Hypothesis: sea lice, either naturally occurring or passed from fish farms, are an important contributor to the Fraser sockeye situation

Simon Jones

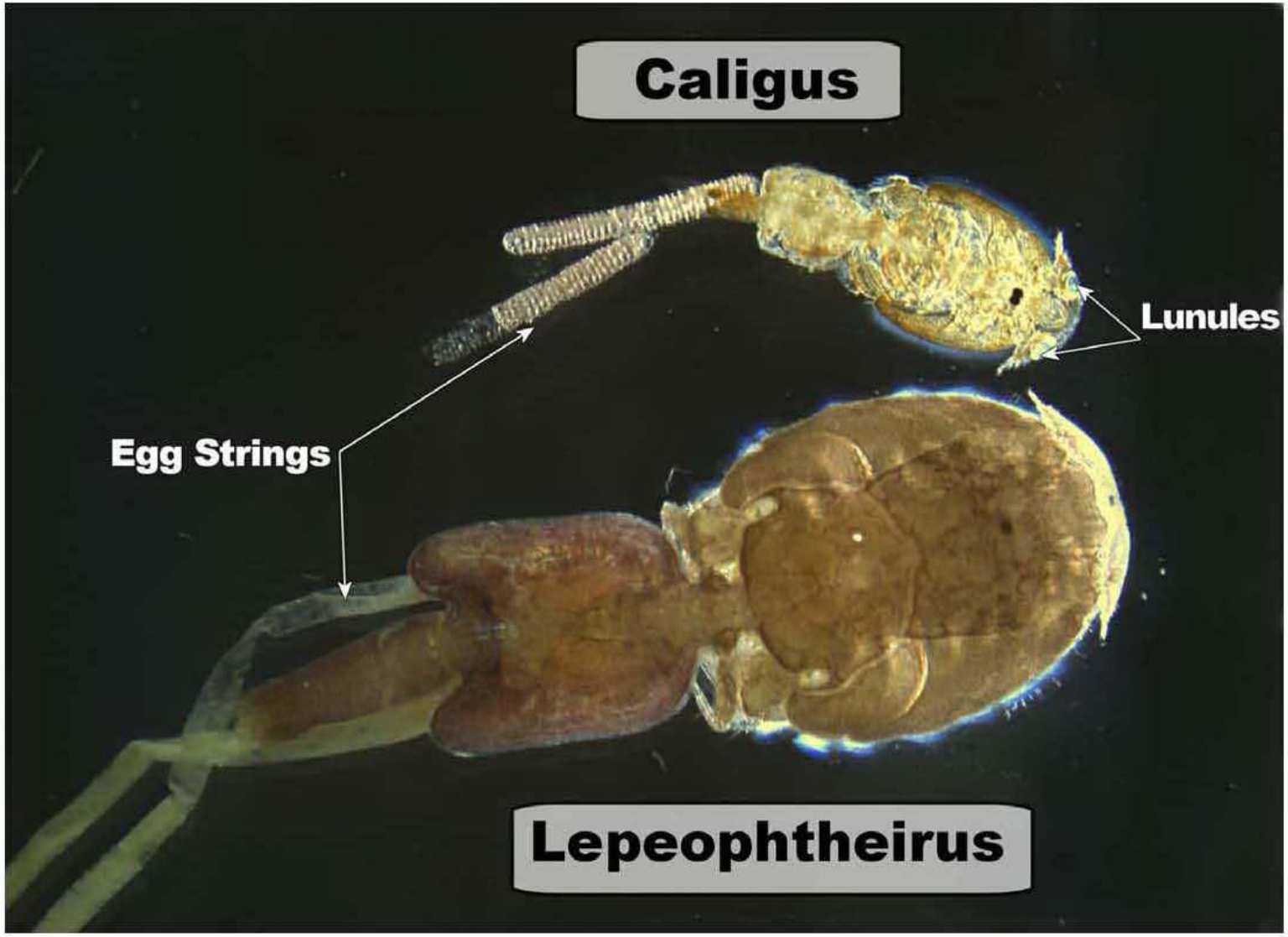
Fisheries and Oceans Canada

Pacific Biological Station

Sea lice?

- Parasitic copepods
- Early developmental stages are free-living in the plankton
- Development and survival depends on salinity, temperature and on locating a suitable fish host
- Later stages are found on skin of marine fish
  - Feed on mucous and tissues associated with the skin

Two species of sea lice most frequently reported from wild and farmed salmon in British Columbia



Direct evidence for sea lice on juvenile (<100g) sockeye and other salmon in and adjacent to the Strait of Georgia

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  - Salmon collected "upstream" and "downstream" of farms
  - Abundance ratio of Caligus / Lepeophtheirus ranged from 5:1 to 54:1
  - Site with highest infection upstream of salmon farms
  - Evidence of Caligus and Lepeophtheirus on some adjacent salmon farms, other species not examined

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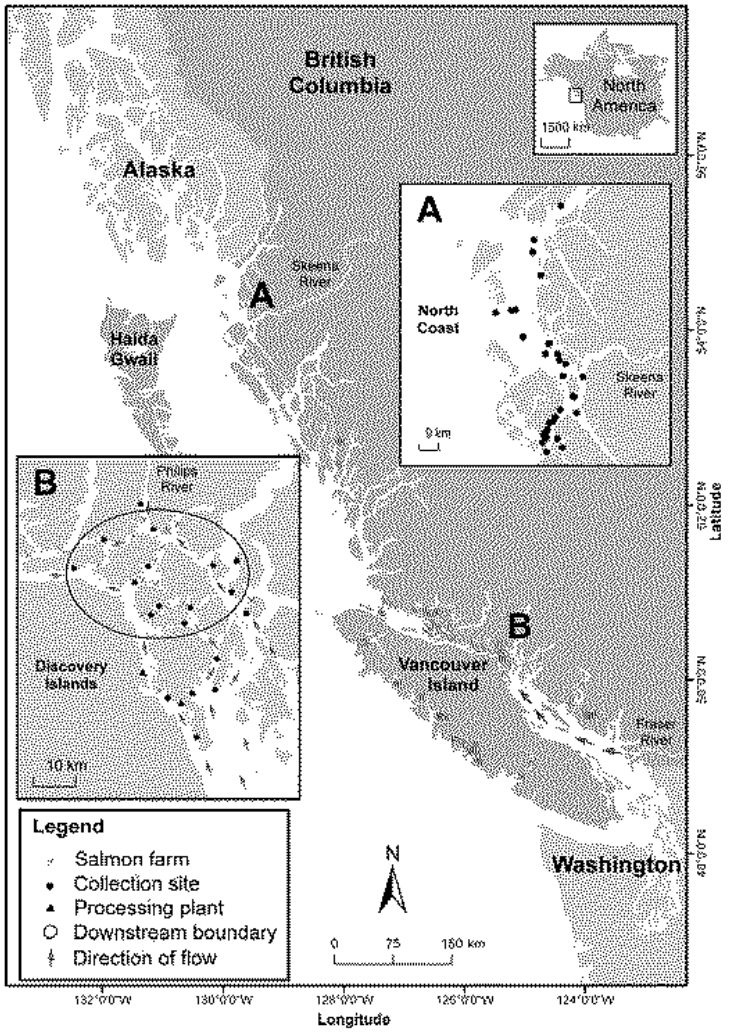
  - Sockeye salmon not common in area at time of survey (N=3), abundance = 3.0
  - Mean sea lice abundance (Salmon: 2.9 $fish^{-1;}$ Herring: 4.6 $fish^{-1)}$
  - Sea lice on salmon (ratio of *Caligus* : *Lepeophtheirus* ~ 60 : 1)
  - No salmon farms within 100km

- Morton A, Routledge R, Krkosek M. 2008. Sea louse infestations in wild juvenile salmon and Pacific herring associated with fish farms off the east-central coast of Vancouver Island, British Columbia. N. Am. J. Fish. Manag. 28: 523-532
  - Sockeye collected in 2 years
    - 2005 (n=322, length range 54-124 mm)
    - 2006 (n=7, length range 30-96 mm)
  - Mean sea lice abundance (2005): Caligus ~2.9, *Lepeophtheirus*: ~1.0

Study areas in Price et al. 2010



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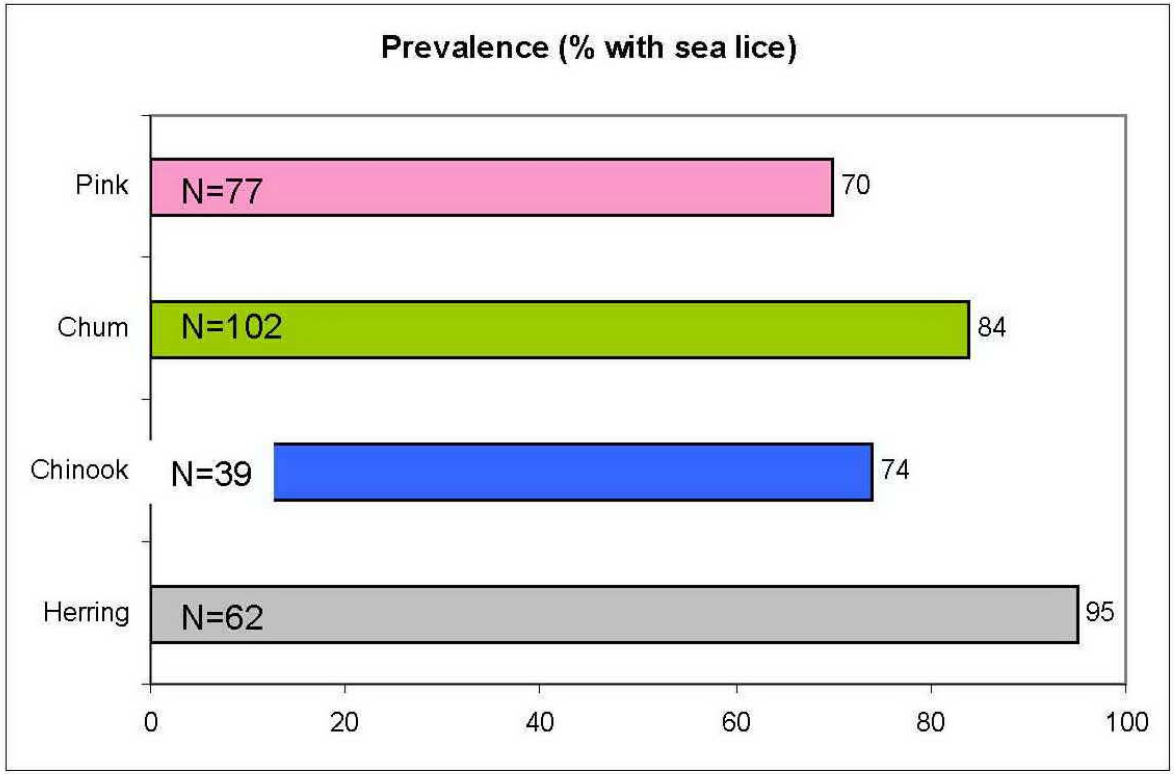
Sea lice on juvenile salmon: Gulf Islands 2008



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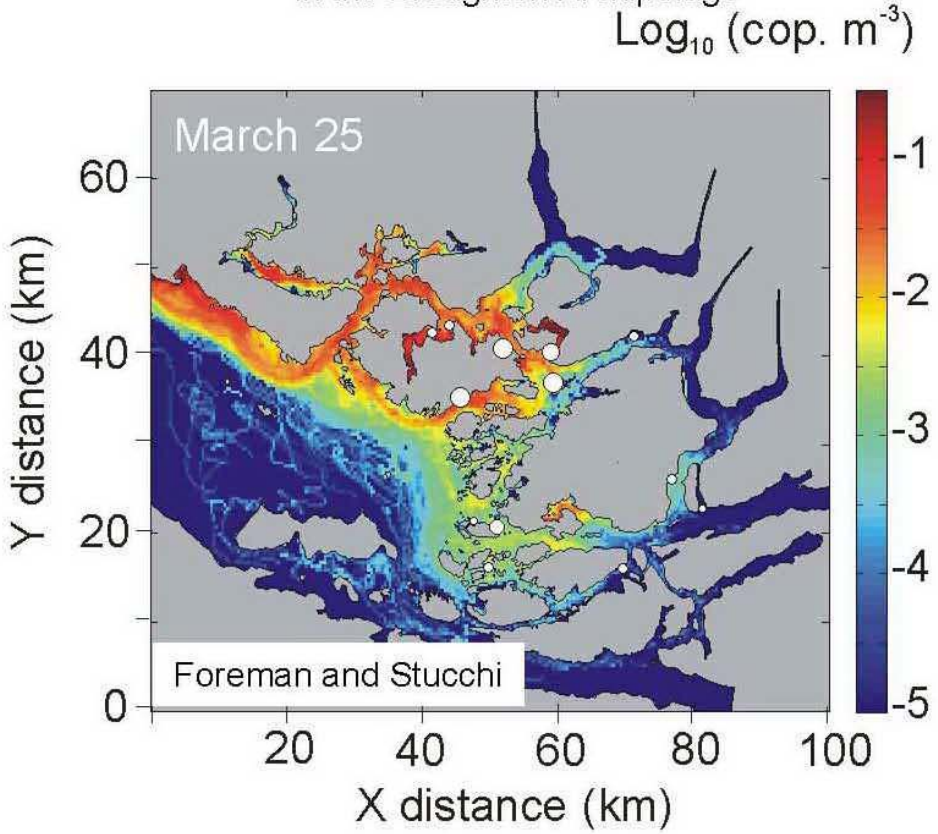
Evidence of impacts of sea lice to sockeye salmon

- Effects of sea lice infections on sockeye salmon
  - Johnson SC, Blaylock RB, Elphick J, Hyatt KD. 1996. Disease induced by the sea louse (*Lepeophtheirus salmonis*) (Copepoda: Caligidae) in wild sockeye salmon (*Oncorhynchus nerka*) stocks of Alberni Inlet, British Columbia. Can. J. Fish. Aquat. Sci. 53: 2888-2897.
    - Adult salmon: high density, high temperature, low oxygen, high salinity
    - High prevalence (100%) and intensity (up to 1372)
    - Significant skin damage and mortality
  - The consequences of sea lice infections on juvenile sockeye salmon have not been studied

Evidence for the dispersal of sea lice larvae

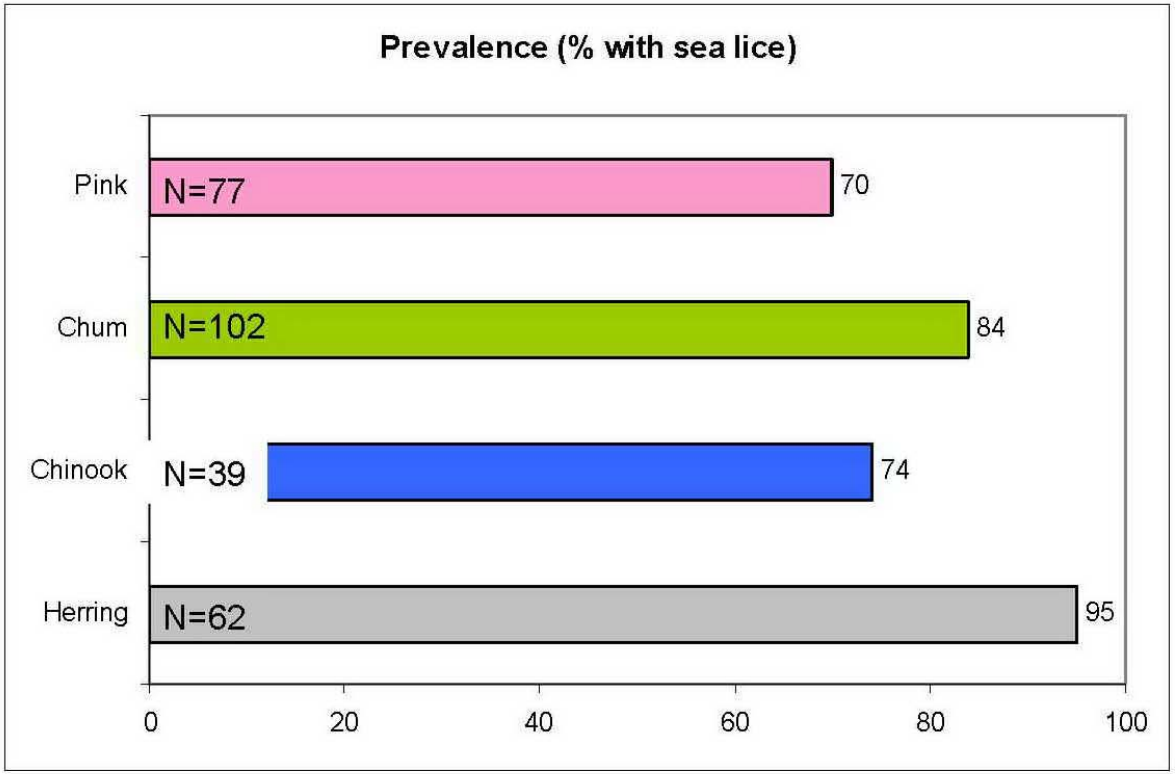
- Origins or sources of sea lice infections on sockeye salmon
  - Sea lice larvae are planktonic before becoming infective
  - Dispersal and survival determined by water movements, salinity and temperature
- Surveys not conducted and hydrodynamics of Discovery Islands area not previously characterized

Numerical modeling of larval sea lice movements in the Broughton Archipelago



Evidence for the source of *Caligus clemensi* in the Gulf Islands

- Mean abundance of *Caligus clemensi* on herring
  - 4.6 fish^{-1}



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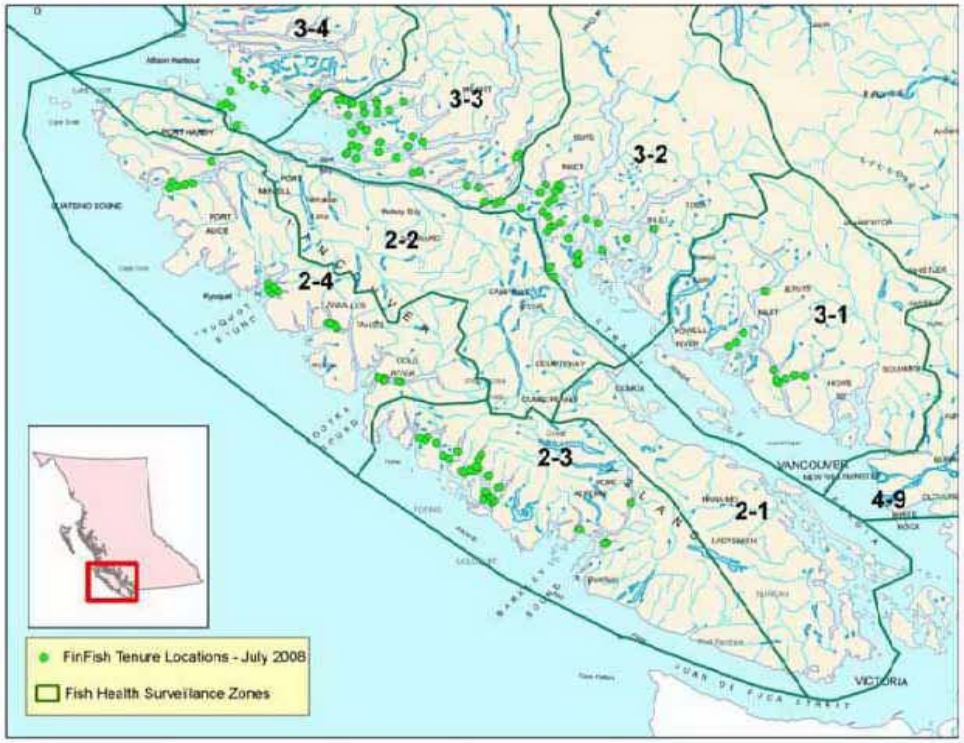
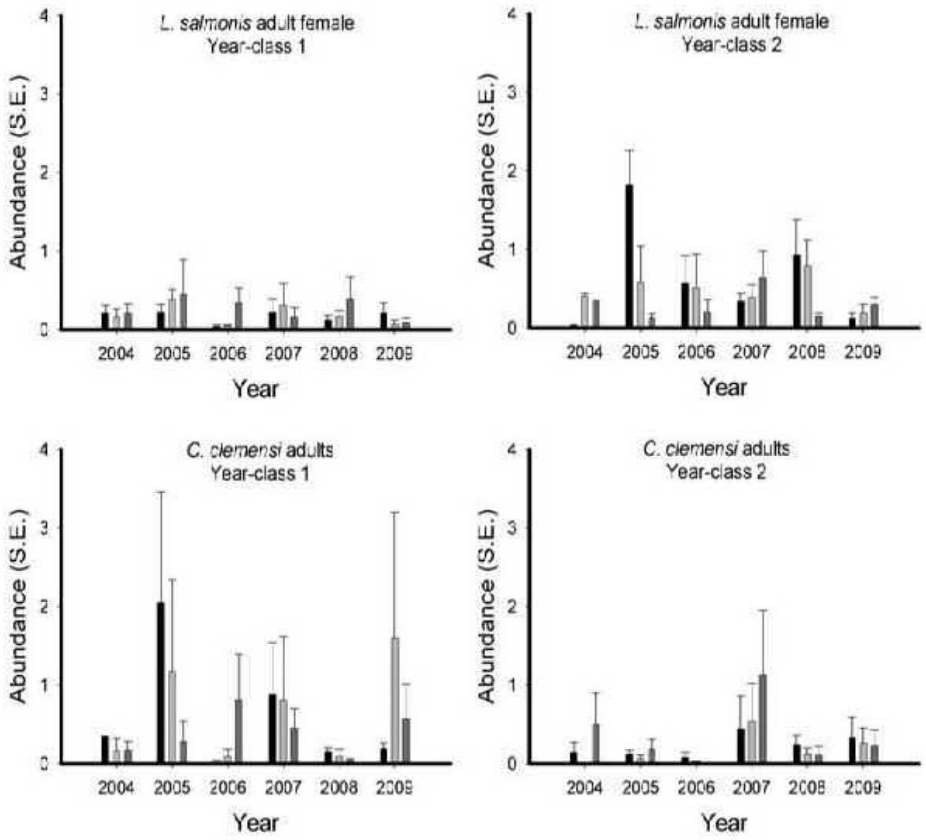
Evidence for sources of sea lice on sockeye salmon in the northern Strait of Georgia





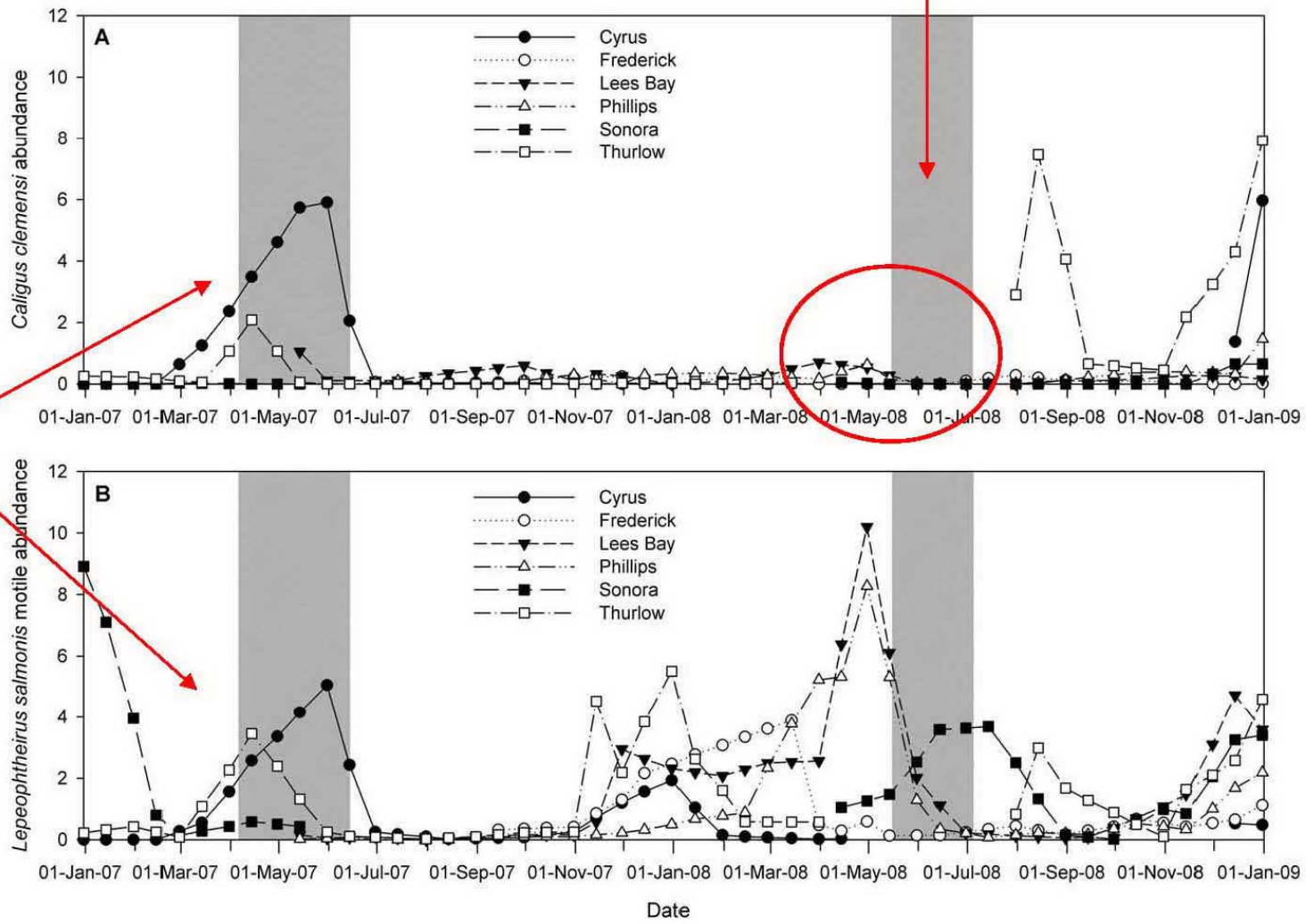
Mean abundance (S.E.) of adult female *L. salmonis* and adult *C. clemensi* on farmed Atlantic salmon in Fish Health Zone 3-2 (Discovery Islands), based on data at the BCMAL web-site. Within each year bars are April, May and June. (http://www.al.gov.bc.ca/ahc/fish_health/sealice_monitoring_results.htm). Salmon production data not available.

Lice on salmon farms in Discovery Islands region (Price et al., 2011)

Variability among farms in abundances of both parasites

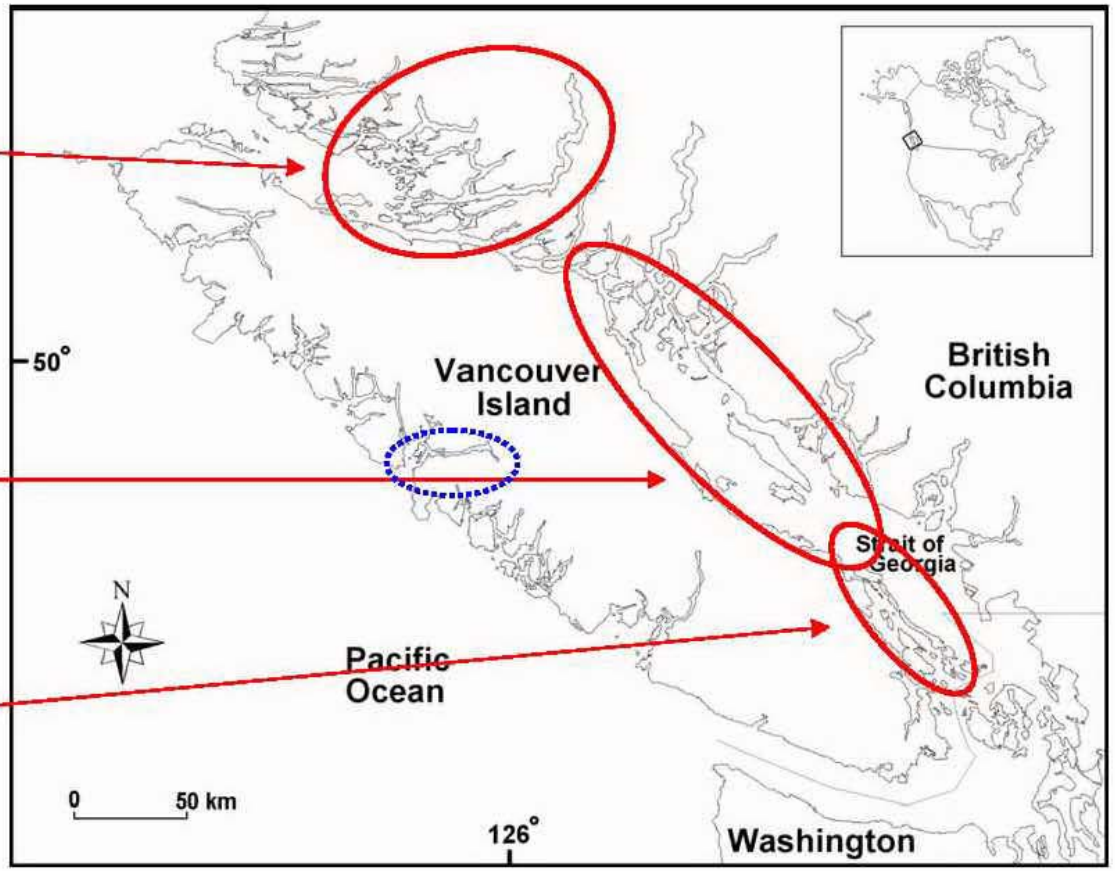
Caligus upstream:downstream = 1.7X

2007 Downstream Caligus to Lepeophtheirus = 54x

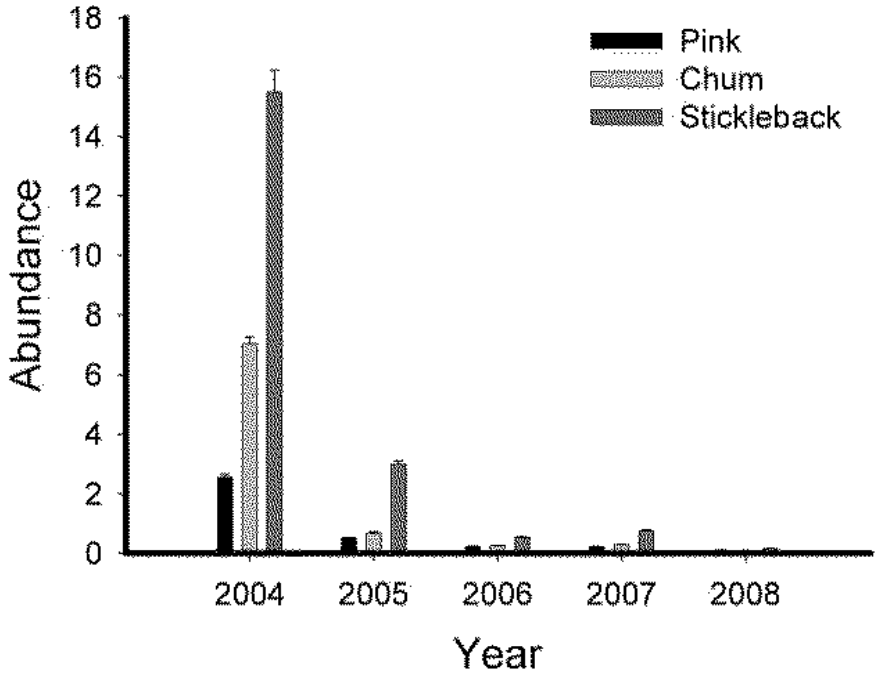


DFO sea lice surveillance in BC

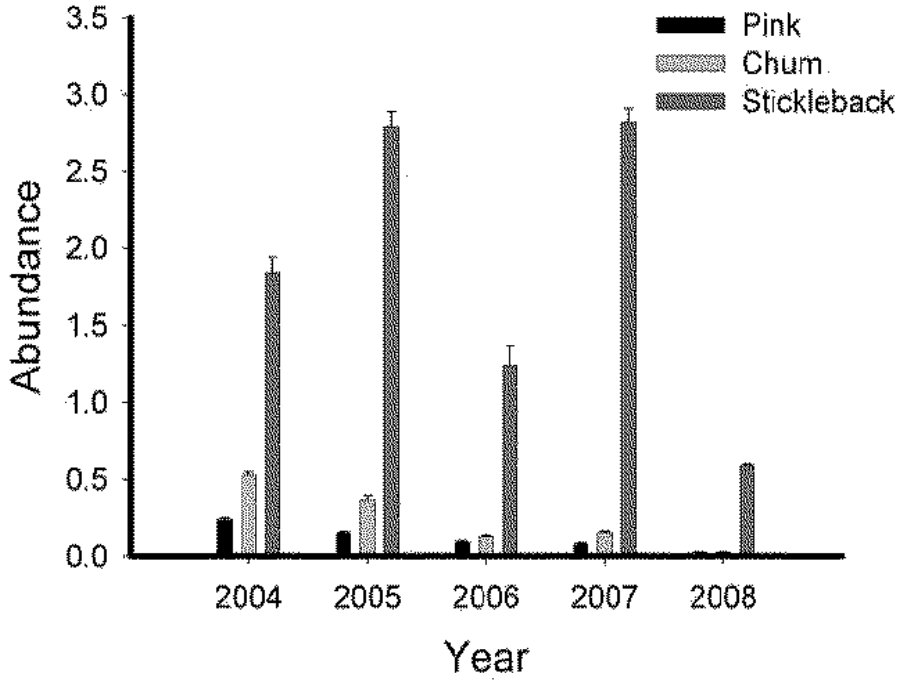
- Broughton Archipelago (DFO Pink Salmon Action Plan – 2003 to 2009)
  - Juvenile pink and chum salmon
  - Continued as BAMP since 2010
- Strait of Georgia (PARR project 2010 to 2012)
  - Juvenile sockeye salmon
- Strait of Georgia Gulf Islands (Beamish surveys 2008-2010)
  - Juvenile salmon



Broughton: *Lepeophtheirus* is more abundant than *Caligus*, and both parasites are more abundant on sticklebacks than on juvenile salmon



Lepeophtheirus



Caligus

Strait of Georgia: summary of sea lice on sockeye salmon (2010)

Month	N	Length(mm) /Weight(g)	Prevalence	Intensity	Abundance
May	157	102.6/12.7			
L. salmonis			3.7%	1.0	0.04
C. clemensi			72.6%	3.5 (1-13)	2.6
June	316	120.0/20.5			
L. salmonis			4.1%	1.1 (1-2)	0.04
C. clemensi			72.8%	3.0 (1-16)	2.2
August	72	78.2/6.4			
L. salmonis			0%	---	---
C. clemensi			0%	---	---

Strait of Georgia: summary of sea lice on pink salmon (2010)

Month	N	Length(mm) /Weight (g)	Prevalence	Intensity	Abundance
May	177	68.1/3.8			
L. salmonis			6.0%	1.5	0.08
C. clemensi			9.0%	1.2 (1-2)	0.11
June	144	83.8/7.8			
L. salmonis			2.0%	1.3 (1-2)	0.03
C. clemensi			13.9%	1.3 (1-2)	0.17
August	180	130.0/32.9			
L. salmonis			18.3%	1.0	0.19
C. clemensi			10.0%	1.2 (1-2)	0.12

Strait of Georgia: summary of sea lice on chum salmon (2010)

Month	N	Length(mm) /Weight (g)	Prevalence	Intensity	Abundance
May	166	79.3/6.0			
L. salmonis			7.2%	1.4 (1-4)	0.10
C. clemensi			16.3%	1.1 (1-2)	0.18
June	488	93.9/11.8			
L. salmonis			4.3%	1.2 (1-3)	0.05
C. clemensi			12.9%	1.2 (1-3)	0.16
August					
L. salmonis					
C. clemensi					

Strait of Georgia: summary of sea lice on 3-spine stickleback (2010)

Month	N	Length(mm) /Weight (g)	Prevalence	Intensity	Abundance
May	110				
L. salmonis			13.6%	1.3	0.17
C. clemensi			57.3%	2.2 (1-8)	1.25
June	45				
L. salmonis			15.5%	1.0	0.15
C. clemensi			17.8%	3.0 (1-14)	0.53
August					
L. salmonis					
C. clemensi					

Strait of Georgia: summary of sea lice on herring (2010)

Month	N	Length(mm) /Weight (g)	Prevalence	Intensity	Abundance
May					
L. salmonis					
C. clemensi					
June	15				
L. salmonis			0	0	0
C. clemensi			33.3%	1.2 (1-2)	0.4
August					
L. salmonis					
C. clemensi					

Conclusions

- *Lepeophtheirus salmonis* and *Caligus clemensi* infections observed on juvenile sockeye and on other salmonid and non-salmonid species in the SoG
  - There are no multi-year datasets – what are normal levels of infection on these species?
- In contrast to the Broughton, *Caligus clemensi* is the dominant sea lice species on juvenile salmon and other fish species in the SoG
  - Wide range of natural hosts
  - Herring and sticklebacks are a source host species
  - Levels higher on farmed salmon in Discovery Islands vs Broughton Archipelago
  - Farmed Atlantic salmon are a potential source of *L. salmonis* in the Discovery Islands area
- Effects of sea lice on juvenile sockeye salmon not known
  - Level of harm will most likely result from multiple factors (e.g. stress, poor nutrition, other infections)
  - Pink salmon <0.7g at risk of direct mortality due to *L. salmonis*
  - Sockeye salmon smolts ~10x larger when entering ocean – suggests increased resistance
- Insufficient evidence to conclude that sea lice are an important contributor to the Fraser River sockeye situation

Specific research to test hypothesis

- Establish inter-annual variations in sea lice levels for juvenile sockeye in Strait of Georgia
  - Related studies in the Broughton Archipelago showed significant interannual variation in sea lice on wild juvenile salmon
- Establish inter-annual variations of infections with bacteria, virus or other parasites
  - Diseases other than those caused by sea lice may be significant determinants of sockeye health and survival
  - Sea lice may increase the risk of other diseases in juvenile sockeye
- Determine lethal and other impacts of sea lice on individual sockeye salmon in controlled laboratory experiments
  - Use protocols and methods already developed for the study of sea lice effects on juvenile pink and chum salmon
- Integrate and analyse health data from farmed and wild salmon in the Strait of Georgia and elsewhere to obtain a global assessment of pathogen dynamics
  - Establish an ecosystem-based perspective of sea lice ecology that includes wild and farmed hosts, multiple lice species and hydrodynamic modelling
  - Inform a rational basis for sea lice management on farms