

Effects of Lake Fertilization on Kokanee in Kootenay Lake, B.C.

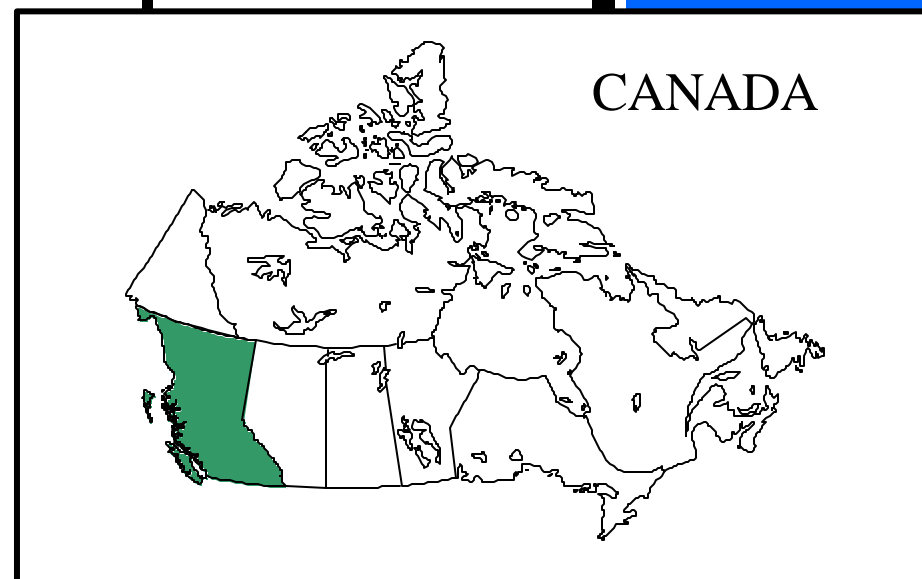
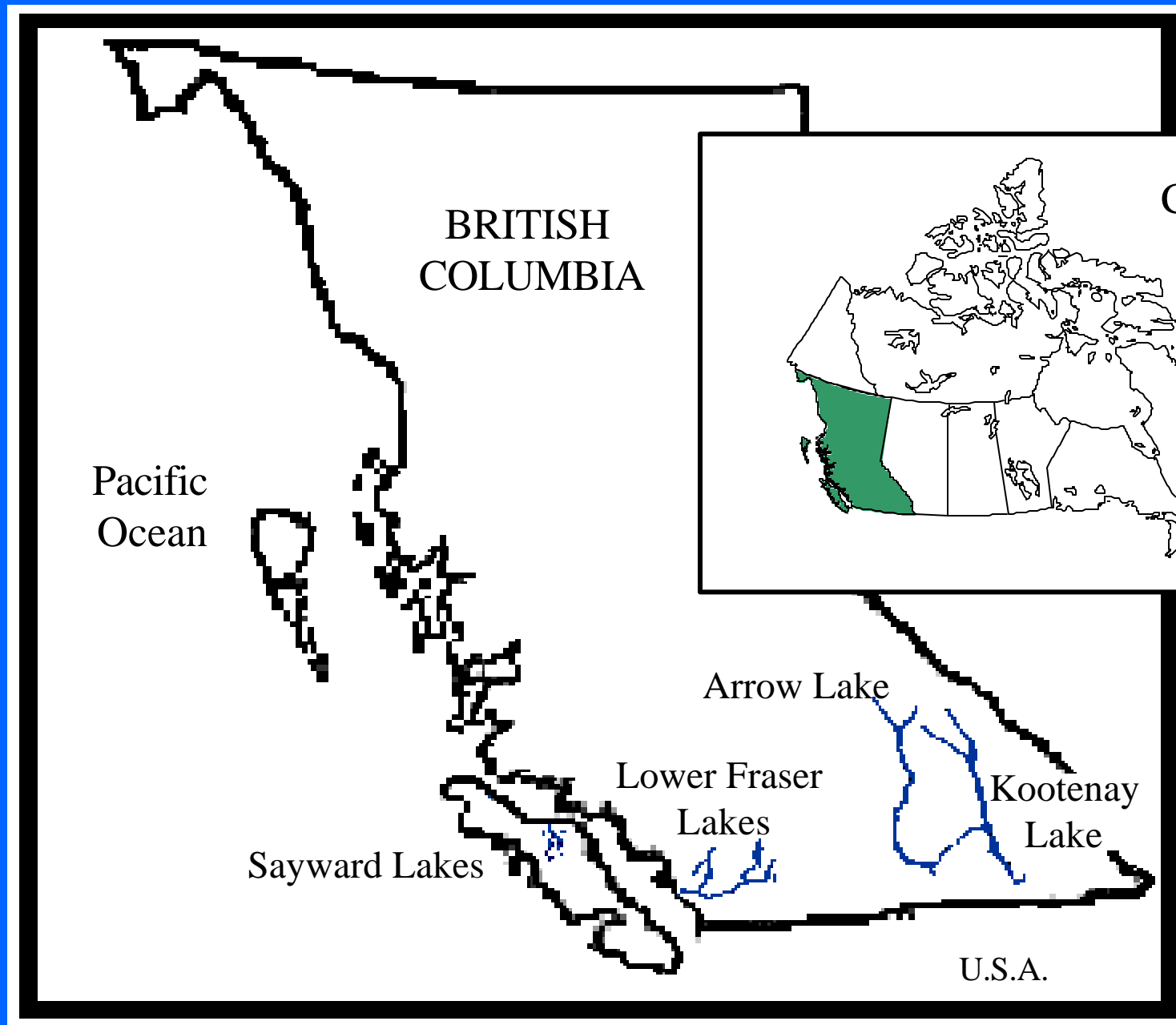
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Presentation Outline

- Effect of upstream impoundments and *Mysis* introduction on Kootenay Lake
- Lake fertilization experiment
- Response of kokanee and Gerrard RBT's to enrichment
- Conclusions



Mysid-kokanee history in BC

- 1949 – first BC introduction to Kootenay Lake: an inappropriate model due to unique morphometry+nutrients
- 1968+1974 - Upper and Lower Arrow
- Mysids added to 16 more BC lakes by 1980 and throughout Western North America and Scandinavia



Patterns of major human disturbance: Kootenay Lake

- Dam construction and operation
 - Duncan Dam - 1967 (Columbia River Treaty on inflow Duncan River)
 - Libby Dam - 1973 (Columbia River Treaty on inflow Kootenai River)
- Cominco fertilizer plant operations
 - Kimberly production starts - 1953
 - production doubles to triples - 1962 to 1965
 - pollution control measures - 1969 to 1979
 - plant closure - 1987
- Biological manipulations
 - Mysid shrimp introduction - 1949 + 1950

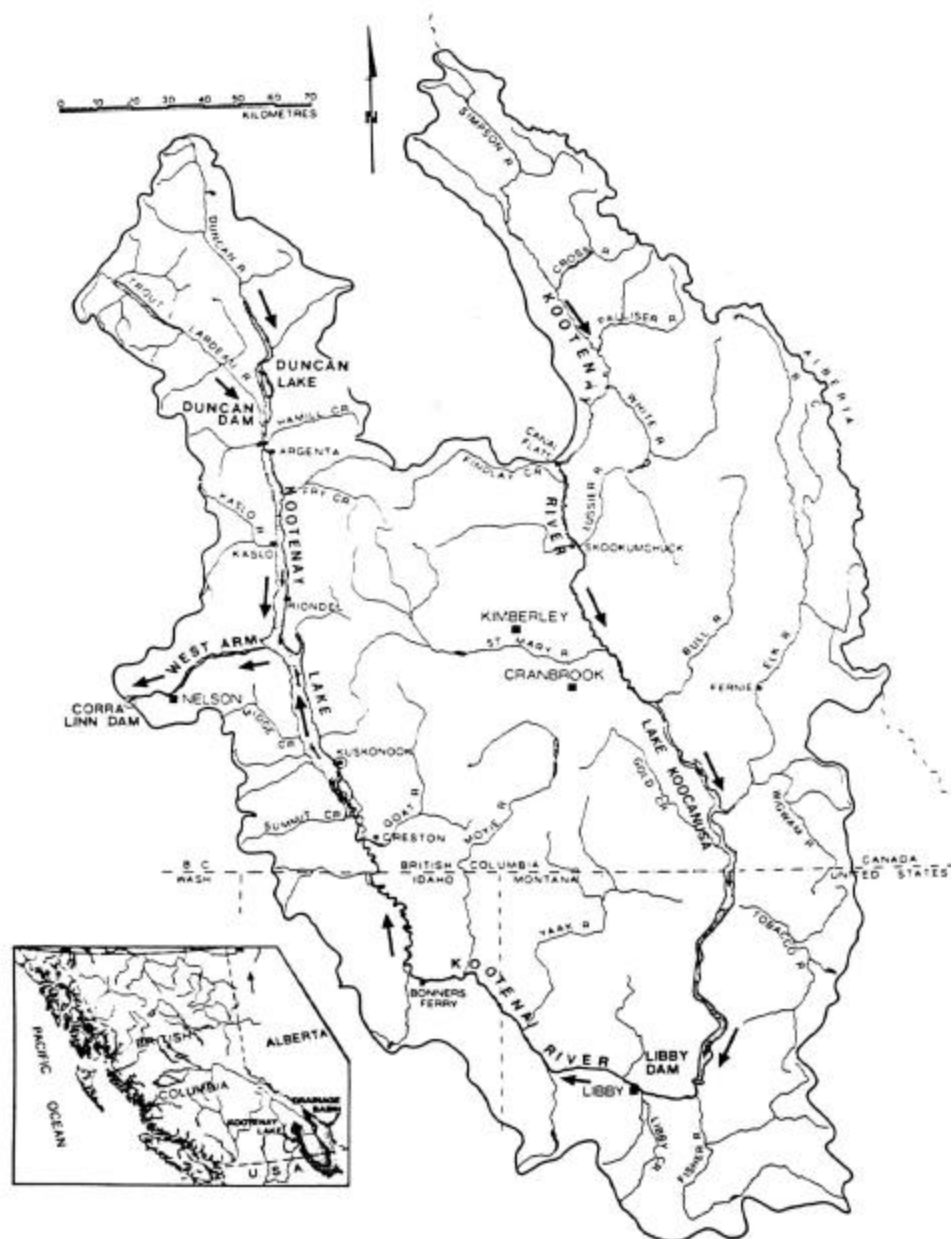


FIGURE 1.—Kootenay Lake and its drainage basin. The lake's west arm is a discharge waterway arising at the junction of the north and south arms.

KOOTENAY LAKE
SOUTH → WEST ARM
MID JULY 1972
(PRE LIBBY DAM)

SECCHI
DEPTH
← 1.5m

1970
SURFACE
4.2m



← 1.1m

← 0.9m

← 0.8m



FIGURE 1 The Kootenay and Okanagan River catchment basins showing their drainage areas (1:1 and 1:100,000) and their relative positions. Note: these basins are the only ones in western North America.

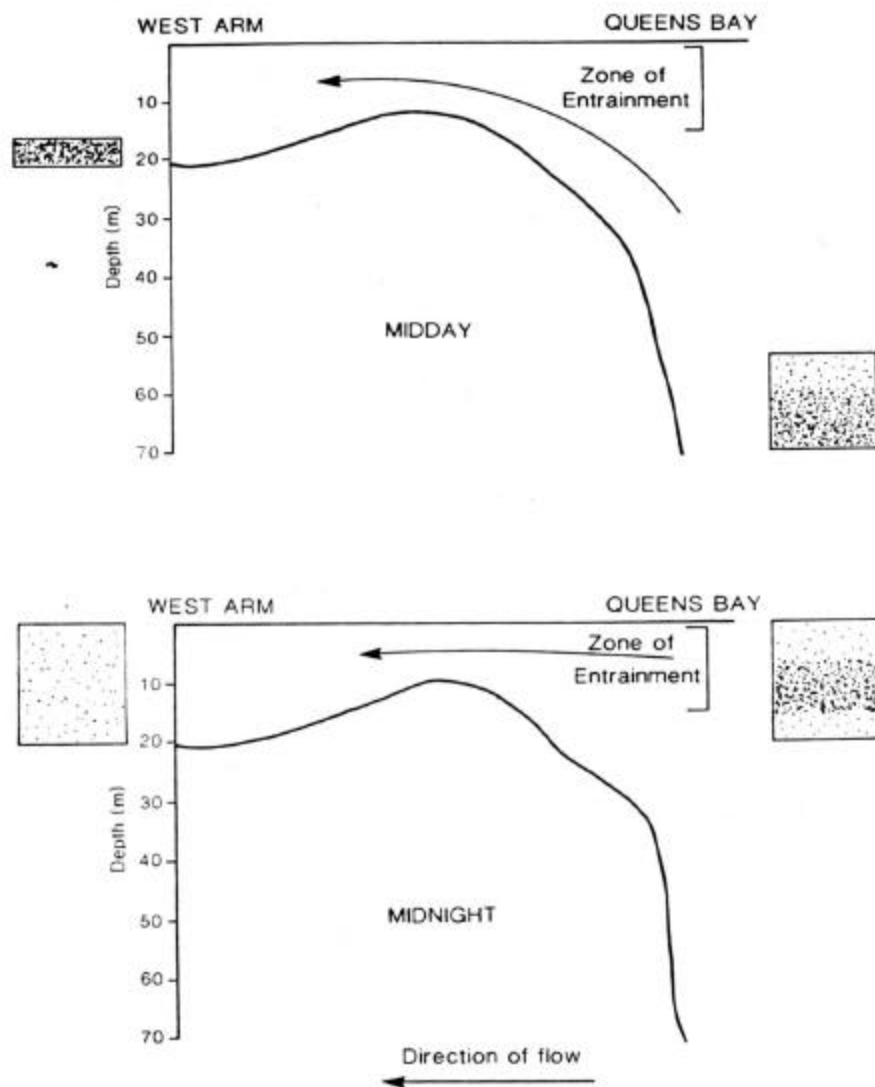


FIGURE 4.—Schematic diagram of the midday and midnight vertical distributions of *Mysis relicta* and the entrainment of mysids across the outlet to the west arm. Stippled areas indicate mysid distribution.

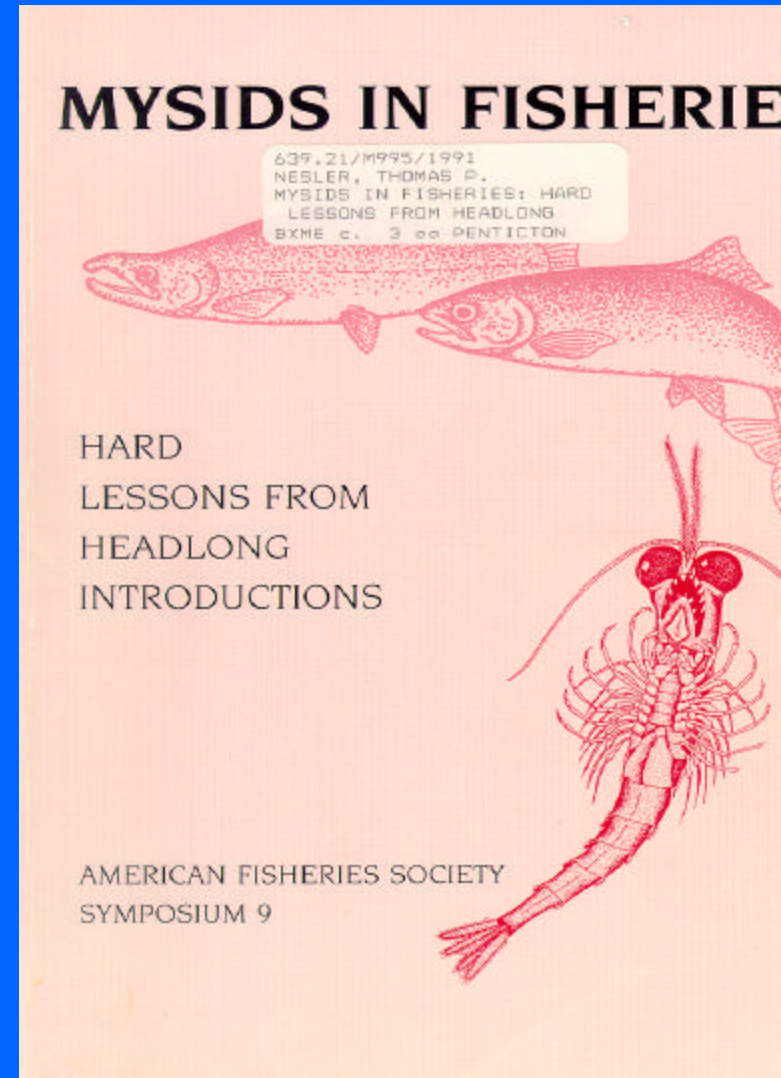
Effect of *Mysis* on productivity of CDN North Temperate Lakes and Reservoirs

Kootenay Lake experience
provided distorted picture

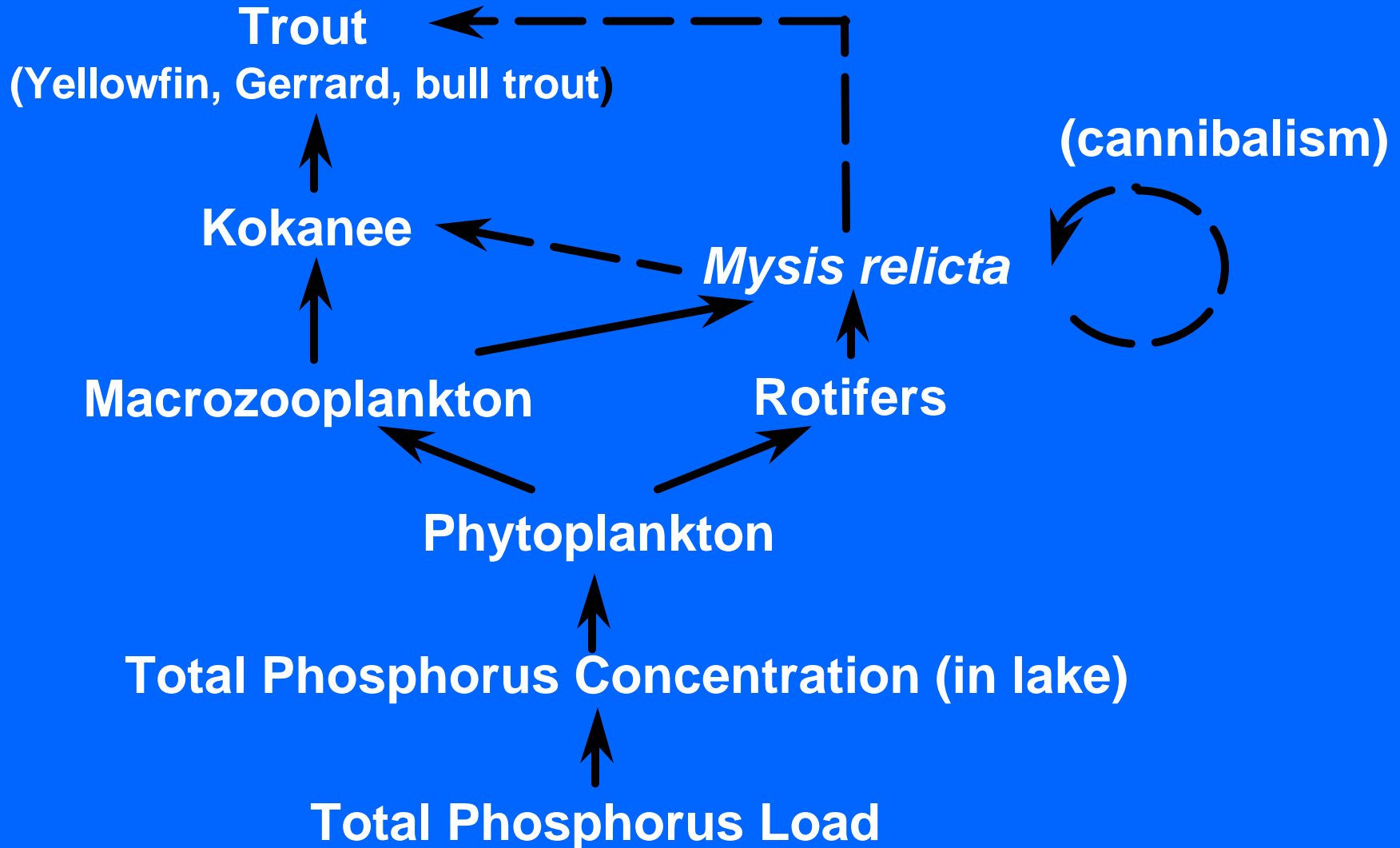
Studies later indicated *M. relicta*
major competitor with kokanee

Severe negative impacts on
kokanee populations

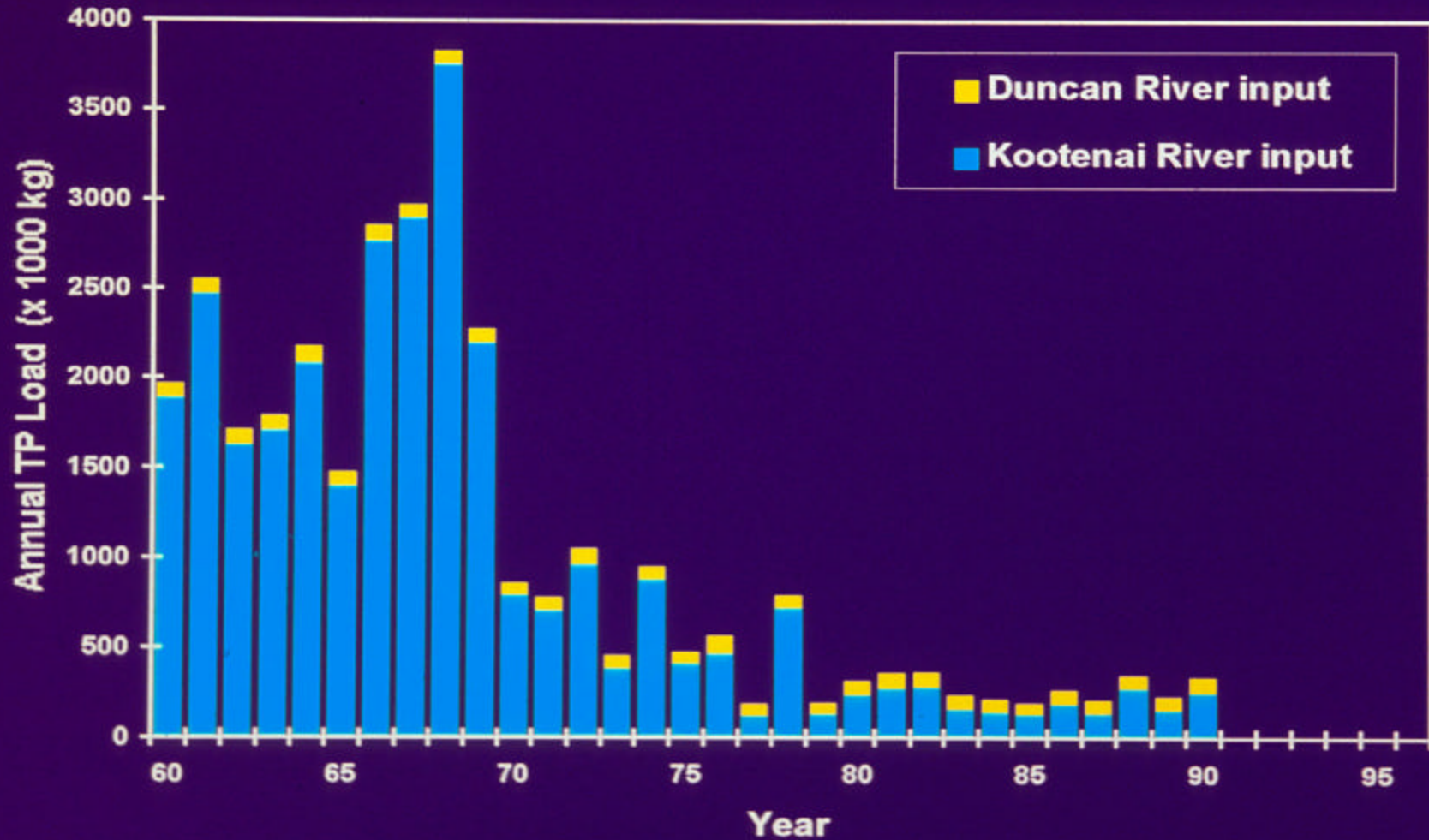
Experiences in other lakes well
documented

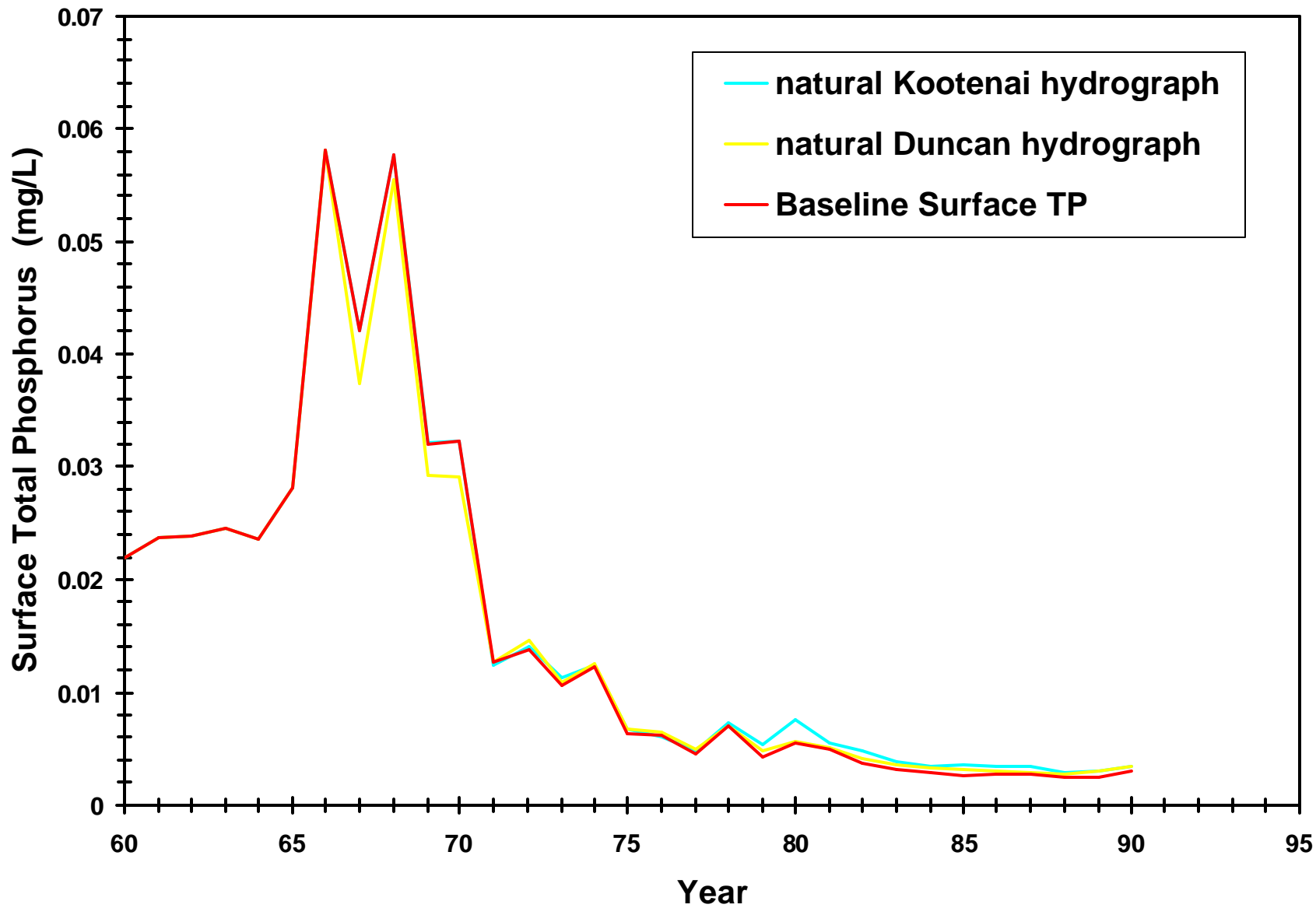


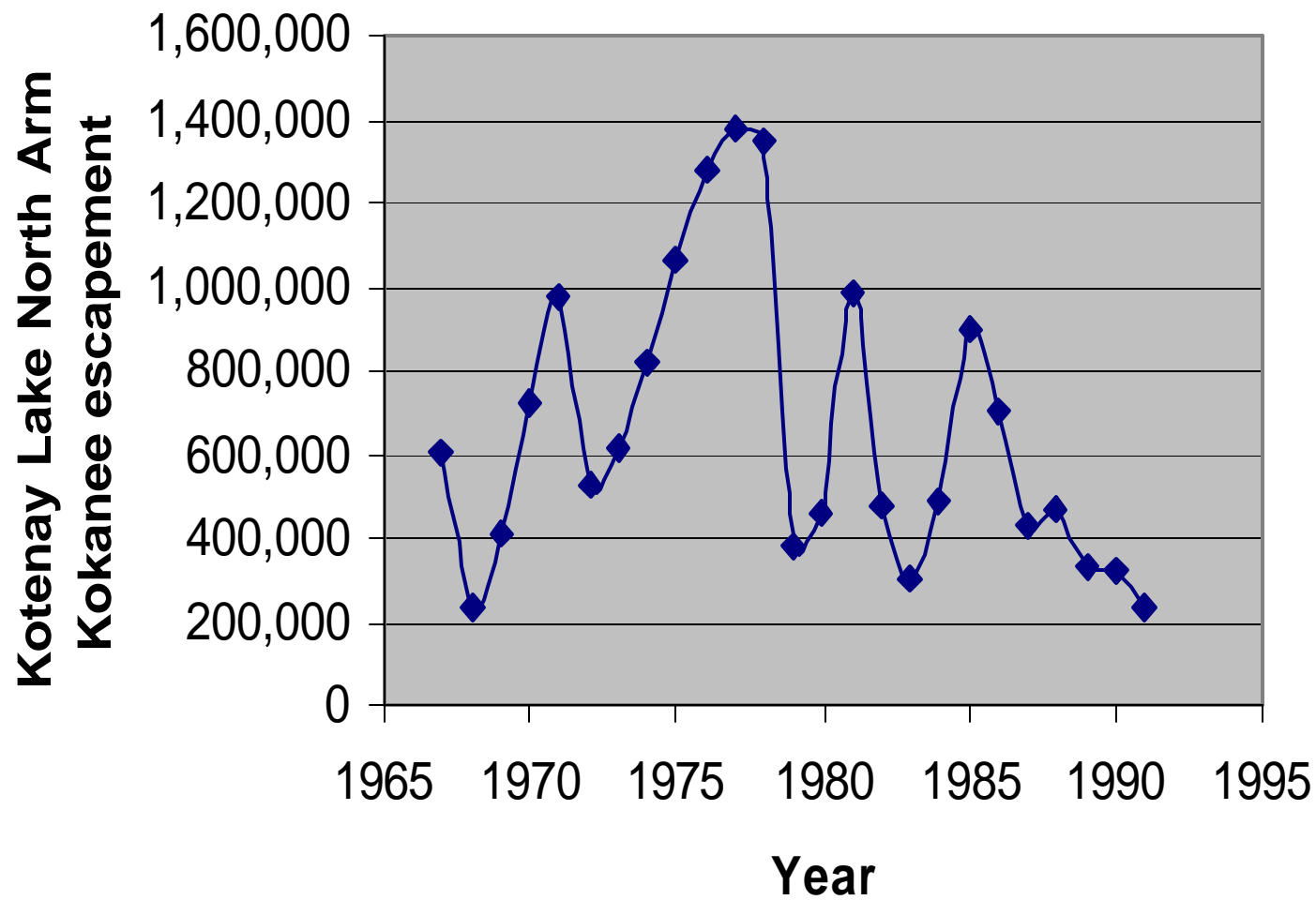
Kootenay Lake Food Web



Annual Phosphorus Load to Kootenay Lake









Effect on oligotrophic food webs

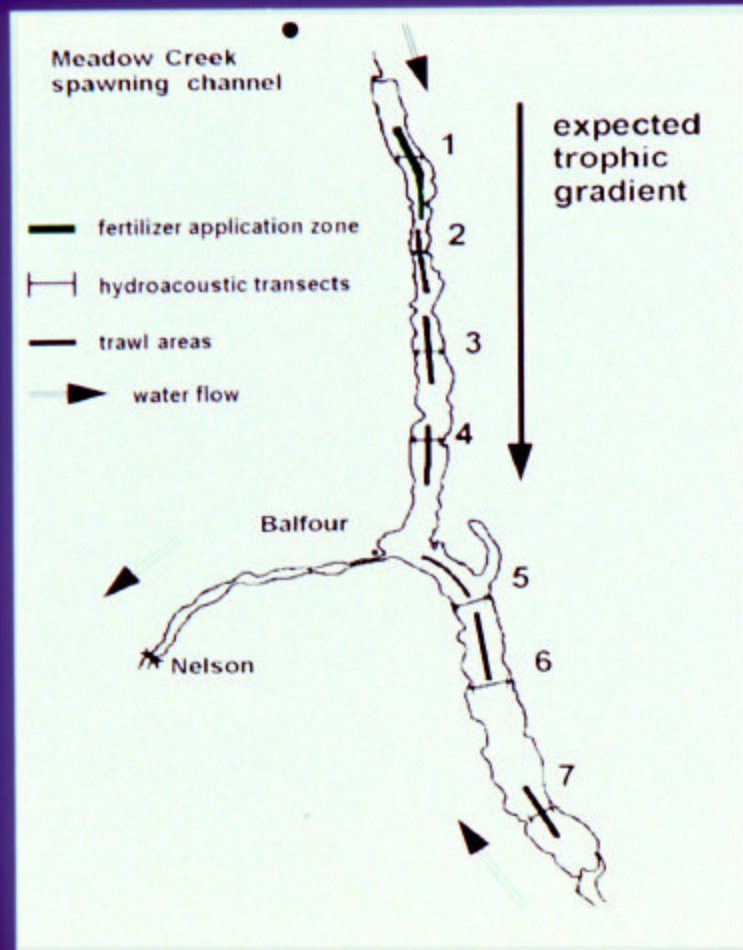
- Mysid introduction generally leads to delayed collapse of pelagic planktivores (kokanee), particularly in oligotrophic lakes and reservoirs
- kokanee collapse was confounded/masked/delayed by multiple basin scale manipulations (nutrients, impoundment)
- planktivore collapse predicted to be followed by collapse of obligate piscivores (Gerrard RBTs)
- restoration of kokanee required innovative solutions
- hatchery solutions were not an option

Adaptive Management

- Active adaptive management
- Definition: policies that rely on deliberate probing for information (Walters, 1986)

Adaptive Management Recovery plans: Kootenay Lake

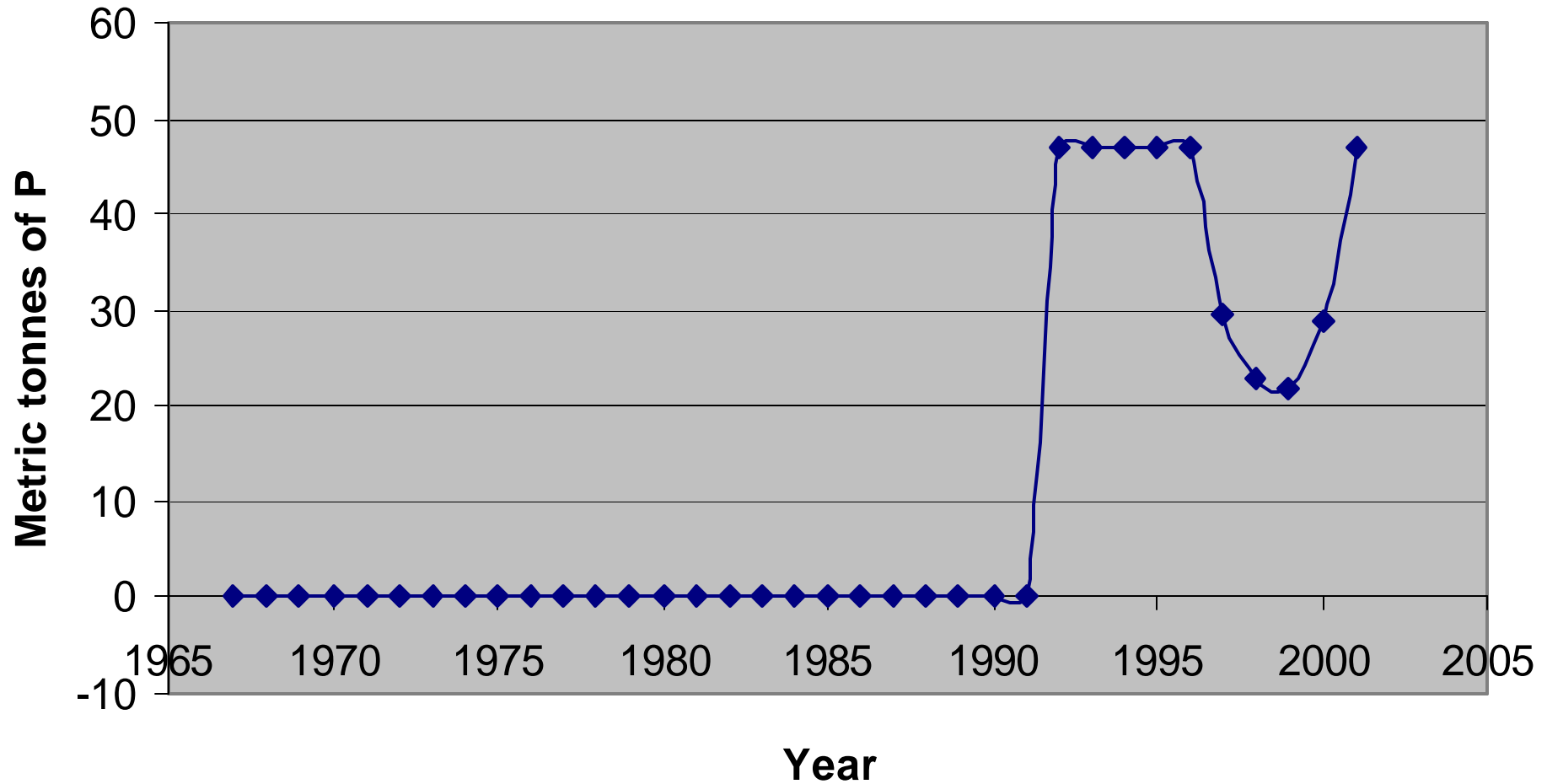
- large scale fertilization experiment
- used in-lake north-south nutrient gradient design
- Fertilizer Loading schedule:
 - Phase 1 (5 years): 1992-1996 – constant at 47.1 MT P
 - Phase 2 (5 years): 1997-2001 – variable P loading:
 - 1997- 29.5 MT, 1998 – 22.9 MT, 1999 – 22 MT
 - 2000 – 29 MT, 2001 – 47.1 MT, 2002 – 47.1 MT



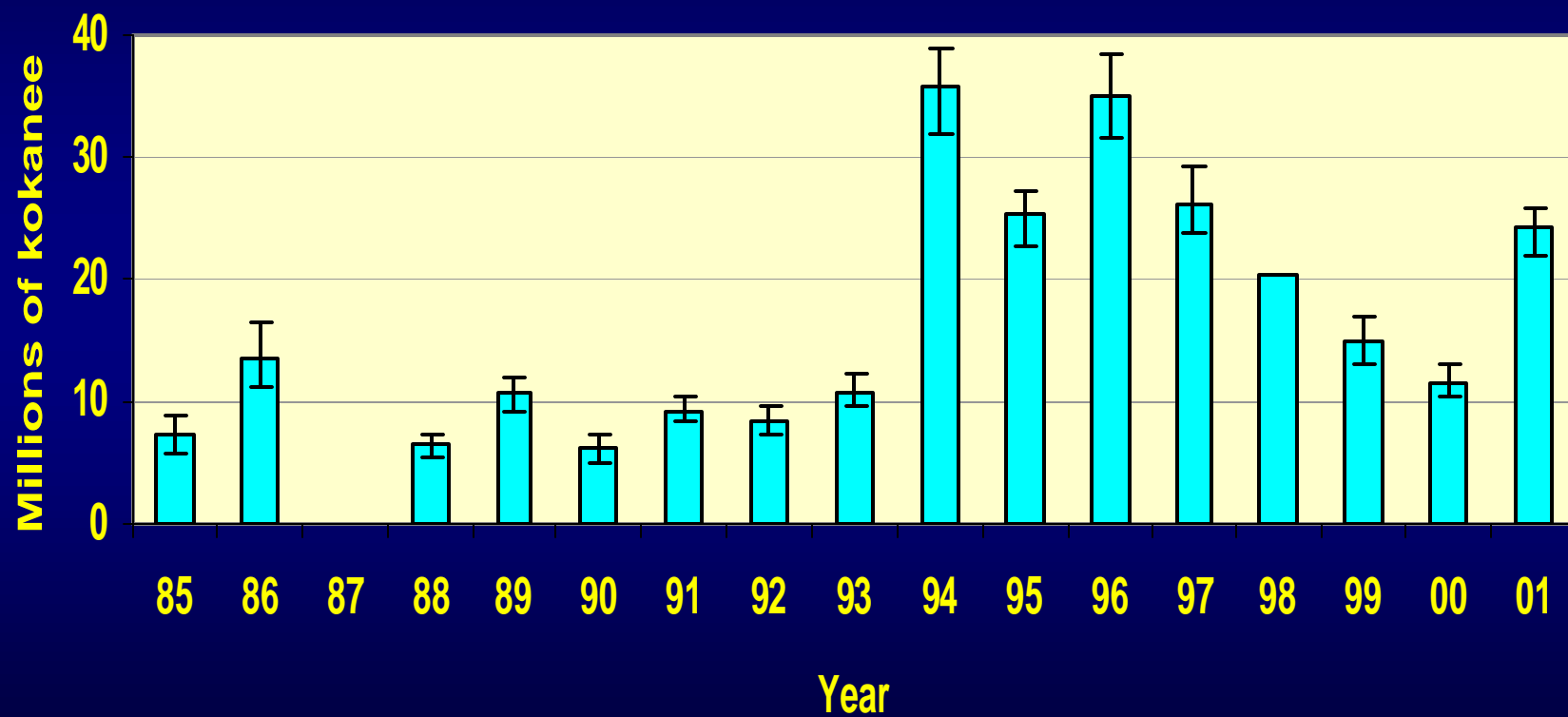




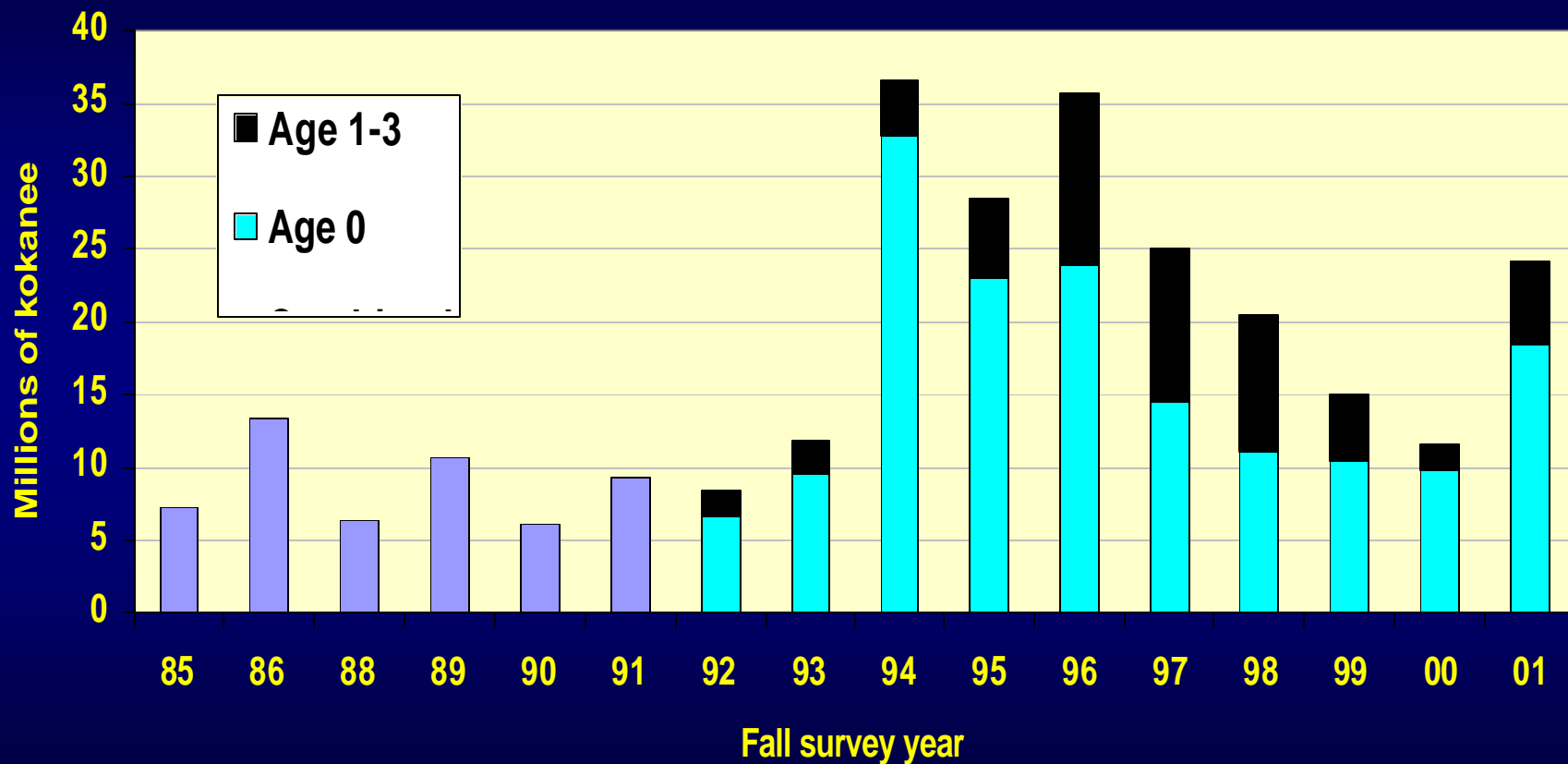
Kootenay Lake Fertilizer P loading



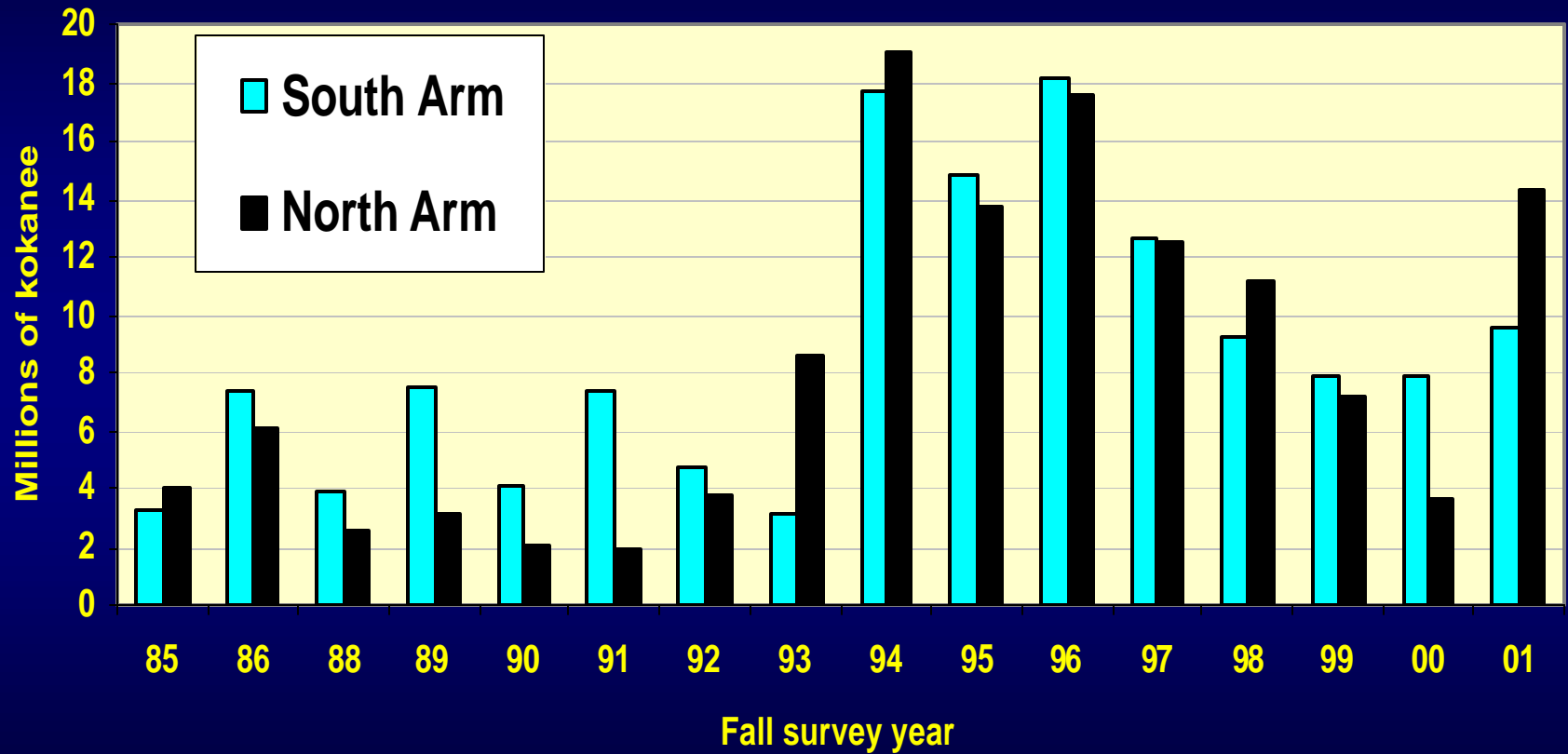
**Kootenay kokanee abundance (Maximum Likelihood Estimates) from fall
acoustic surveys, 1985-99.**



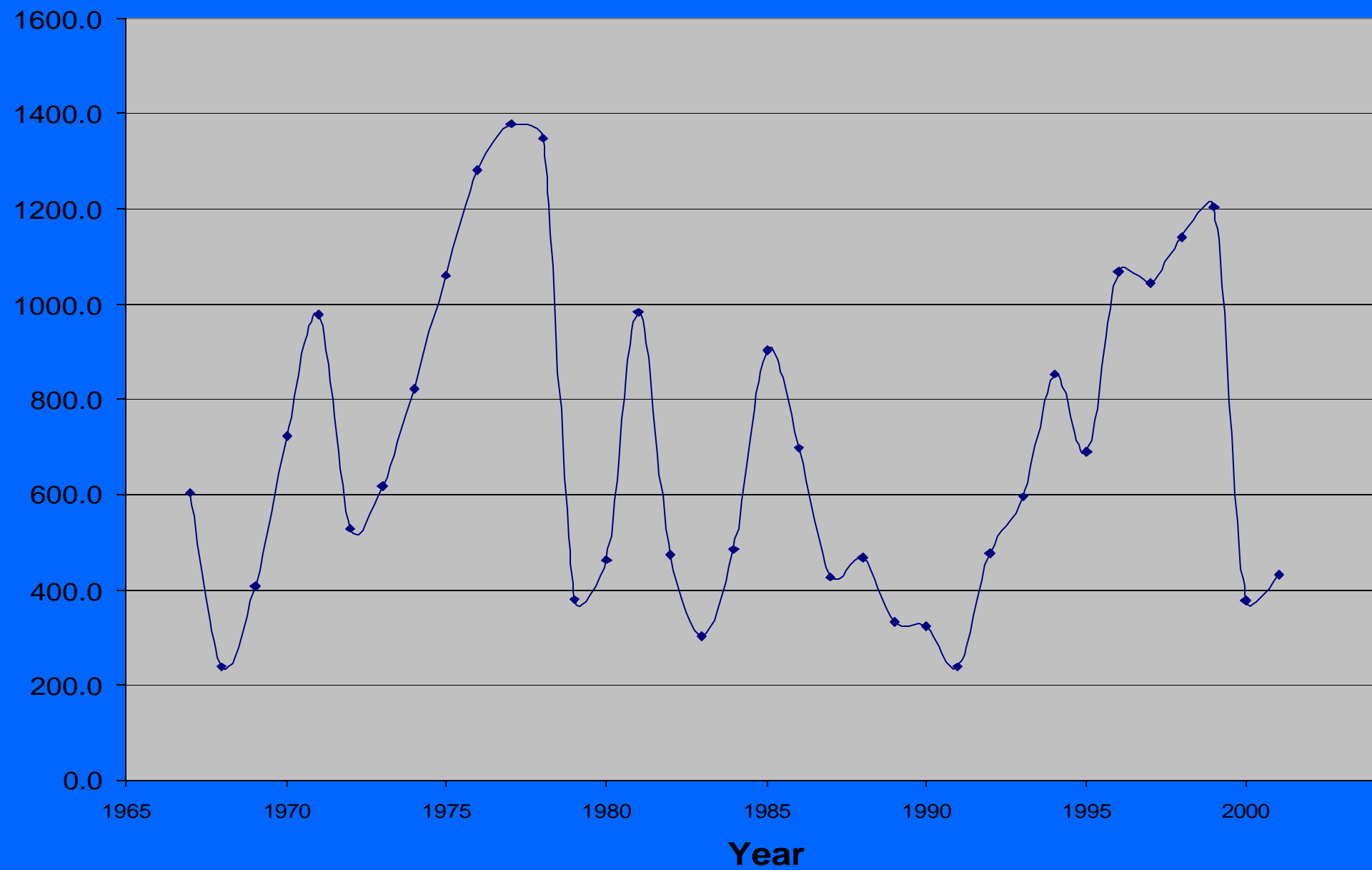
Kootenay L. kokanee - abundance by age group (stacked)



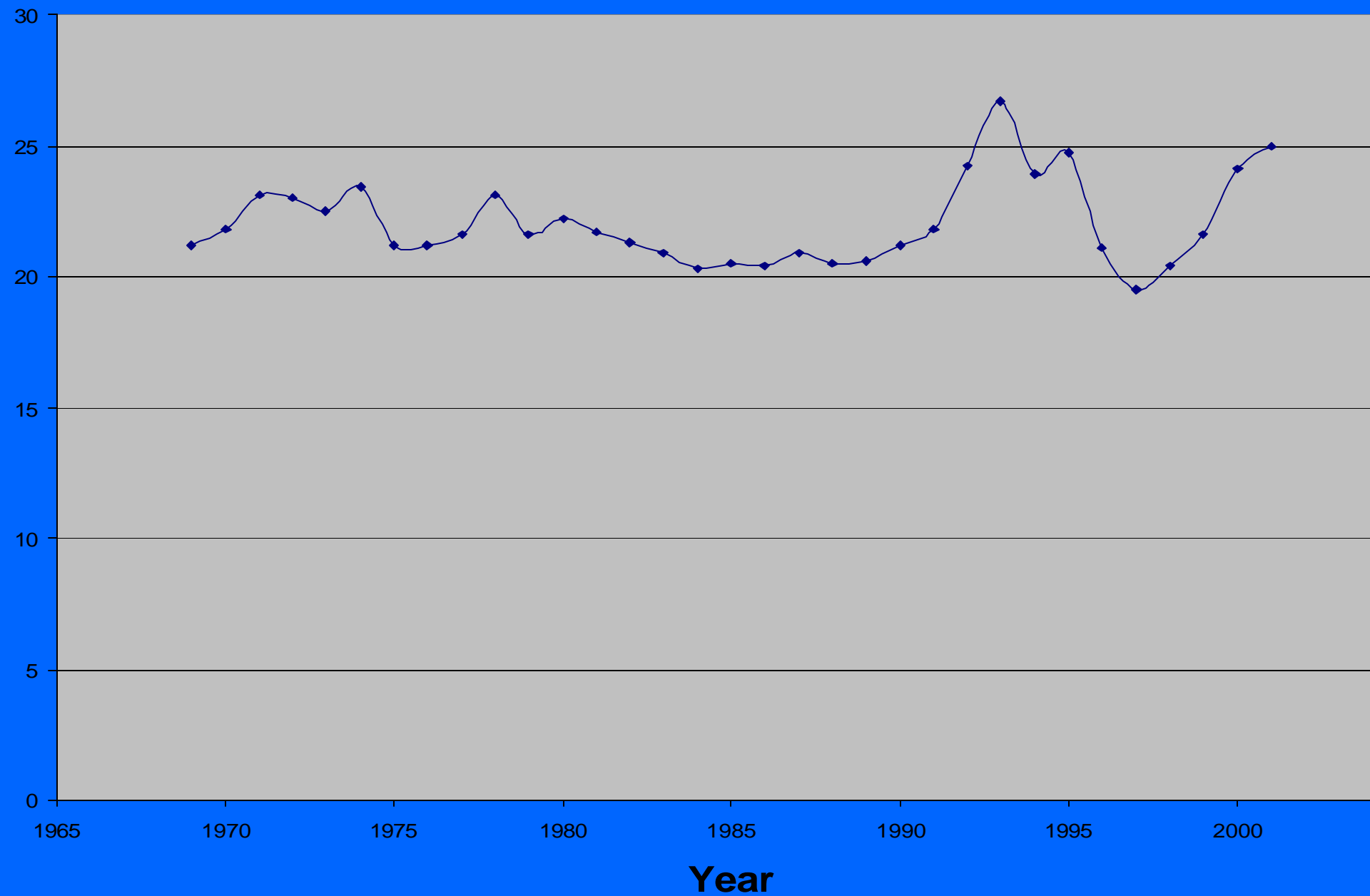
Kootenay L kokanee - North vs South Arm



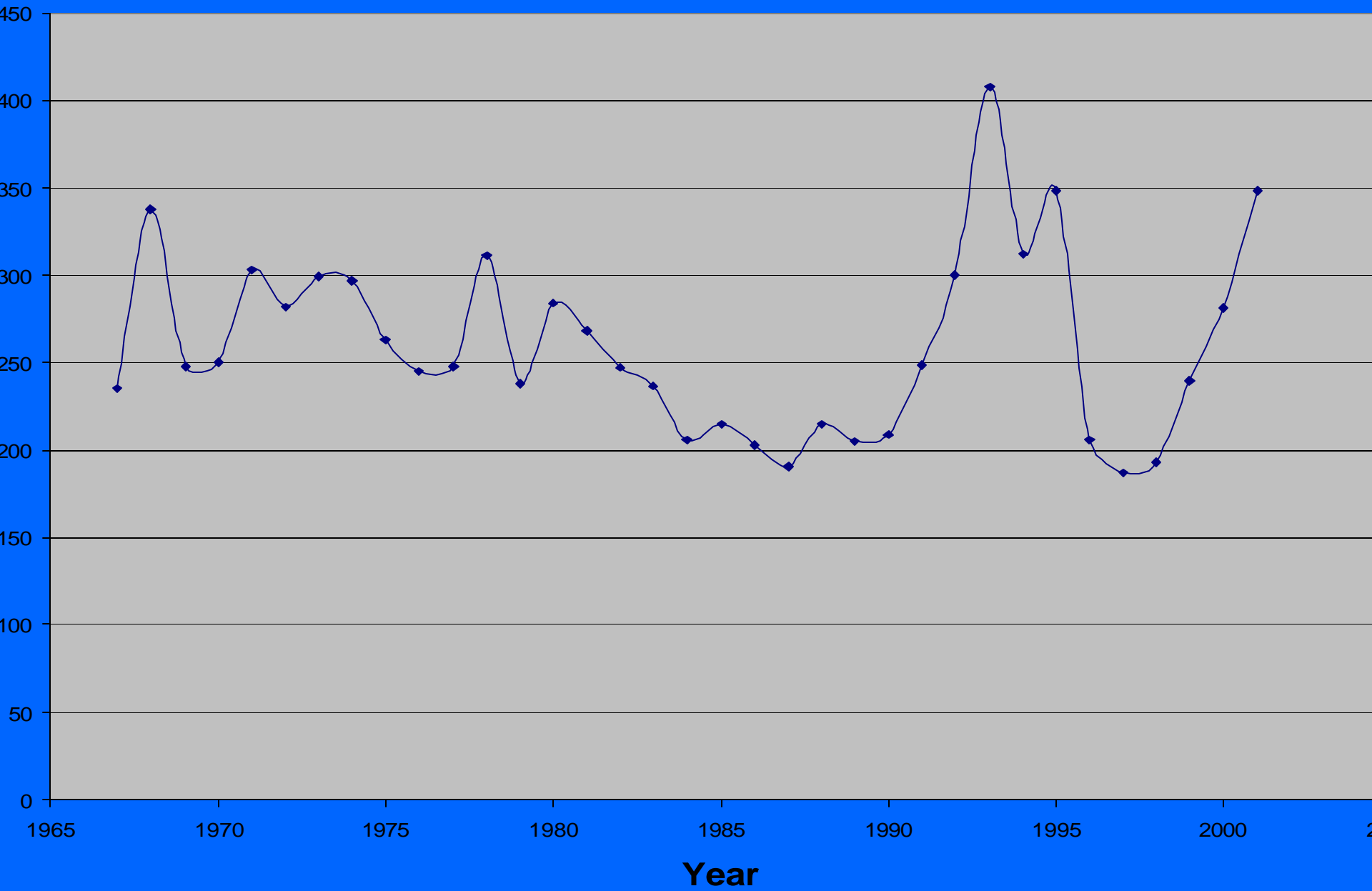
Meadow Creek Kokanee



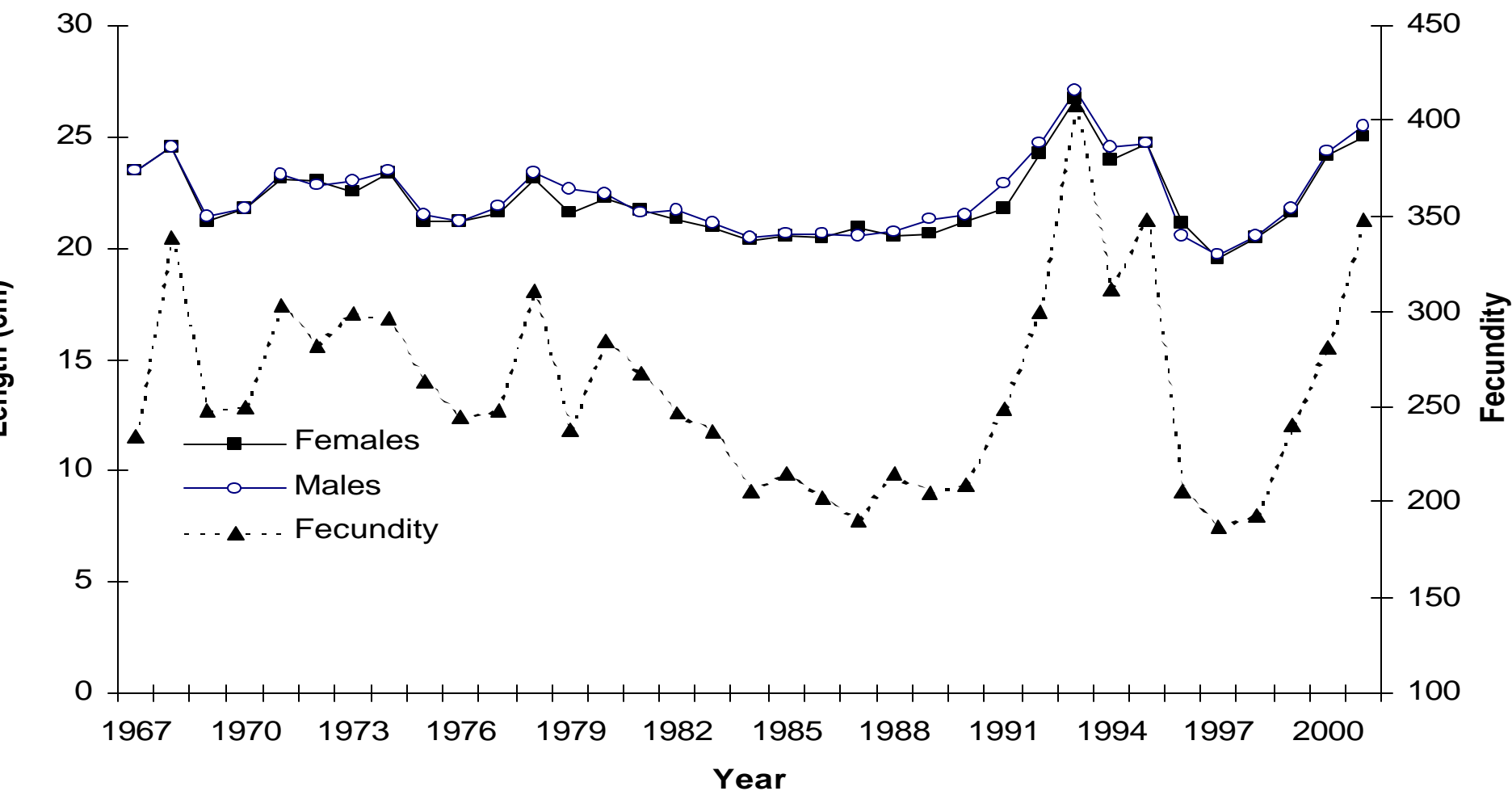
Meadow Creek Kokanee



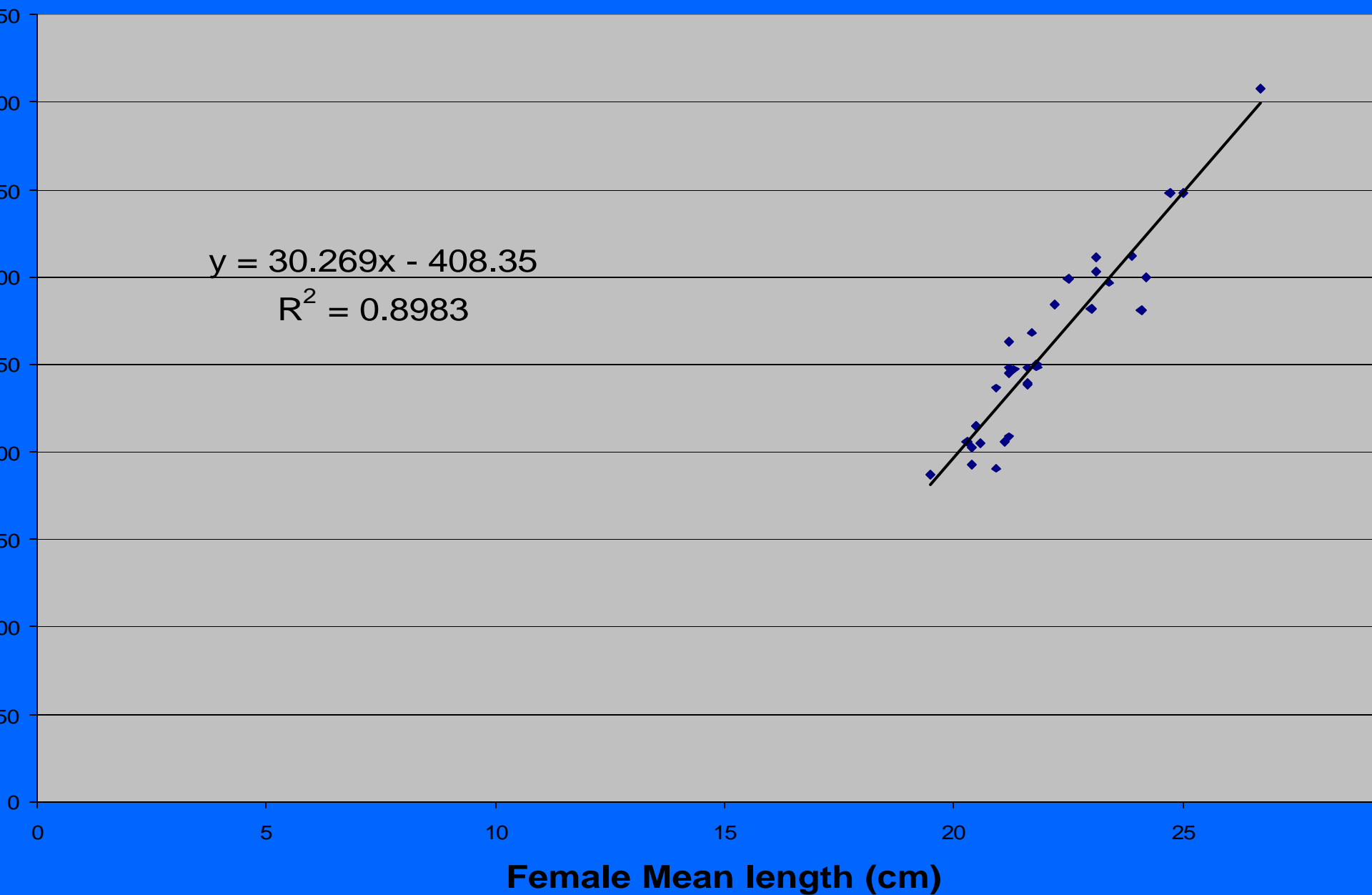
Meadow Creek Kokanee



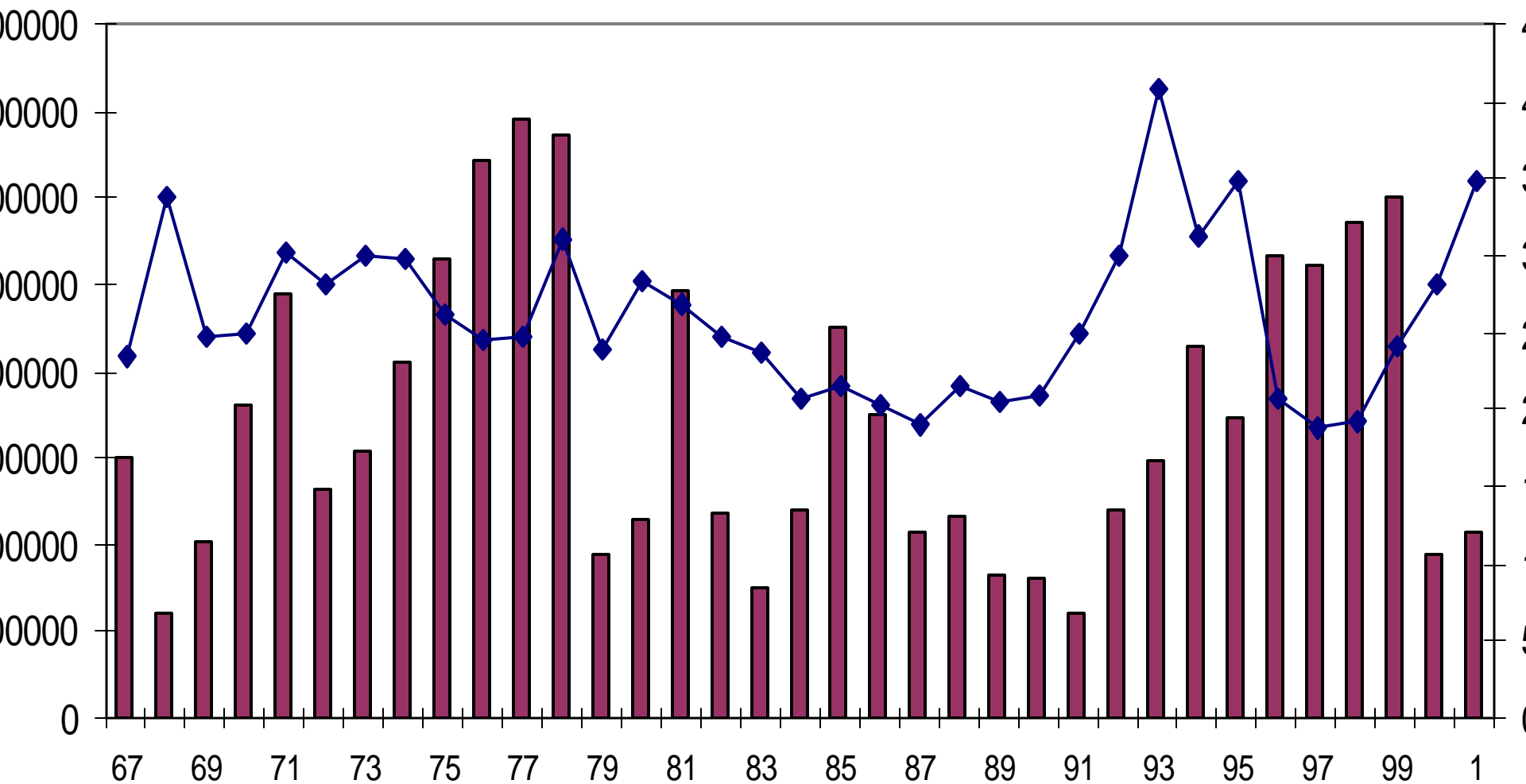
Mean length (cm) of Meadow Creek kokanee spawners and fecundity



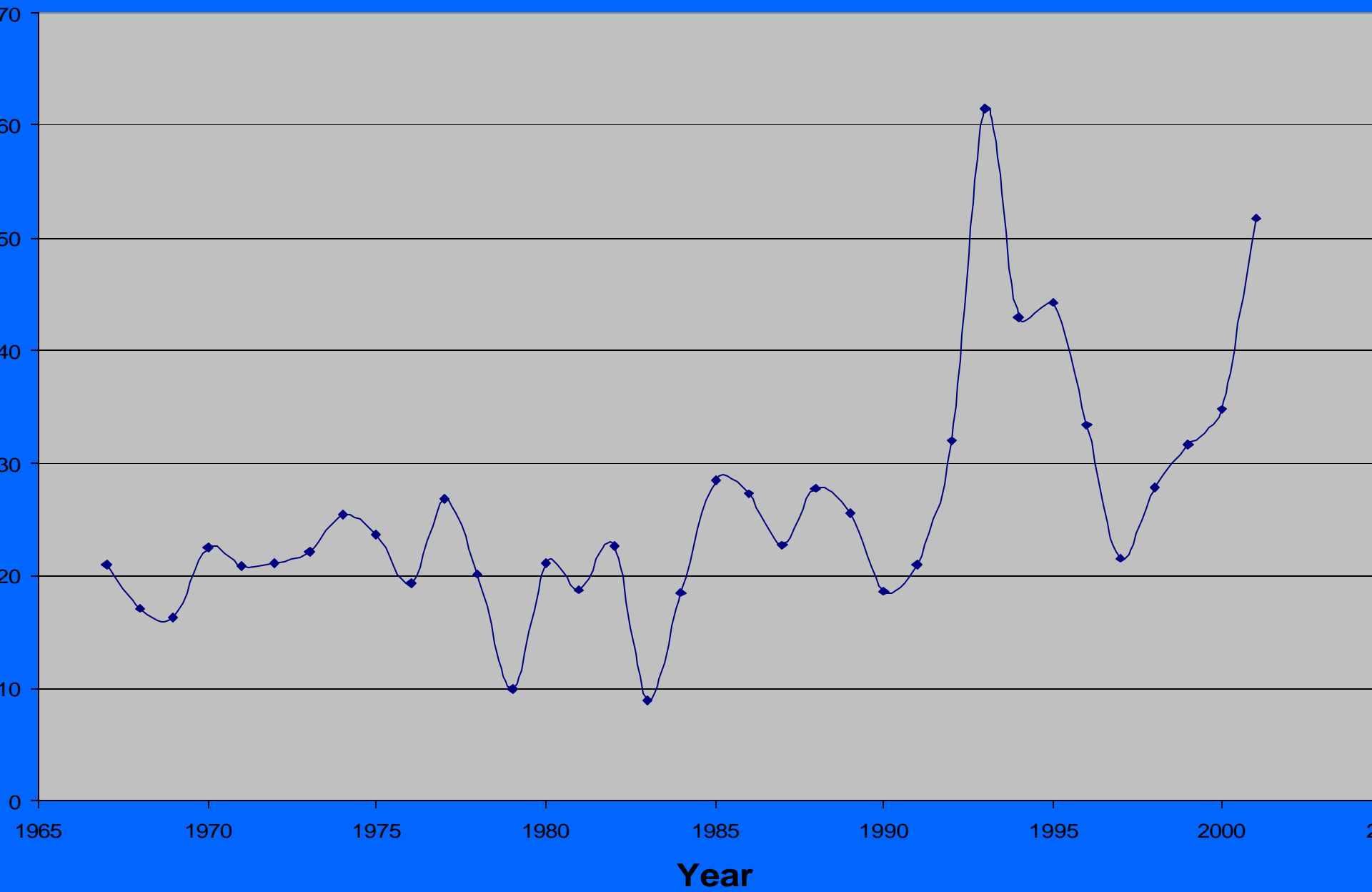
Meadow Creek Kokanee



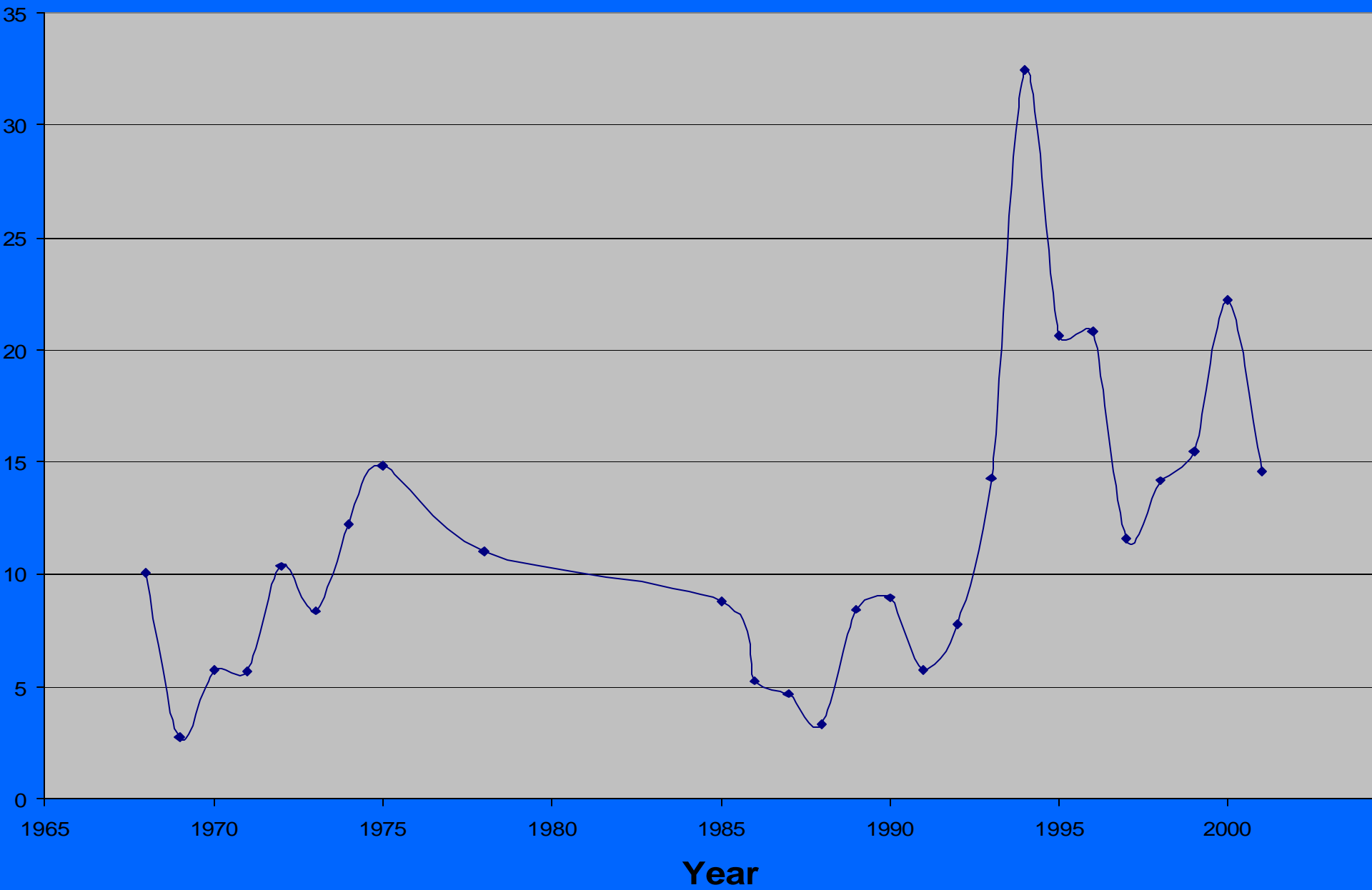
Meadow Creek and Lardeau kokanee escapement and fecundity



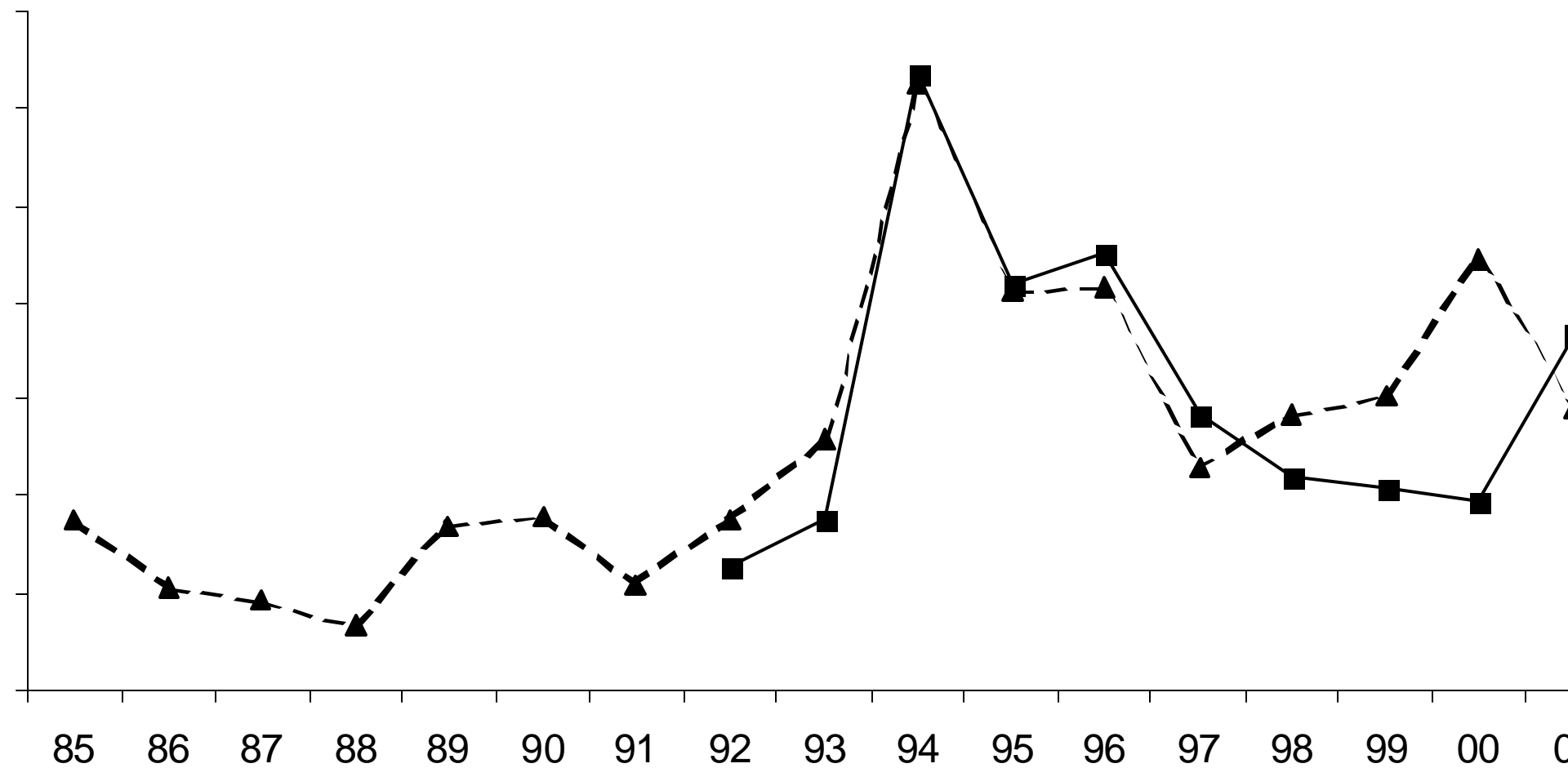
Meadow Creek Kokanee



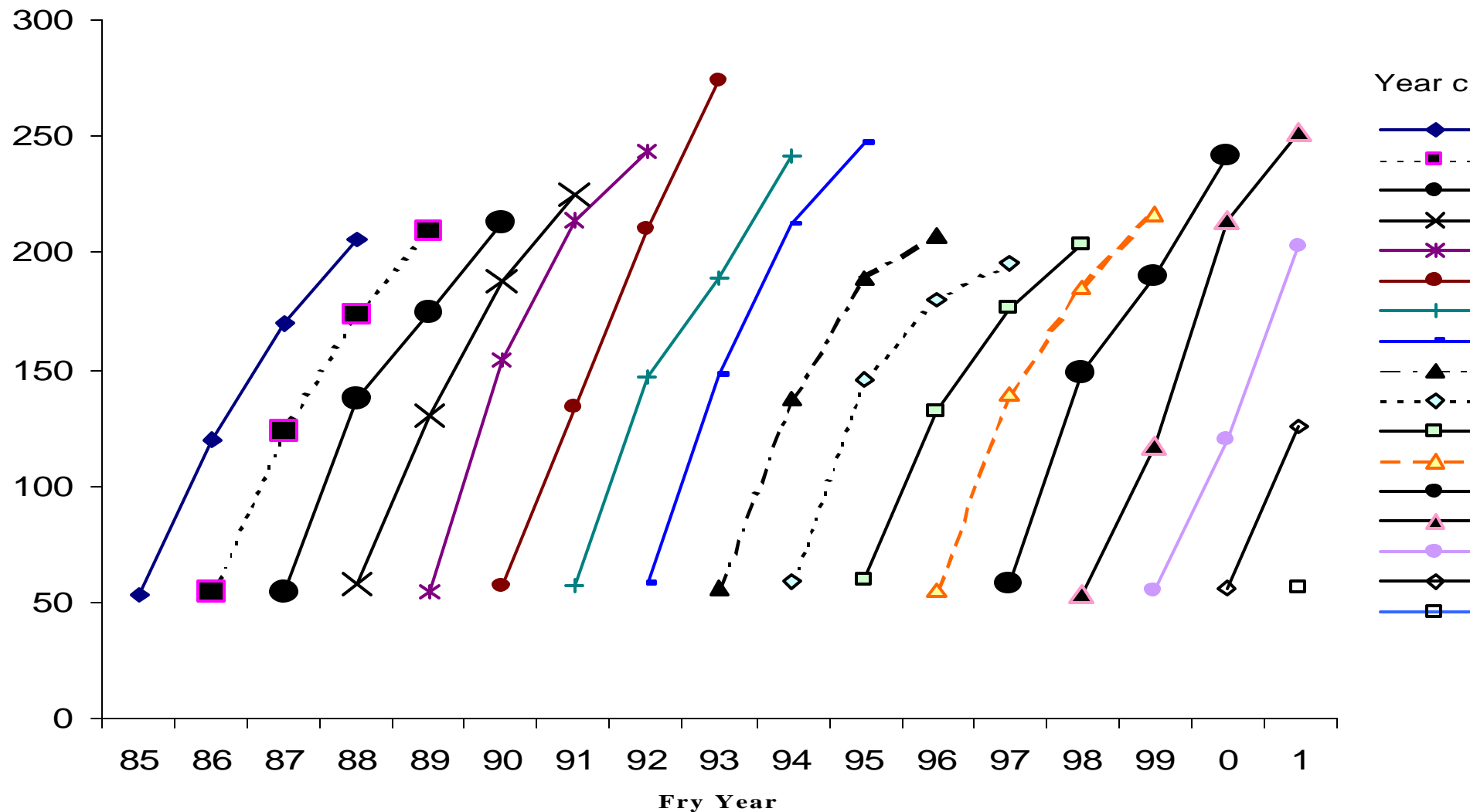
Meadow Creek Kokanee



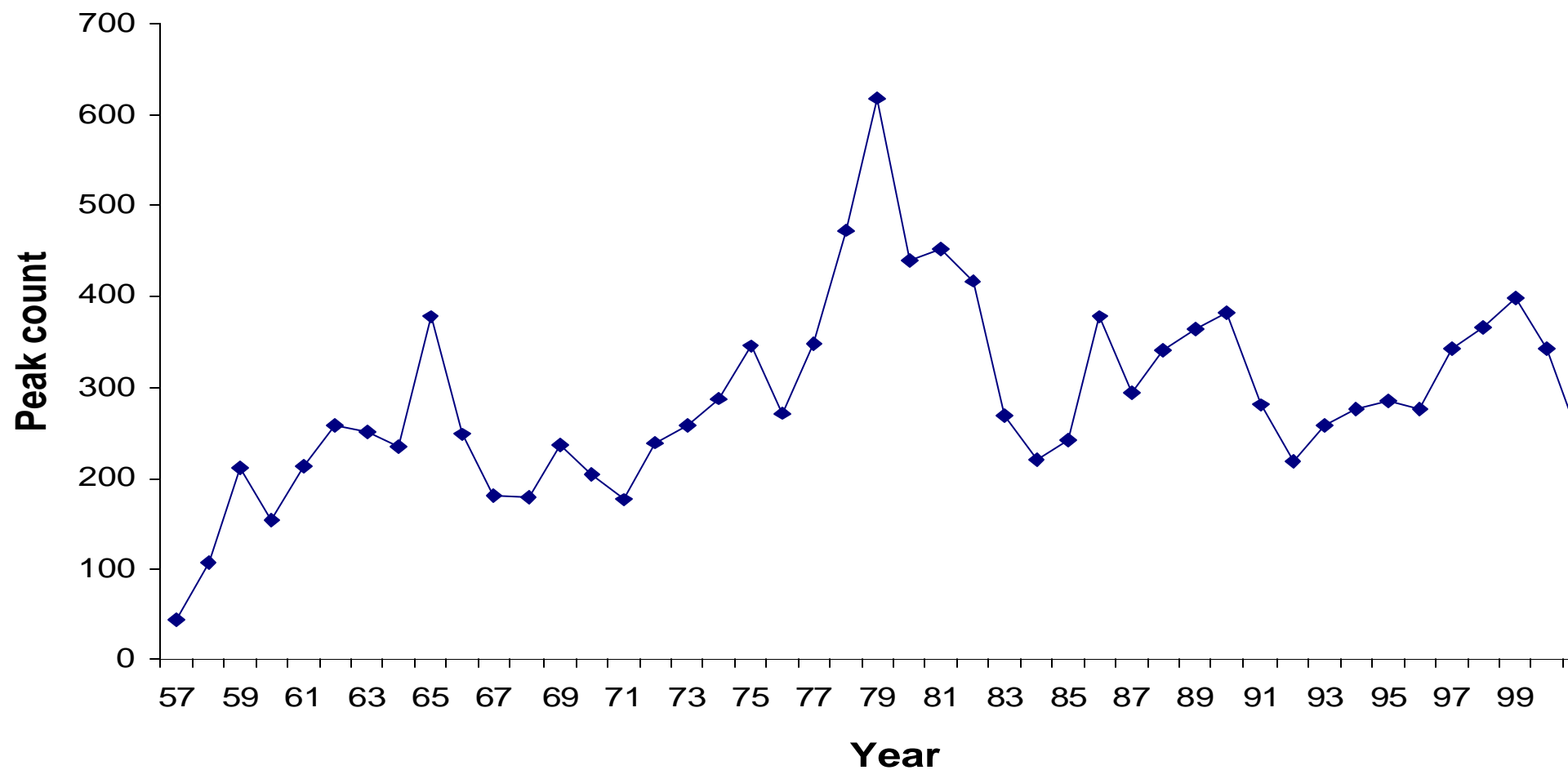
Meadow Creek fry measured production estimates compared to total in-lake fry hydroacoustic estimates



Kokanee length-at-age over time (1985-2001). Data from trawl caught fish for ages 0+ to 2+ with lengths standardized to account for different capture dates between years. Age 3+ lengths are mean lengths of spawners from Meadow Creek.



Annual escapement of Gerrard rainbow trout measured by the highest single day count (Total count is x 2.3)



Comparison of number of kokanee all ages and numbers of large fish assumed to be predators from acoustic monitoring

Kootenay Lake kokanee and Gerrards

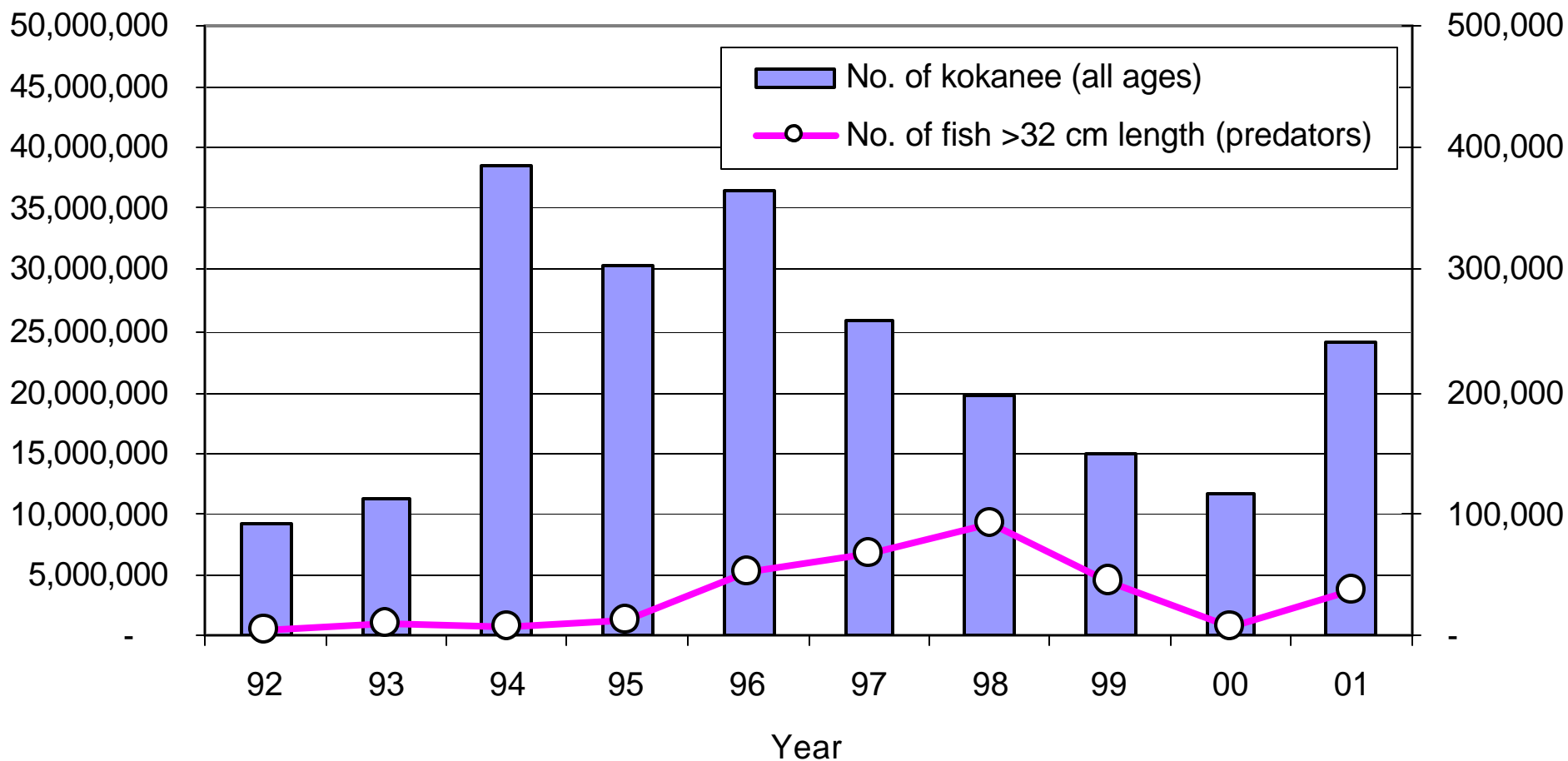
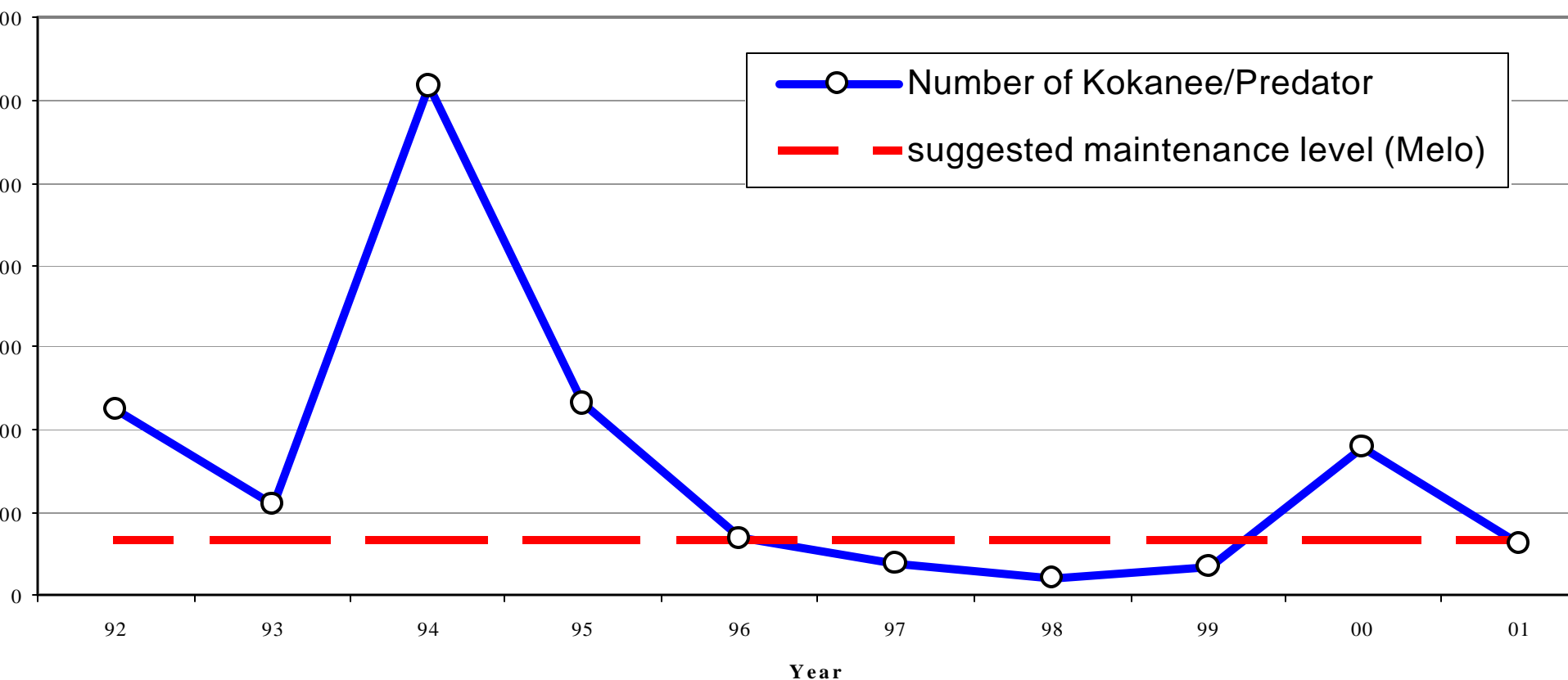
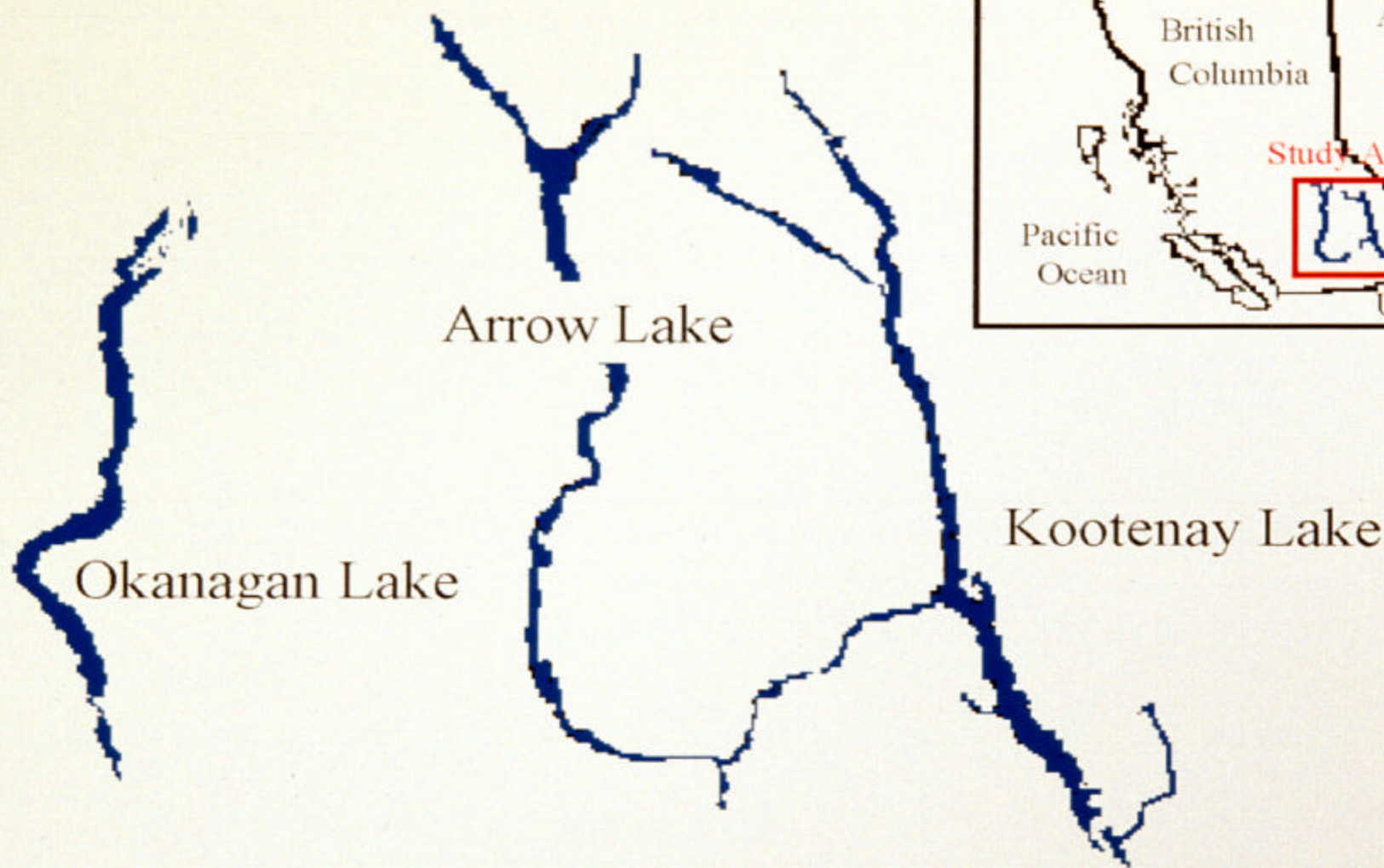


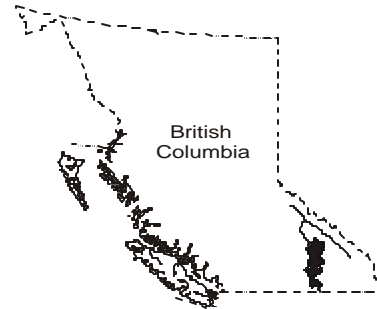
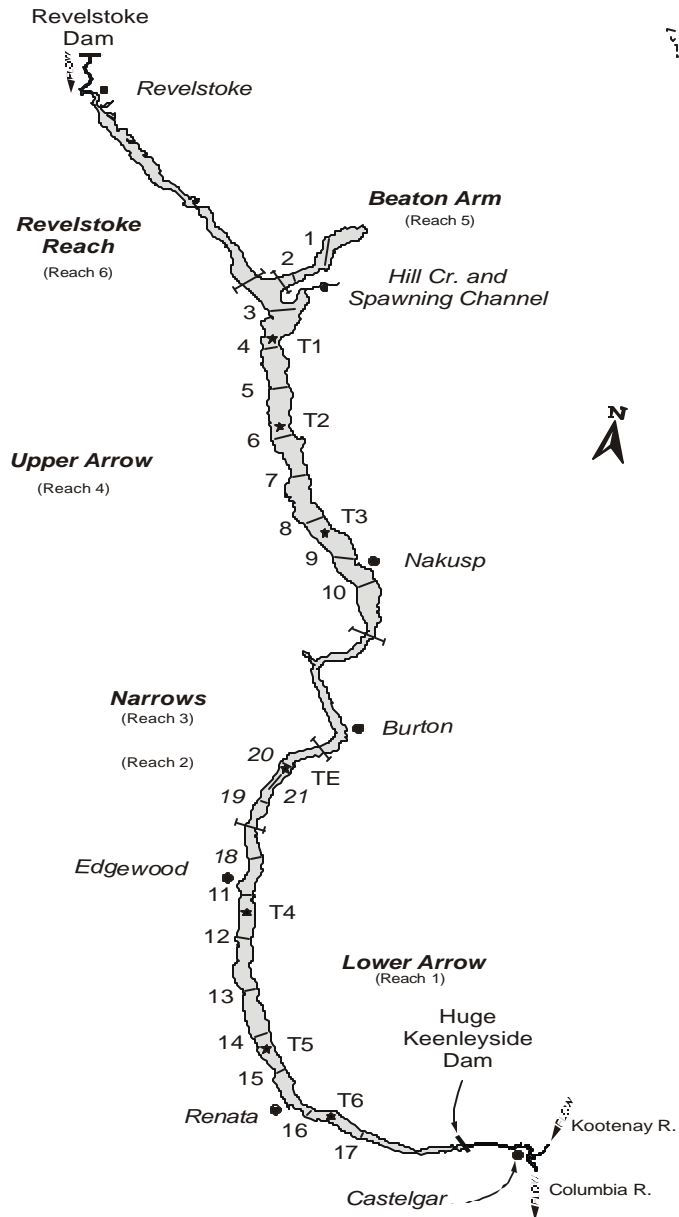
Figure 11. Trends in prey to predator ratios in Kootenay Lake during the fertilization period based on acoustic monitoring. **Note: 700 kokanee/rainbow is considered minimum levels to maintain prey populations in Idaho**

Kootenay Lake - predator prey ratios






OKANAGAN, ARROW AND KOOTENAY LAKES



Hydroacoustic Surveys

Transects  1 - 20


Trawl Survey

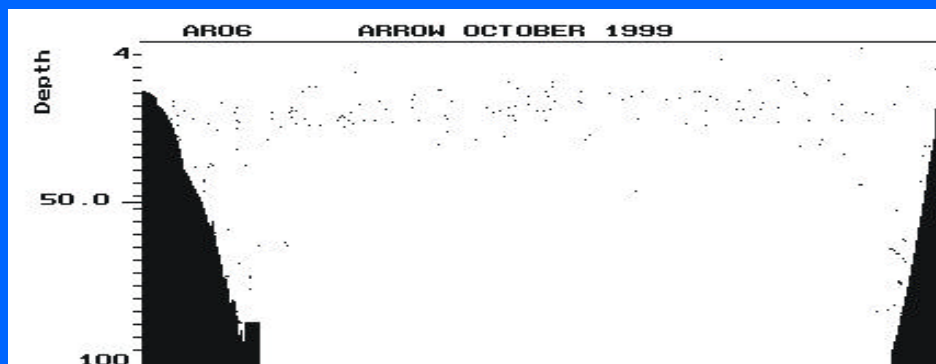
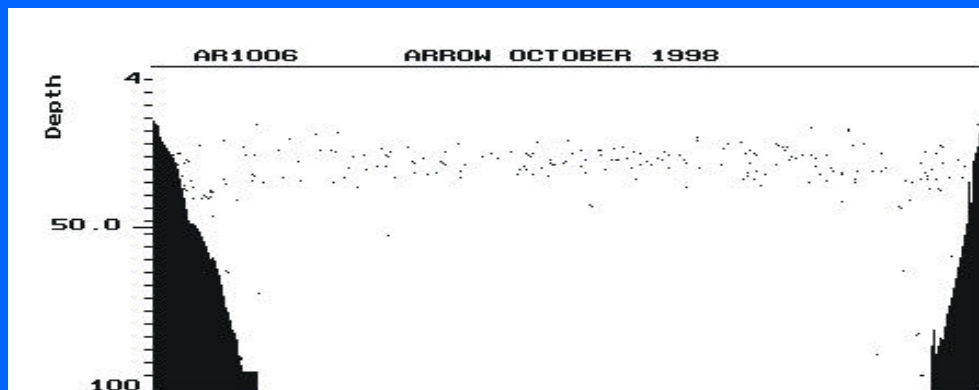
Trawl Locations  T(1 - 6)

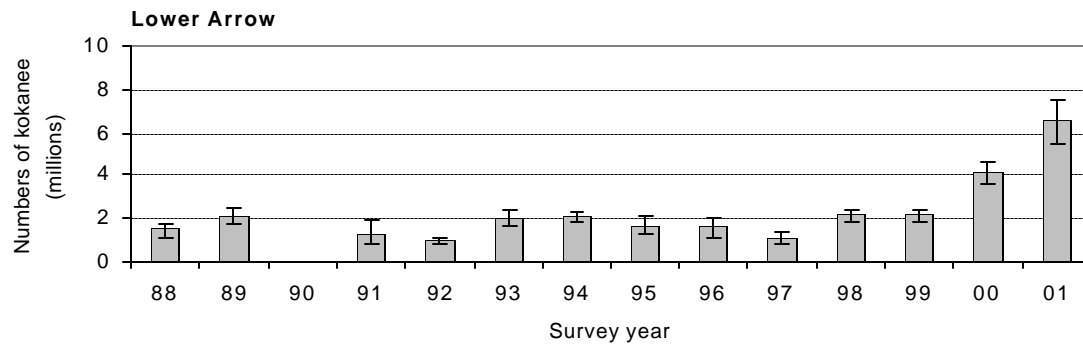
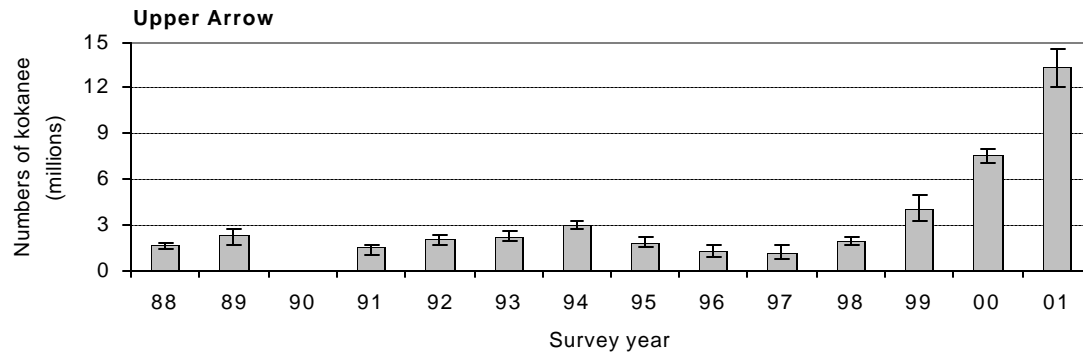
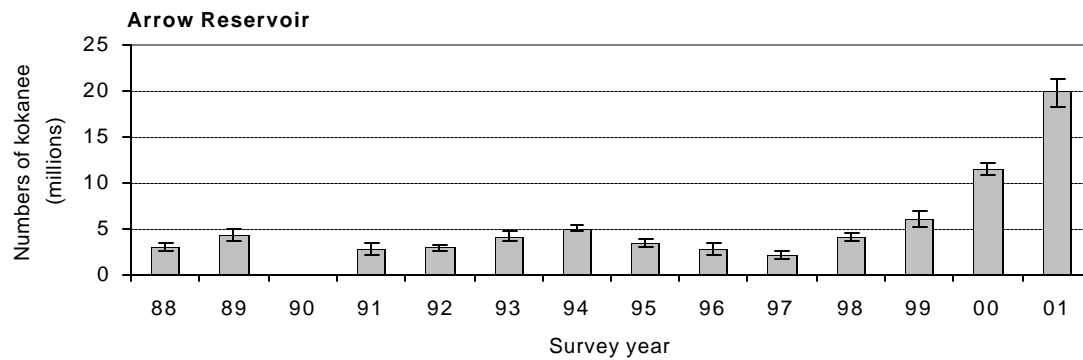
T1 Shelter Bay
 T2 Halfway River
 T3 Nakusp
 TE Below Narrows (extra)
 T4 Edgewood
 T5 Bowman Creek
 T6 Cayuse Creek

Study area reach breaks 

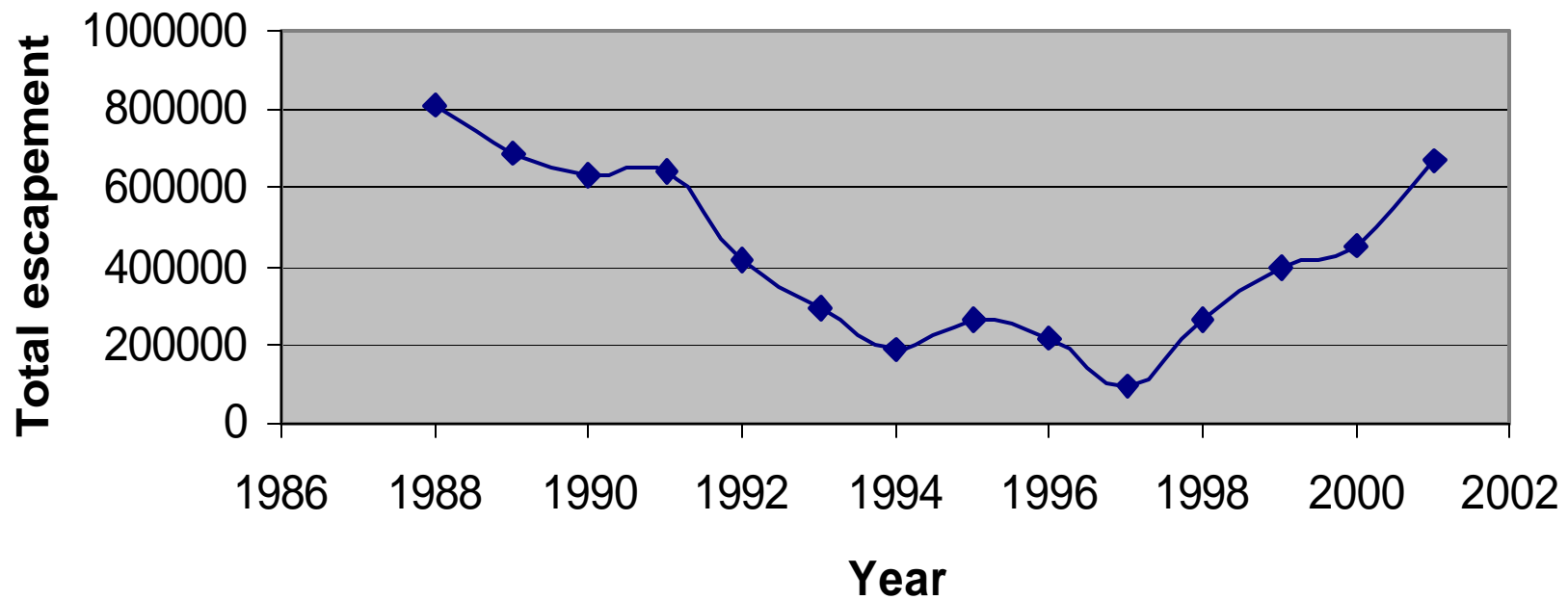
0 5 10 15 20 km







Upper and Lower Arrow Reservoir kokanee escapement



Closing comments

- Lake enrichment has been successful to date in restoring kokanee in Kootenay Lake and Arrow Reservoir
- these ecosystems are large, but fragile - kokanee are the canary in the coal mine
- restoration can be expensive, and uncertain
- Active adaptive management approach is a key part of BC's lake/reservoir kokanee recovery plans
- remember Aldo Leopold: “The first rule of intelligent tinkering is to keep all of the parts”.

**Kootenay Lake North Arm
Kokanee escapement**

