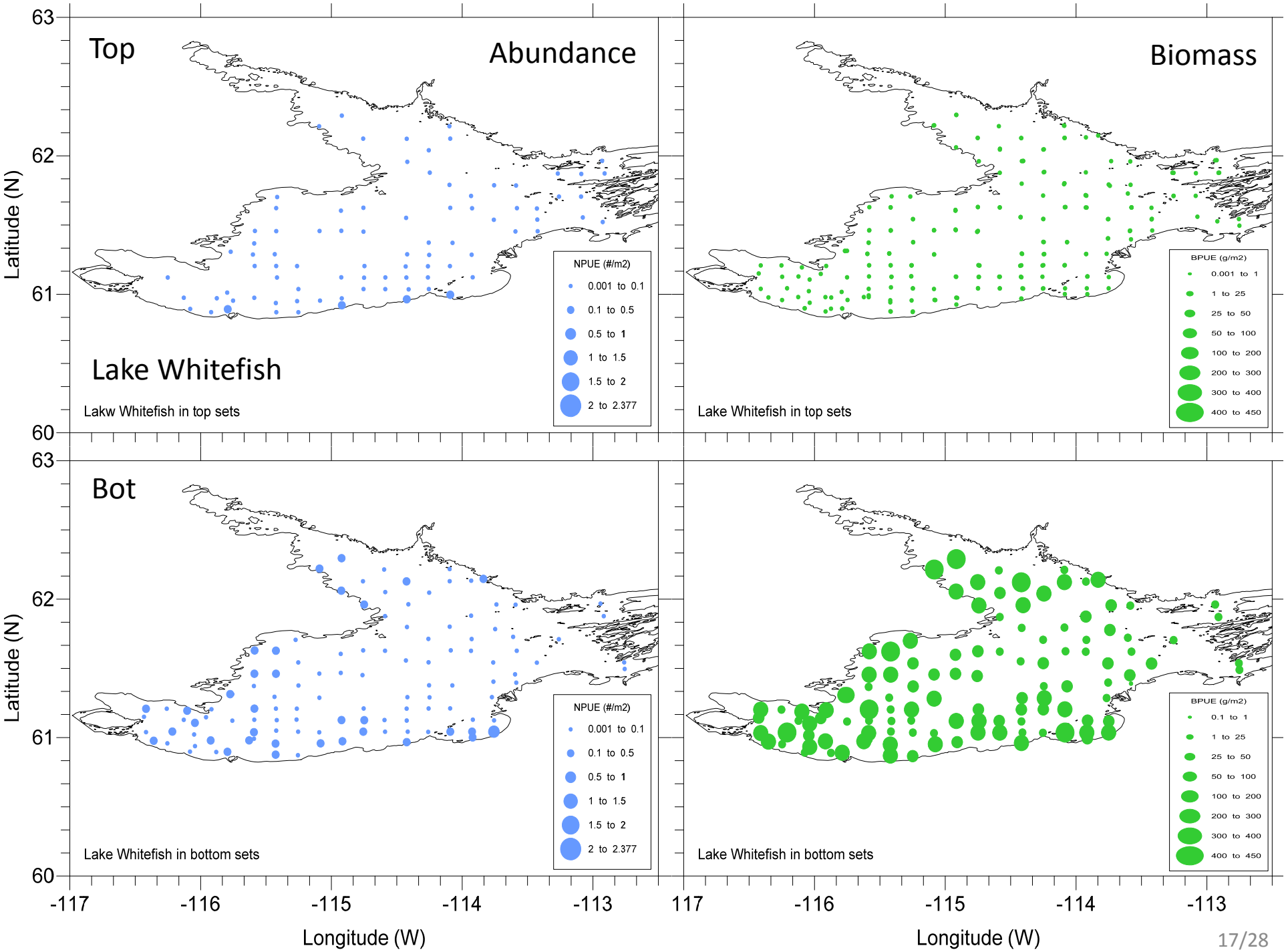


GSL Commercial Fisheries

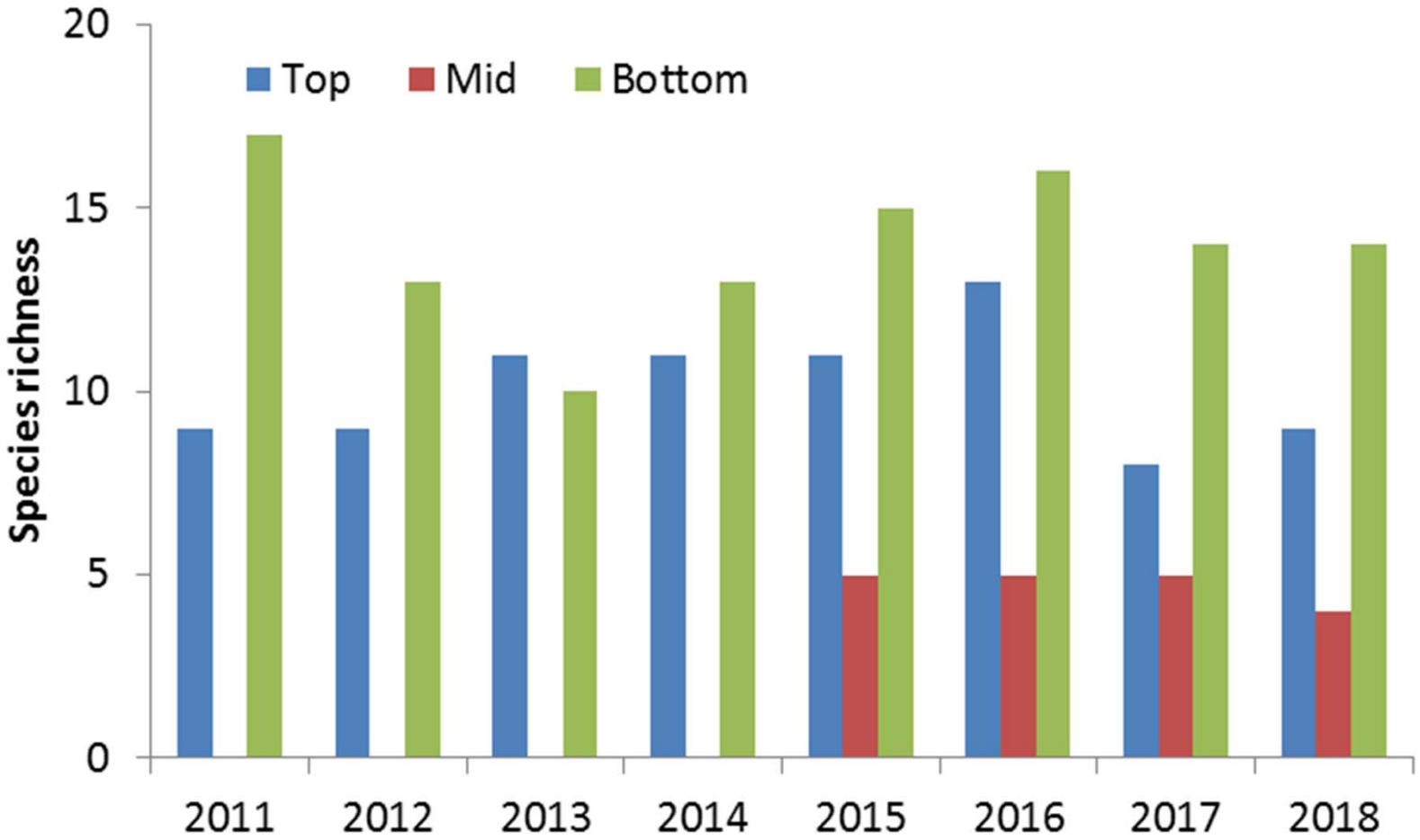
- Unique fisheries management regime
  - Gillnet with certain mesh size changes
    - 140 mm (5 ½”) @ 1948-1976
    - 133 mm (5 ¼”) @ 1977-1996
    - 127 mm (5”) @ 1997- present
  - Harvests are controlled by area-specific fishing quota since 1972
  - Fish plant sampling program—biological data
  - No succession of invasive species
- Unproportioned commercial exploitation in western GSL only
  - Non-uniform distribution of population abundance
  - Fluctuation of population abundance over years
  - Synchronic shifts of body size and growth

Current Stock Status

- Spatial variation in main GSL
- Temporal change
  - Species richness
  - Abundance and biomass of all species
  - Lake Whitefish abundance and biomass
  - Trophic properties
  - Vulnerability

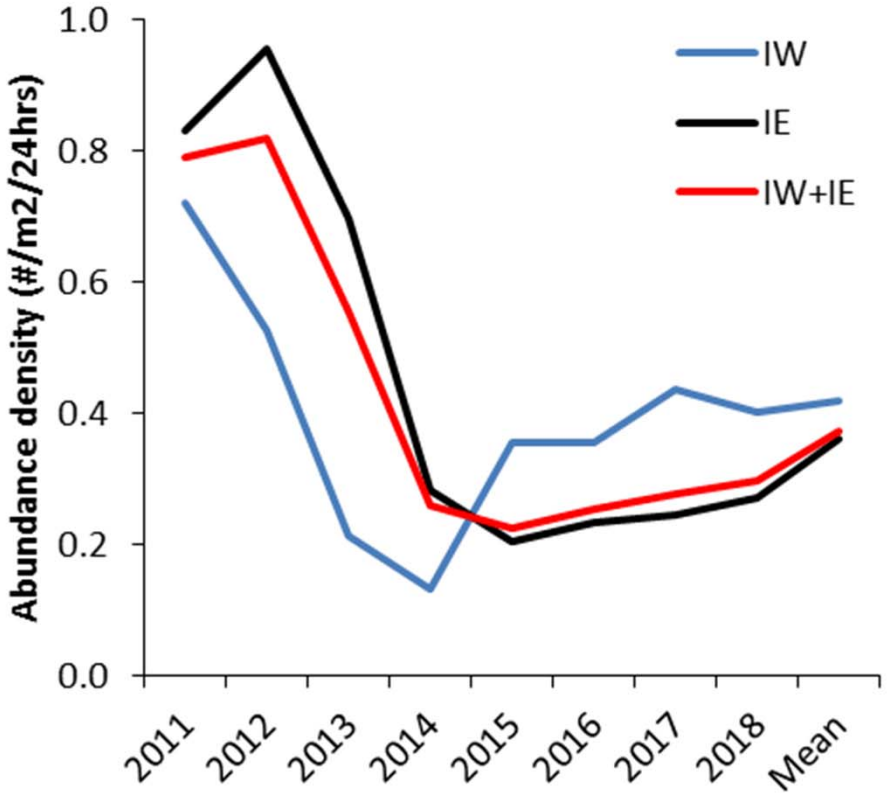

Top
Abundance
Lake Whitefish
Lakw Whitefish in top sets
NPUE (#/m2)
0.001 to 0.1
0.1 to 0.5
0.5 to 1
1 to 1.5
1.5 to 2
2 to 2.377
Biomass
Lake Whitefish in top sets
BPUE (g/m2)
0.001 to 1
1 to 25
25 to 50
50 to 100
100 to 200
200 to 300
300 to 400
400 to 450
Bot
Lake Whitefish in bottom sets
NPUE (#/m2)
0.001 to 0.1
0.1 to 0.5
0.5 to 1
1 to 1.5
1.5 to 2
2 to 2.377
Lake Whitefish in bottom sets
BPUE (g/m2)
0.1 to 1
1 to 25
25 to 50
50 to 100
100 to 200
200 to 300
300 to 400
400 to 450
Latitude (N)
63
62
61
60
-117
-116
-115
-114
-113
117
Longitude (W)

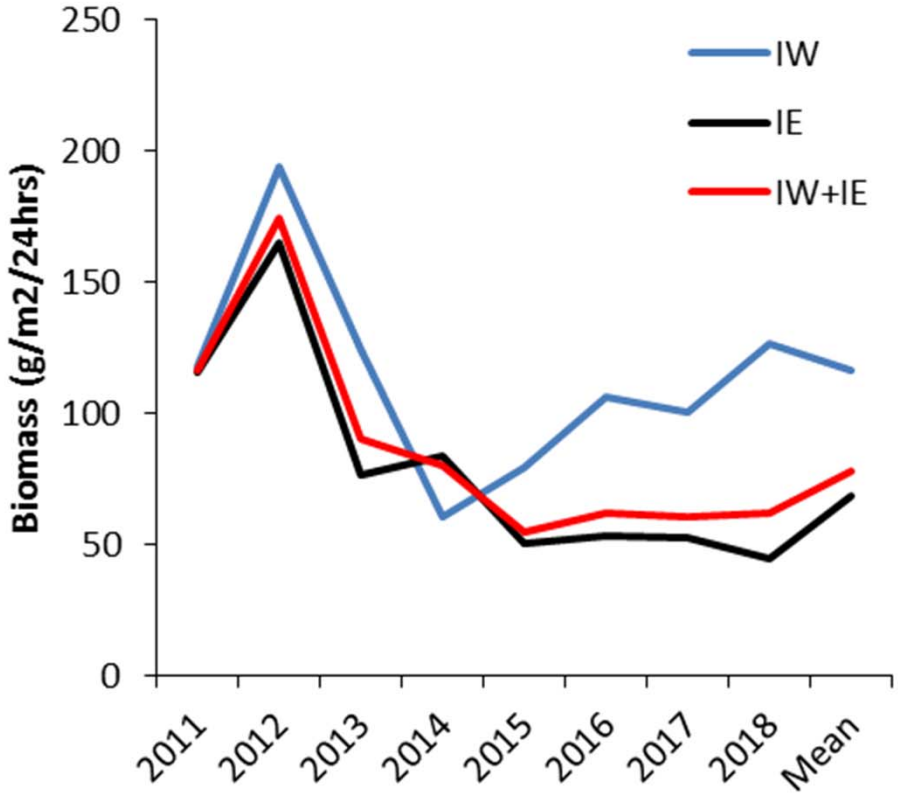
Species Richness



Big changes in species richness were found in western basin, especially in surface water

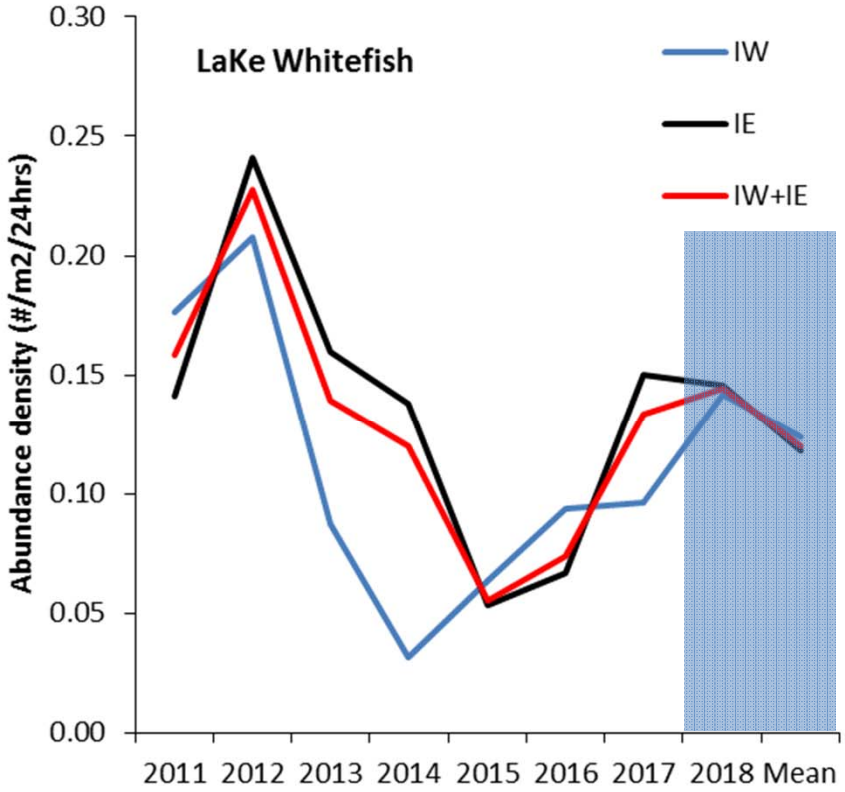
Abundance and Biomass

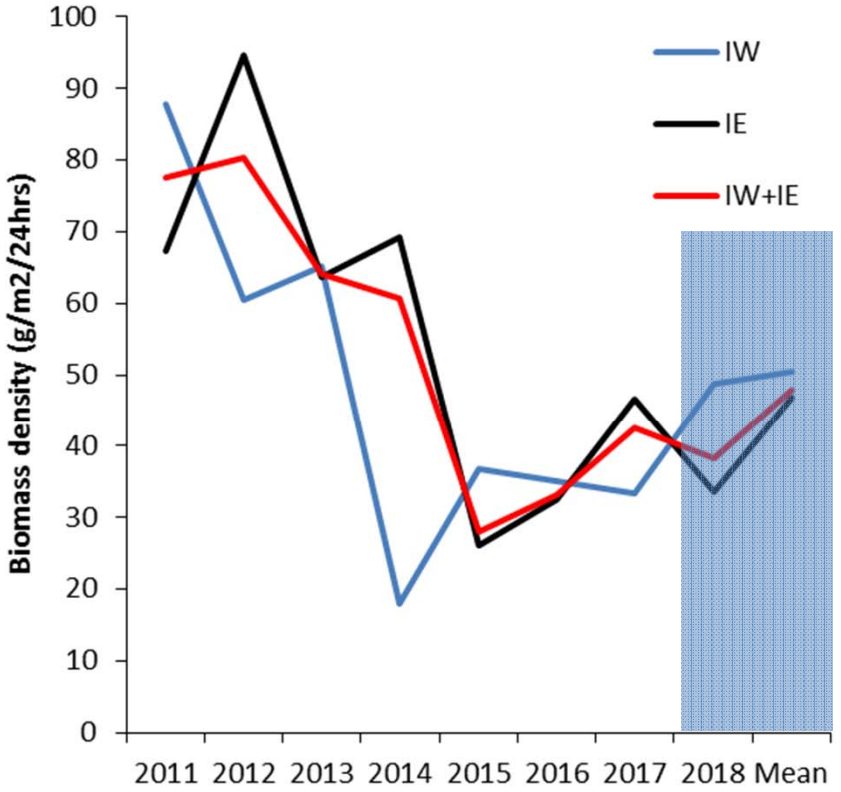




Considerable reduction of fish populations since 2012

Lake Whitefish Abundance and Biomass





Miniaturization: abundance is greater than the average, but biomass is less than the average

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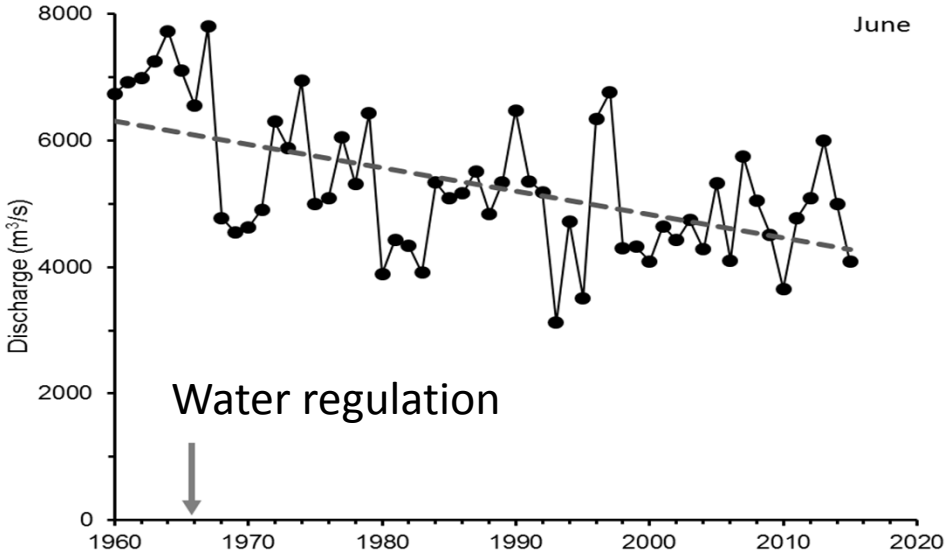
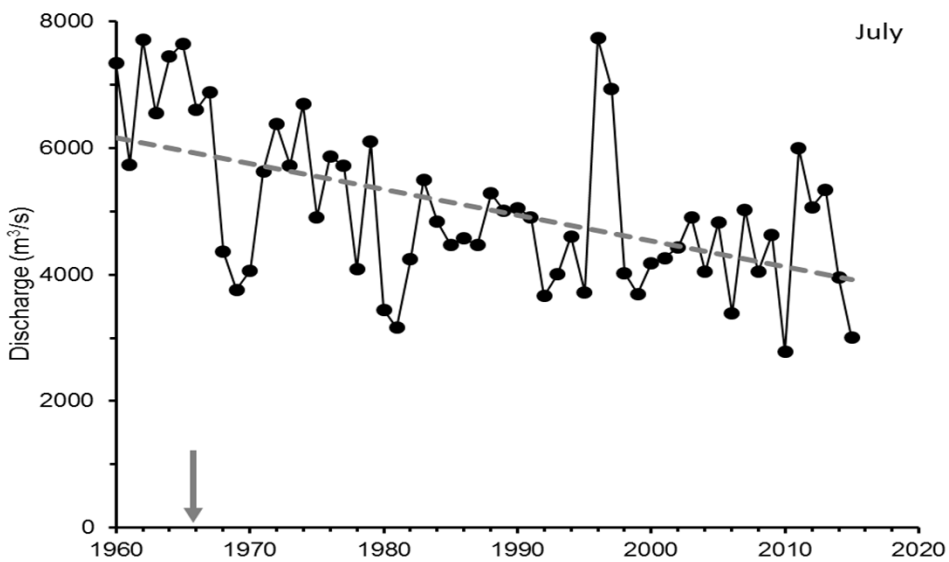
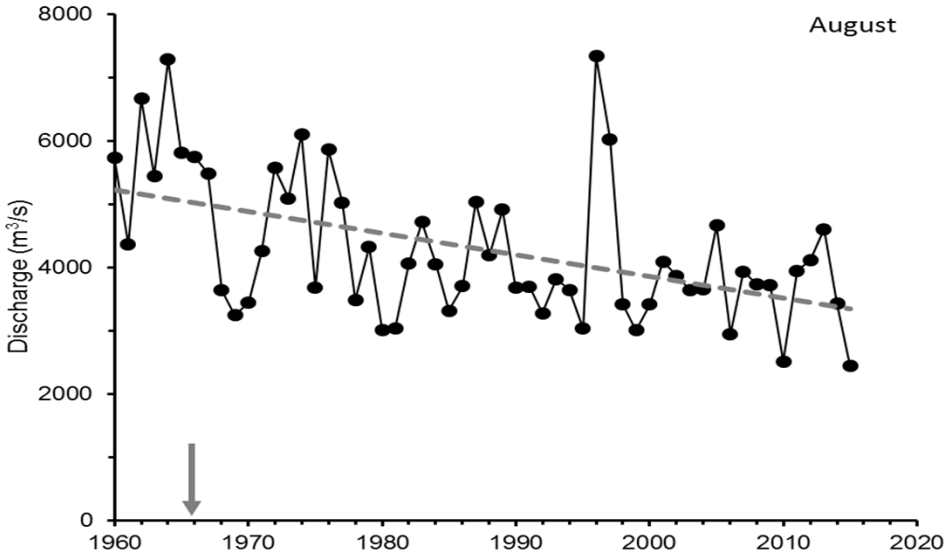
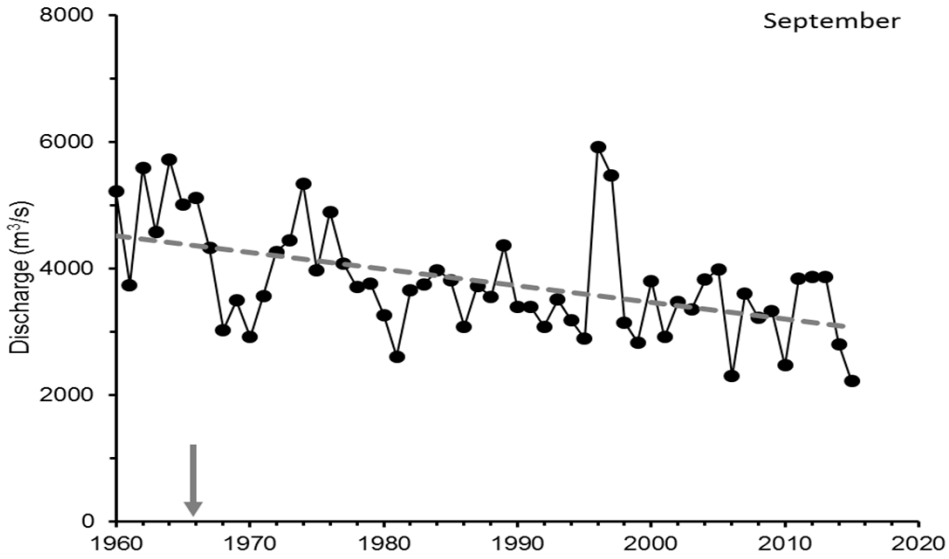
Causal Effects: Slave River Discharge (m^3/s)



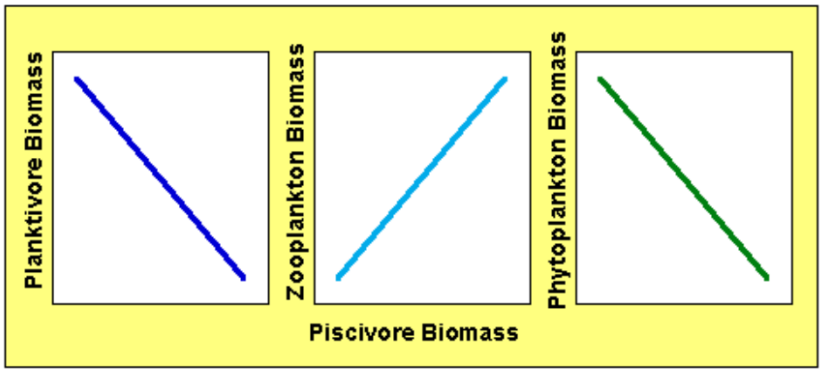




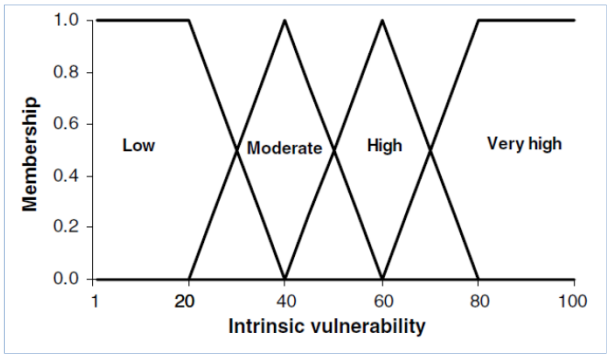


Ecological Traits

- Trophic properties
  - Plantivore → plankton
  - Benthivore → benthos
  - Piscivore → fish
  - Omnivore → everything
  - Proportion of piscivore
- Intrinsic Vulnerability
  - Low
  - Moderate
  - High
  - Very high

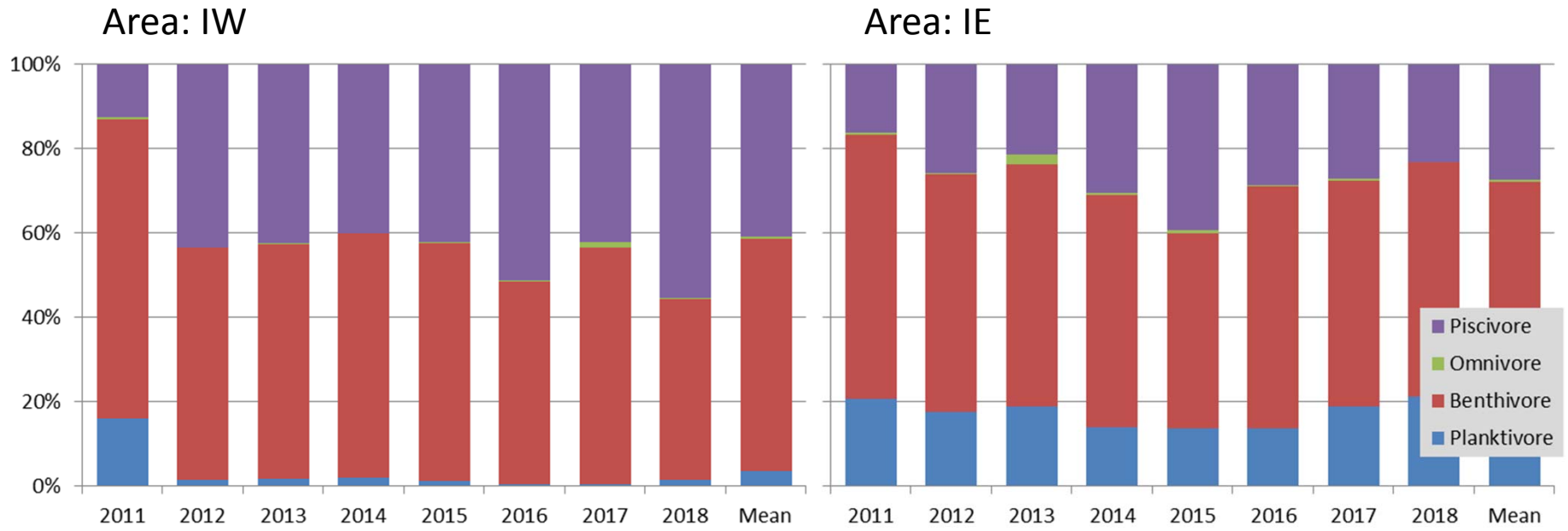


Drenner & Hambright (2002)



Cheung et al. (2005)

Changes of Trophic Properties

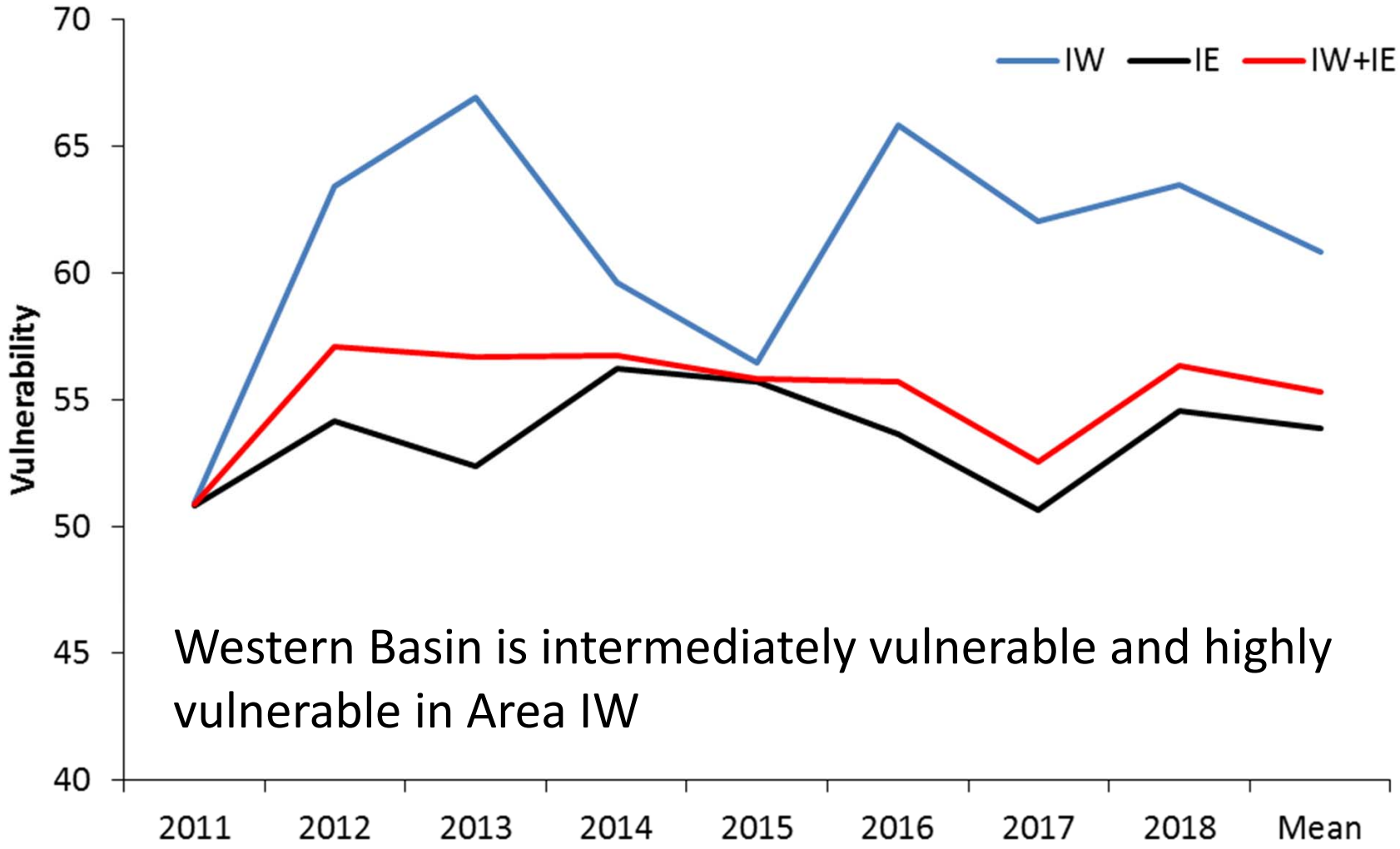


The lake ecosystem is dominated by benthivorous fishes, which stabilized the food web structure. However, changes of relative proportions of low trophic planktivore and high-level predators (piscivores) were likely resulted from seasonal water regulations in Slave River.

Intrinsic Vulnerability

Common Name	Acronym	Trophic Level	Feeding	Vulnerability
Arctic Grayling	AG	3.3±0.2	Piscivore	59
Arctic Lamprey	ALP	4.5±0.8	Piscivore	54
Arctic Sculpin	ASP	3.4±0.5	Benthivore	43
Burbot	BBT	3.8±0.2	Piscivore	66
Lake Chub	CHUB	3.4±.43	Omnivore	31
Goldeye	GDI	3.2±0.2	Omnivore	63
Inconnu	INCO	4.2±0.7	Piscivore	74
Least Cisco	LCK	3.2±0.2	Planktivore	41
Lake Dace	IKDS	2.9±0.1	Planktivore	48
Lake Herring	LKH	3.4±0.4	Planktivore	43
Lake Trout	LKT	4.3±0.5	Piscivore	69
Lake Whitefish	LKWF	3.2±0.2	Benthivore	44
Longnose Sucker	LNSK	2.5±0.3	Benthivore	64
Northern Pearl Dace	NPD	3.1±0.4	Omnivore	38
Northern Pike	NPK	4.1±0.4	Piscivore	85
Ninespine Stickleback	NSSBK	3.1±0.1	Omnivore	27
Round Whitefish	RDWF	3.3±0.4	Benthivore	51
Sauger	SAUGER	4.1±0.7	Piscivore	49
Shorthead Sculpin	SHSP	3.7±0.6	Omnivore	34
Shortjaw Cisco	SJCK	3.4±0.4	Omnivore	43
Spottail Shiner	SPT	2.1±0.1	Planktivore	25
Troutperch	TP	3.4±0.5	Omnivore	25
White Sucker	WSK	2.8±0.2	Benthivore	57
Walleye	WY	4.5±0.1	Piscivore	40

Intrinsic Vulnerability



Western Basin is intermediately vulnerable and highly vulnerable in Area IW

Conclusions

- Great Slave Lake is one of arctic great lakes, experiencing multiple disturbances in spite of downsized commercial harvest;
- Accumulated studies have laid down sound foundation for exploring biological characteristics and fisheries production;
- Current unproportioned utilization for commercial harvest in the western basin stimulated a series of substantial effects in biological characteristics and ecological traits;
- The affected biological characteristics included the reduction of species richness, miniaturization and production of target species;
- There caused several modifications of ecological traits, including changes of trophic components and intrinsic vulnerability. GSL is under highly vulnerable conditions.

Acknowledgements

- ✓ Funding sources: NWT-CIMP, DFO-AFS and DFO A-base;
- ✓ GSLAC for consultation and technical supports;
- ✓ Involvements of aboriginal communities: KFN, NWTMN, WPFN, DKFN, ATG
- ✓ George Low, Diane Giroux, Michael Low, Rose Bjornson, Peter Sabourin, Shawn Buckley, Alex Richardson, …
- ✓ Future collaborators: Marlene Evans (Climate Change and Environment Canada), Trevor Pitcher (University of Windsor), and Darren Gillis (University of Manitoba)

Thanks for Your Comments