Have Invasive *Mysis diluviana* Altered the Carrying Capacity of Osoyoos L, for Sockeye Salmon ?.

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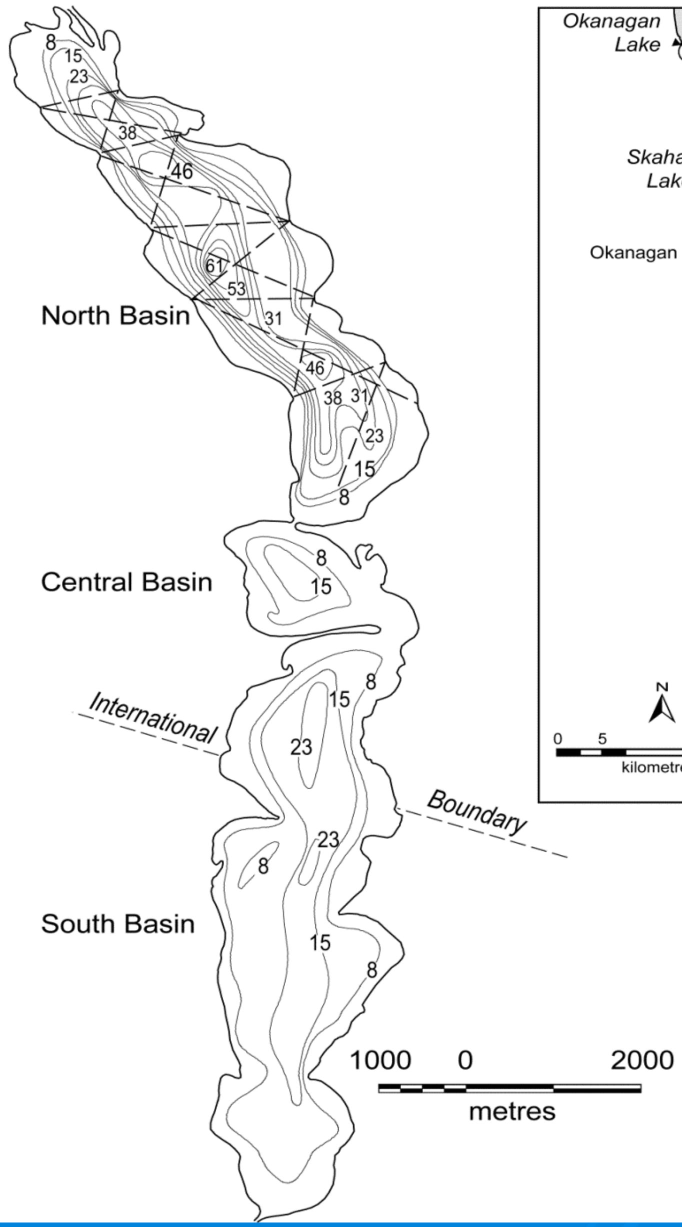
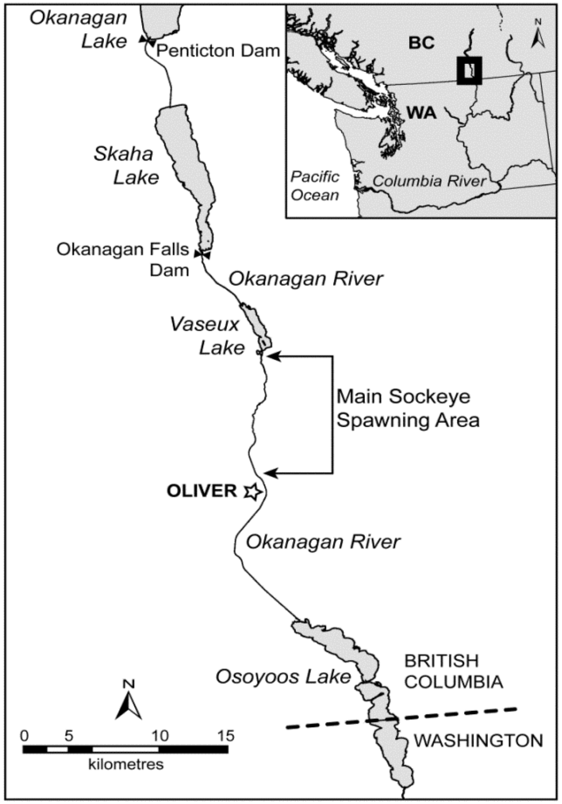
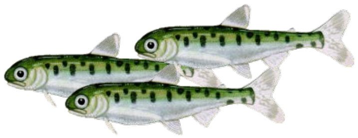


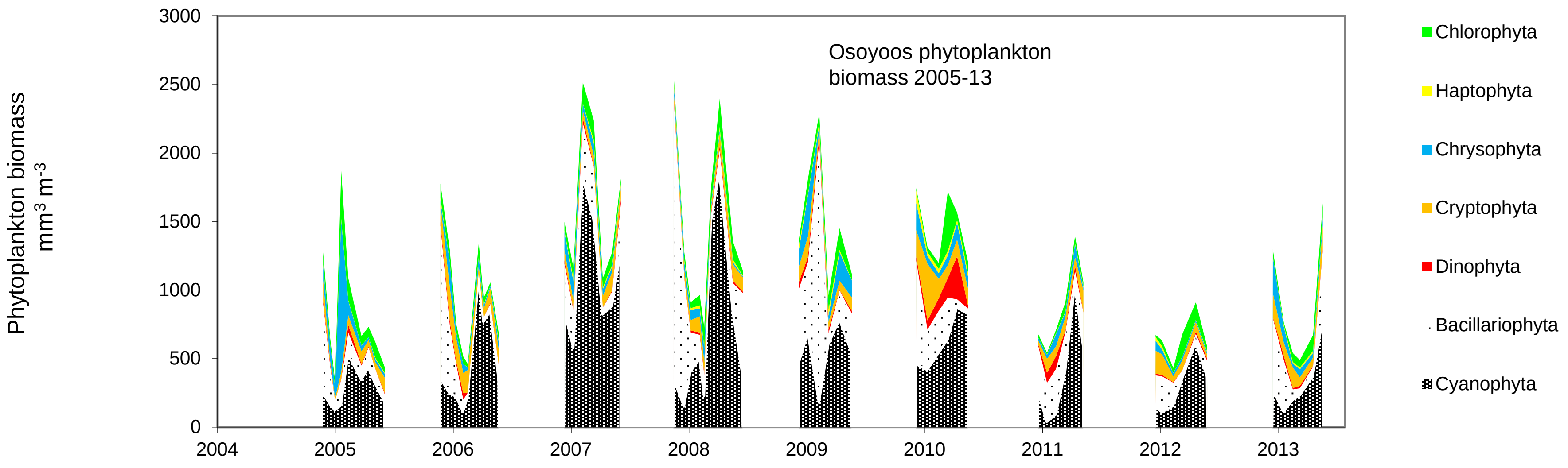




Osoyoos L. Study Site

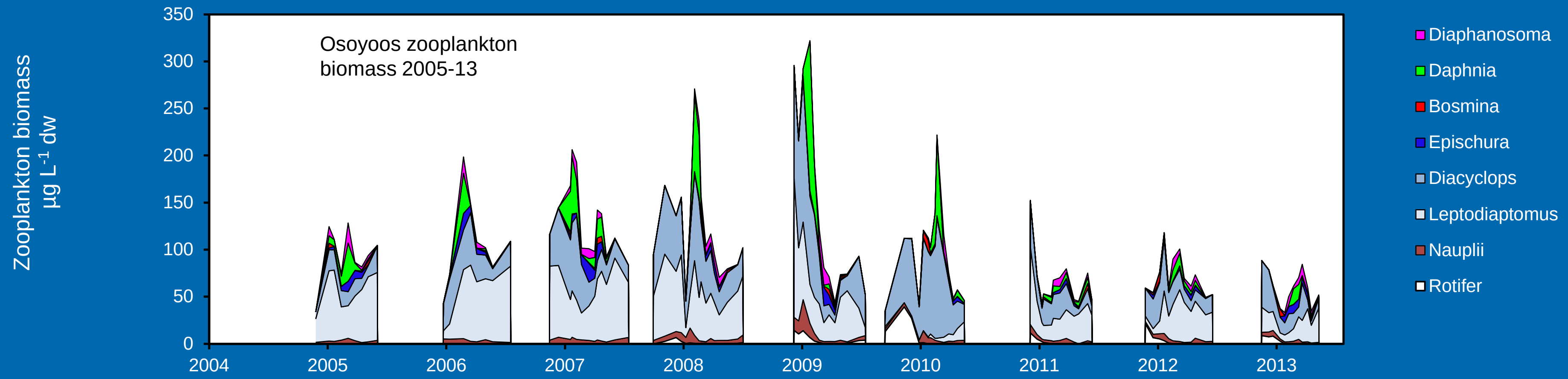
- Shallow (mean 40 m) & warm (surface temps > 25^{0}C)
- Mesotrophic (7-15 ug.l^{-1} P)
- Deeper waters often hypoxic (< 4 ppm O2.l^{-1}) in late summer.
- Historically known to produce relatively large Sockeye smolts (6-40g at age-1).

Mean growing season biomass of phytoplankton ($ug.l^{-1}$) 2005-2013



Blue-greens dominate biomass, followed by diatoms with remainder a mix of greens, golden browns and dinophytes

Seasonal mean biomass of zooplankton (ug.l^{-1} dry wt) 2005-2013



- Zooplankton numbers and biomass both dominated by copepods such as *Leptodiaptomus, Diacyclops* and large, but rare, *Epischura*.
- Cladocerans contribute smaller numbers, less biomass than copepods with 2-3 species of *Daphnia* plus much smaller-bodied *Bosmina*.
- Note the trend for higher biomass of zooplankton from 2005-2010 relative to 2011-2013.

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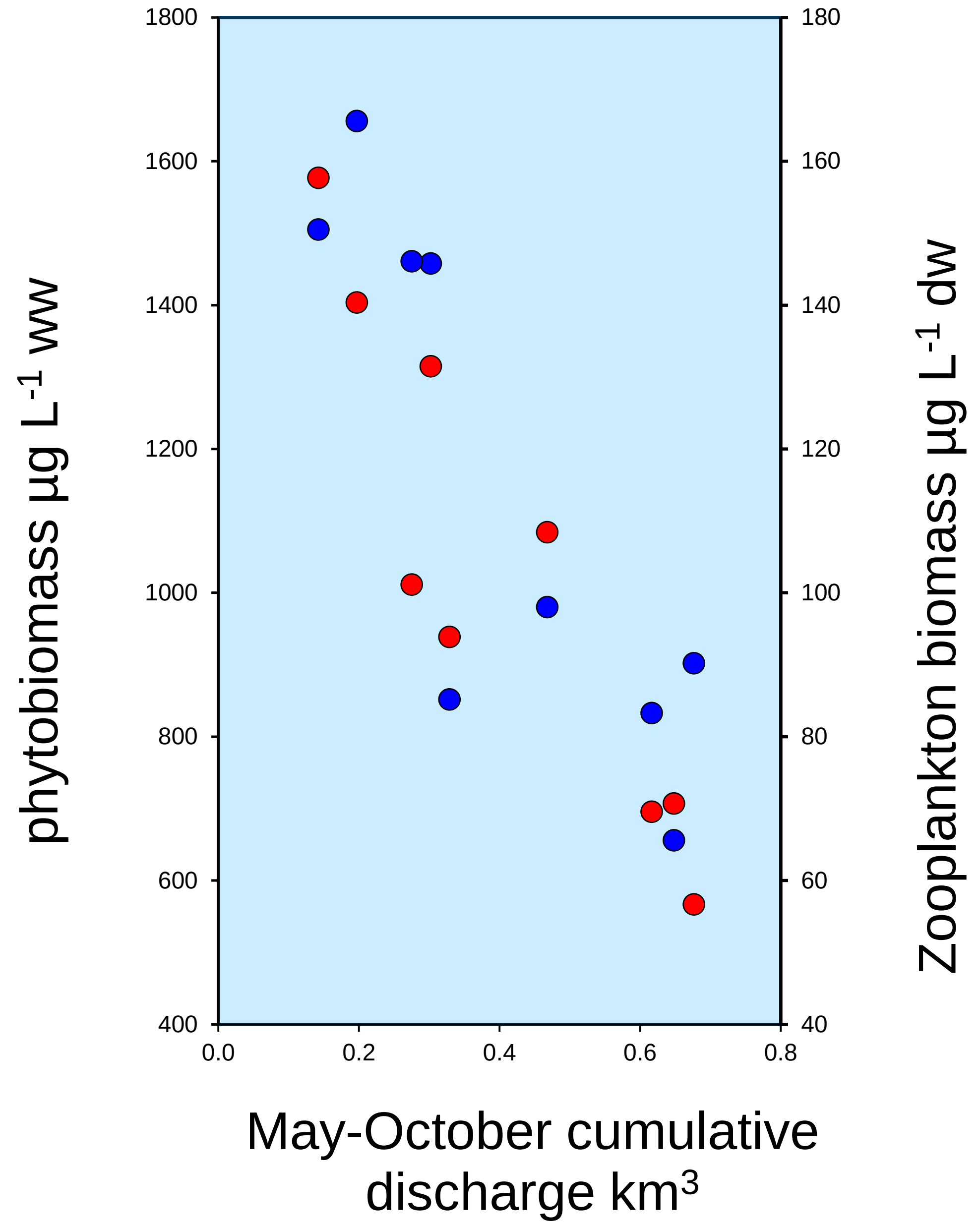
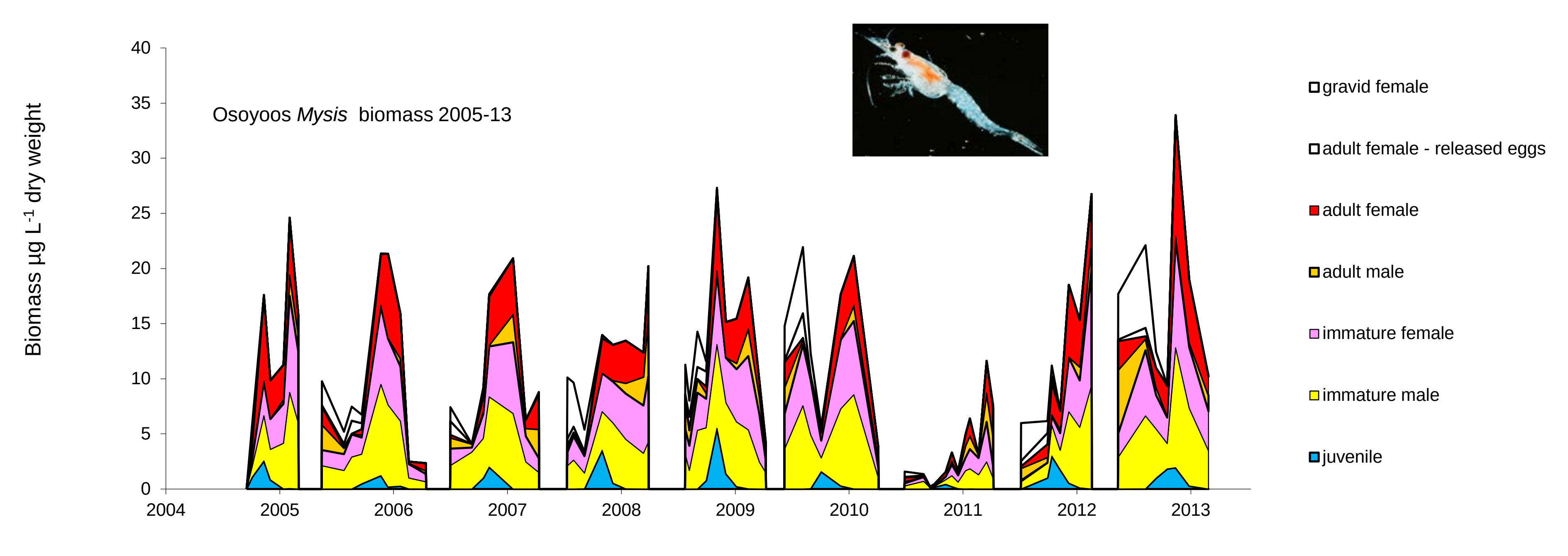


Physical Drivers of Biota

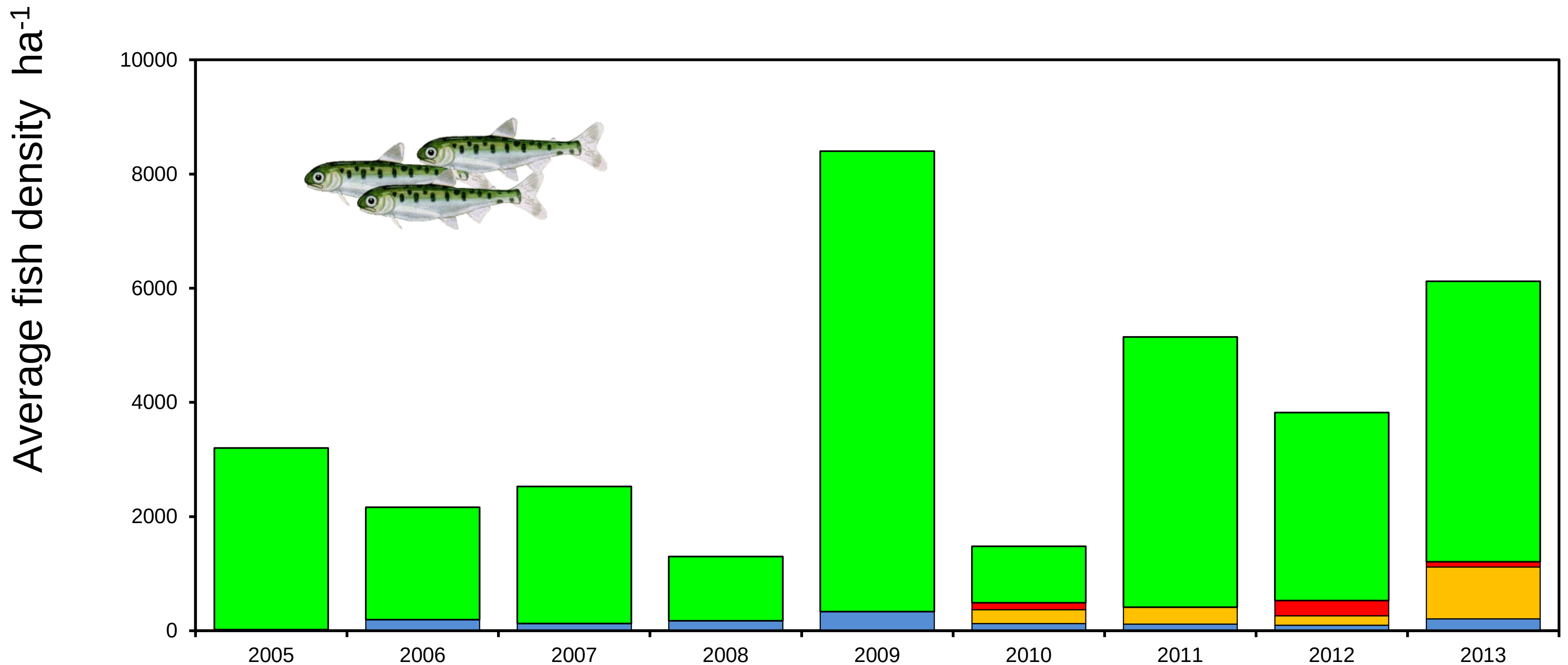
- Phytoplankton and zooplankton biomass in Osoyoos L. controlled by Okanagan R. discharge.
- Discharge drives high contrast (roughly 3-fold changes) in potential “bottom-up” forcing of lower trophic level food abundance for fish & mysids !

Seasonal mean biomass of Mysis diluviana (ug.l^{-1} dry wt) 2005-2013



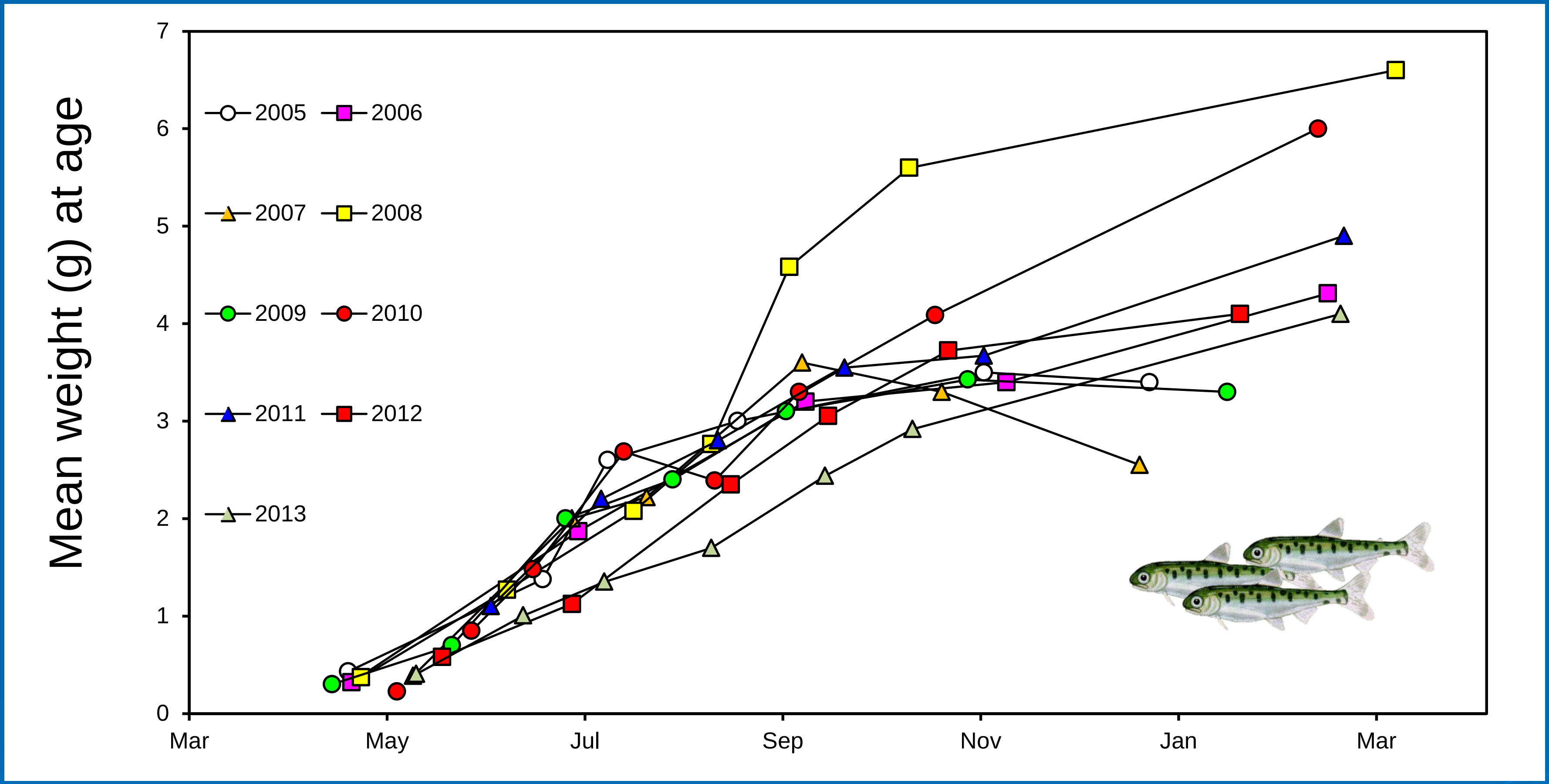
- *Mysis diluviana* is an invasive macrozooplankter that appeared in Osoyoos Lake sometime between the late 1980s (Shepherd, unpublished observations and late 1990s (Hyatt and Rankin) .
- *Mysis* exhibits a one-year life-cycle in Osoyoos L. (unlike Okanagan L) and despite large annual fluctuations in phytoplankton and zooplankton food sources maintains stable numbers and biomass in all years but 2011.

Juvenile Sockeye Abundance (no.ha^{-1}) in Osoyoos Lake 2005-2013



High contrast in pelagic fish abundance during 2005-2013 from as few as 1200 fry.ha^{-1} to as many as 8300 fry. ha^{-1} has potential to establish strong top-down forcing by fish predation on zooplankton prey (i.e. roughly 8 fold change in abundance among years !)

Seasonal Growth Performance of Sockeye Fry in Osoyoos Lake



- Lowest abundance years (2008, 2010) have highest growth performance.
- Highest abundance year (2009) has relatively poor growth performance.
- Suggests exactly what one might expect from a top-down density dependent growth model.

“Top-down” Food-web Correlations

Top-down correlations			p-unt	p-trans	
10	Age-0 fry density	Von Bertalanffy W_∞	0.04		Sig.
11	Age-0 fry density	Von Bertalanffy K	0.16		ns
12	Age-0 fry density	Age-0 fall fry weight (Nov)	0.07		ns
13	Age-0 fry biomass	Age-0 fall-fry weight (Nov)	0.16		ns
14	All fish biomass	Age-0 fall-fry weight (Nov)	0.19		ns
15	Age-0 fry density	Age-0 nerkid survival	0.10		ns
16	Age-0 fry biomass	Age-0 nerkid survival	0.16		ns
17	All fish biomass	Age-0 nerkid survival	0.19		ns
18	Age-0 frydensity	Total Zpl biomass	0.42	0.14	ns
19	Age-0 frybiomass	Total Zpl biomass	0.41	0.15	ns
20	All fish biomass	Total Zpl biomass	0.39	0.21	ns
21	Age-0 fry density	Mysis biomass	0.37		ns
22	Age-0 fry biomass	Mysis biomass	0.44		ns
23	All fish biomass	Mysis biomass	0.50		ns

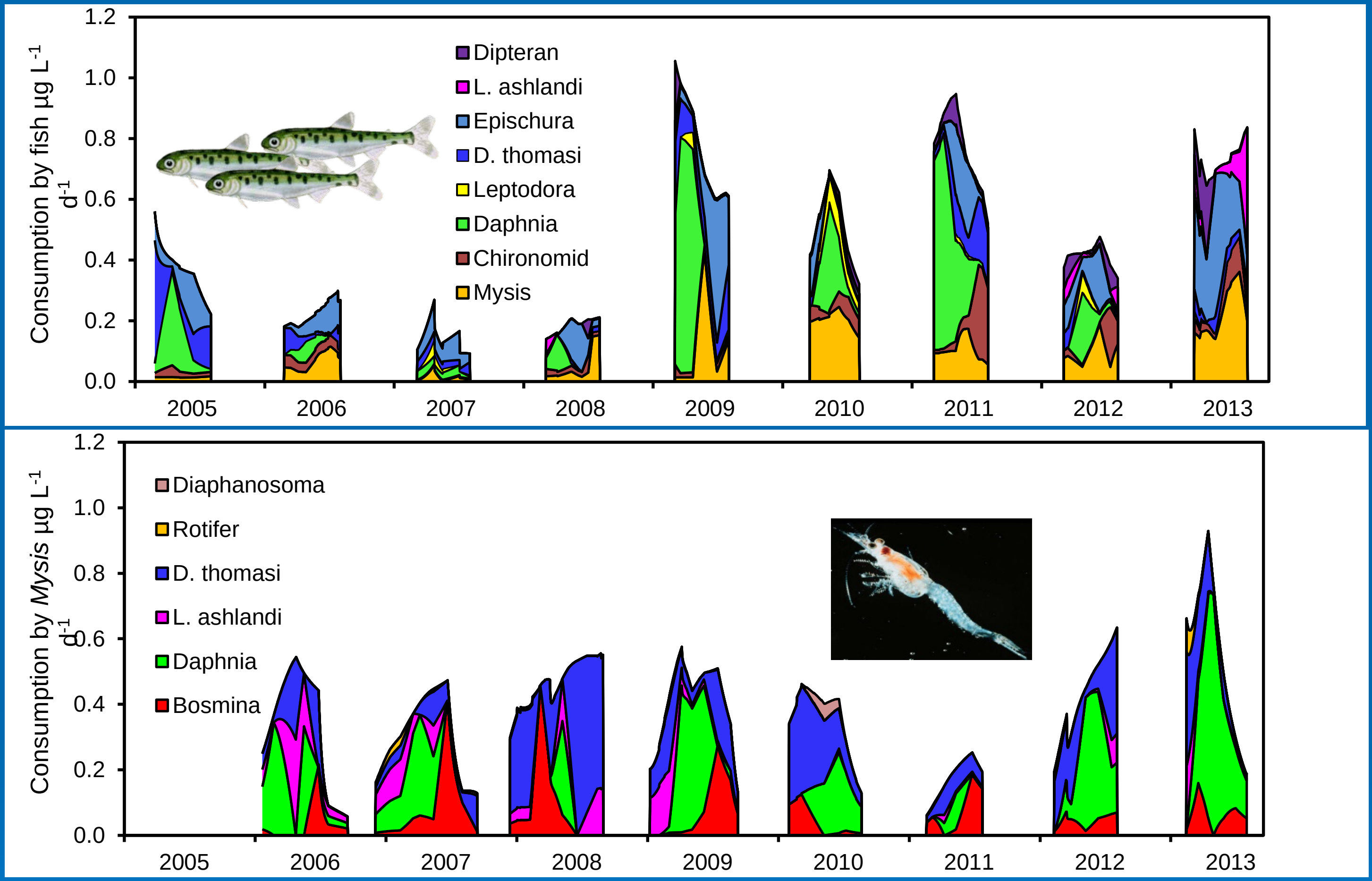
Only 1 of 14 top-down correlations exhibited a significant association between Van-B. W_∞, and Sockeye fry density !

“Bottom-up” Food-web Correlations

Potential bottom up correlations			p-unt	p-trans	
1	Total Zpl biomass	Age-0 nerkid November weight	0.23	0.21	ns
2	Total Zpl biomass	Age-0 nerkid Von Bertalanffy W_∞	0.46	0.10	ns
3	Total Zpl biomass	Age-0 nerkid Von Bertalanffy K	0.39	0.27	ns
4	Total Zpl biomass	Age-0 nerkid survival	0.01		Sig.
5	Daphnia biomass	Age-0 nerkid survival	0.01		Sig.
6	Epischura biomass	Age-0 nerkid survival	0.01		Sig.
7	Mysis biomass	Age-0 nerkid Von Bertalanffy W_∞	0.32		ns
8	Mysis biomass	Age-0 nerkid Von Bertalanffy K	0.39		ns
9	Mysis biomass	Age-0 nerkid survival	0.22		ns

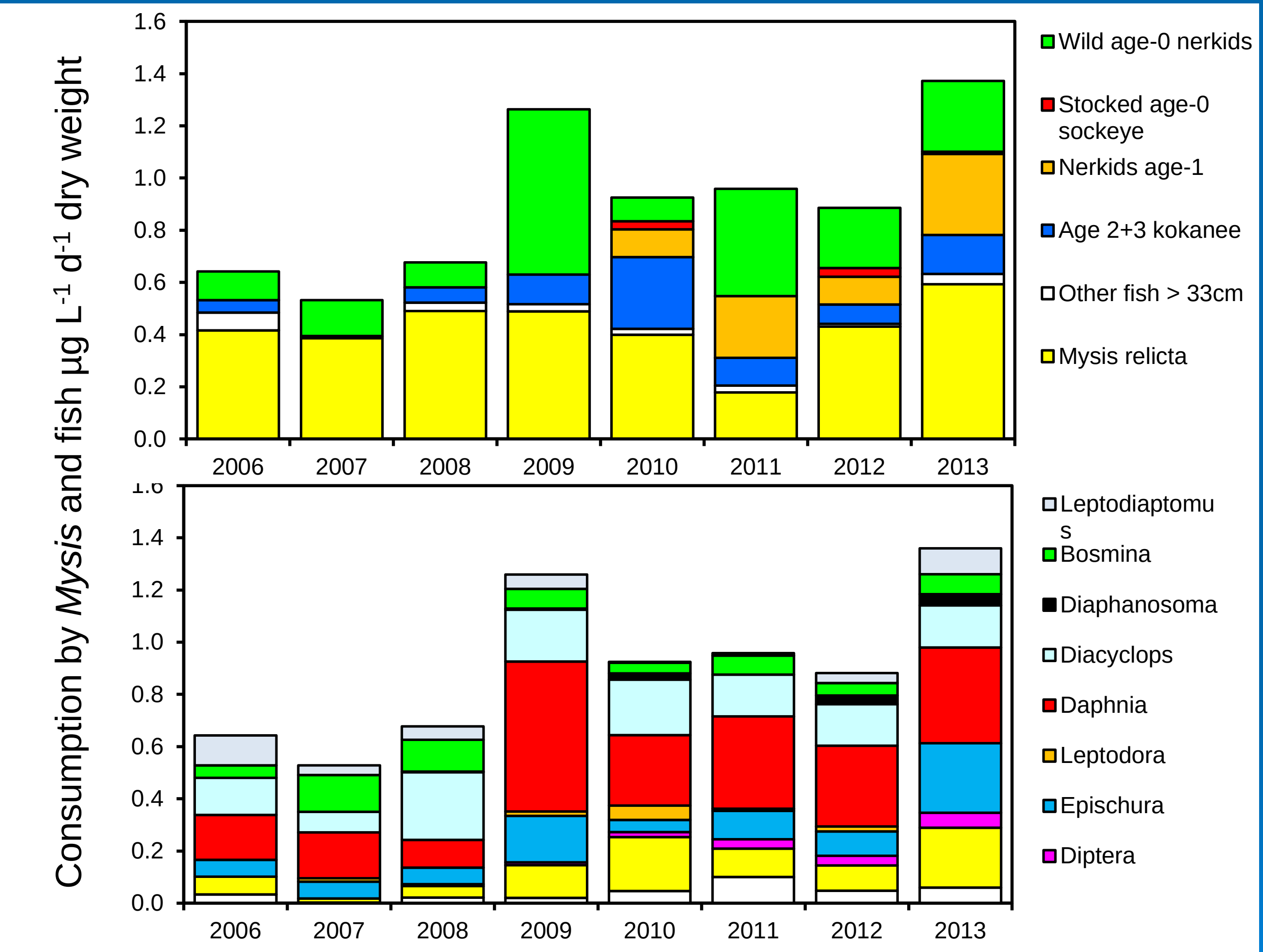
Several bottom-up correlations were significant (red highlights) for zooplankton biomass measures and Sockeye fry survival.

Bioenergetics-based Consumption of Zpl by Fisn & Mysids



Moderate overlap in diets of fish & mysids. Both consume *Daphnia, Diacyclops & Leptodiaptomus*. Only fish eat *Epischura* & mysids; Only *Mysis* eats *Bosmina*.

Relative Consumption by Fish and Mysids of All Zooplankton and Zooplankton by Taxa

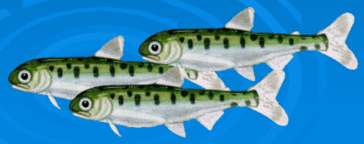


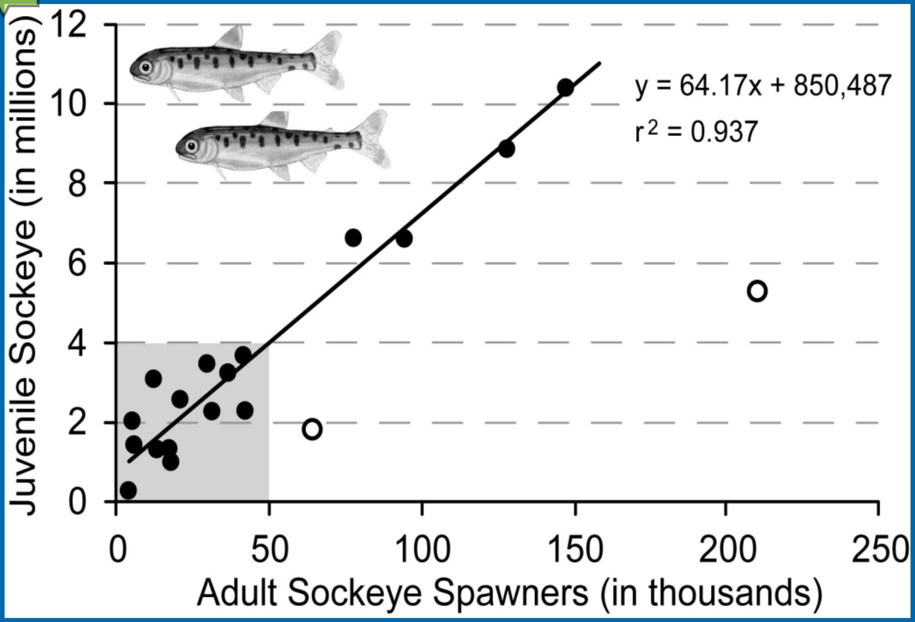
Mysids eat 45% to 75% of the total Zpl consumed by fish and mysids together.

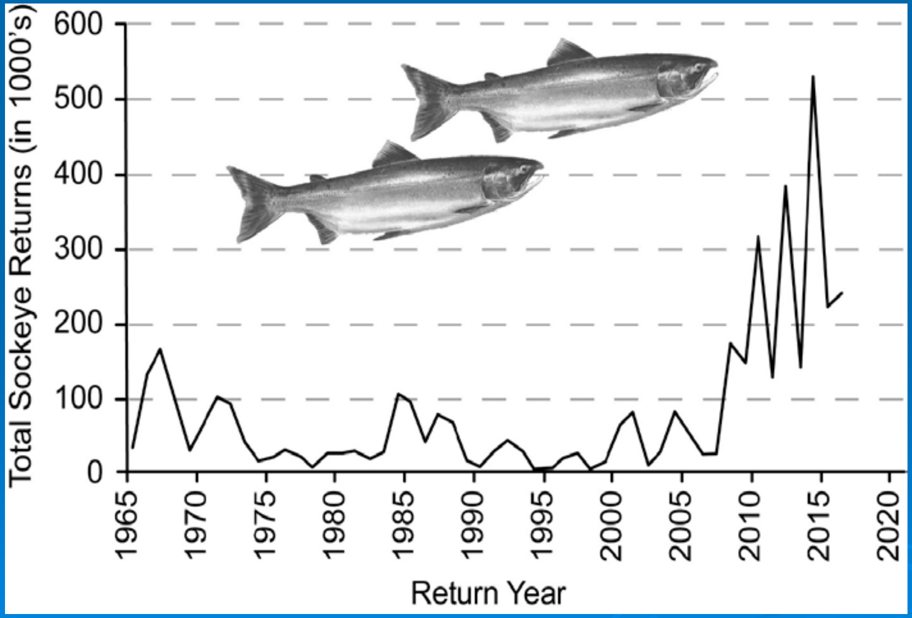
Bioenergetics analysis indicates that at the highest fish density levels observed (>8000.ha^{-1}) and lowest Zpl production levels observed, Zpl consumption by fish and mysids together may exert top-down control on cladoceran prey (e.g. *Daphnia and Bosmina*).

What Would Happen if Mysids Were Absent from Osoyoos L ?

- Mysid introductions /invasions are often associated with altered food-webs (losses of Zpl taxa e.g. *Daphnia pulex*) and population collapses by pelagic fish.
- In Osoyoos Lake, pelagic fish and mysids appear to coexist “happily”.
- Mysids, Sockeye fry & zooplankton in Osoyoos L. form a “trophic triangle” in which mysids and Sockeye eat common prey (e.g. *Daphnia, Diacyclops*) but Sockeye also eat mysids (i.e. the latter are a “source” and a “sink” for Sockeye fry from a food-web and energetics perspective).
- Evidence of “bottom-up” control exerted by *Daphnia* on Sockeye fry survival suggests Sockeye fry survival could be higher in the absence of mysids.
- The dominance of “bottom-up” control and virtual absence of strong “top-down” control precludes direct detection of an effect of mysids on Sockeye fry growth.
- **<u>BUT</u>** If one assumes that all the *Daphnia* mysids eat could be eaten by Sockeye, subtracts from this the quantity of *Mysis* that Sockeye eat and expresses the net result as proportion of current Sockeye diet, it would represent a 44% increase in Sockeye fry daily ration over the growing season i.e. Sockeye smolts would likley be significantly larger than at present.







Conclusions

- *Mysis diluviana* alterations of food webs, Sockeye fry survival & growth have likely altered the carrying capacity of Osoyoos Lake for Sockeye production.

<u>BUT</u>

- *Mysis* occupation of Osoyoos Lake has not precluded restoration of Sockeye smolts or adults to levels at or above historic abundance