Sea Lice Report

Salmon Aquaculture Dialogue

Presented by: Crawford Revie

Canada Research Chair - Population Health: *Epi-Informatics*
Department of Health Management
Atlantic Veterinary College
University of Prince Edward Island

Report Authors

Larry Dill
Professor Emeritus
Biological Sciences
Simon Fraser University
Vancouver, BC
Canada

Bengt Finstad
Senior Research Scientist
Norwegian Institute for
Nature Research (NINA)
Trondheim
Norway

Crawford Revie
Professor
Atlantic Veterinary College
University of PEI
Charlottetown, PE
Canada

Chris Todd
Professor
Gatty Marine Laboratory
University of St Andrews
St Andrews, Scotland
UK

Approach

Mirrors structure of the Disease Report

In-depth case study material to complement the breadth of the main report

Two writing workshops (+ lots of late nights!)

- Oslo, Norway (April'07)
- Vancouver, Canada (Sept'08)

Structure

Chap.1: Sea lice as disease organisms

Chap.2: Avoiding infection

Chap.3: Can we prevent disease?

Chap.4: How do we reduce disease impacts?

Chap.5: Disease management systems

Chap.6: Framework for assessing risk

(dealt with as part of main Disease report)

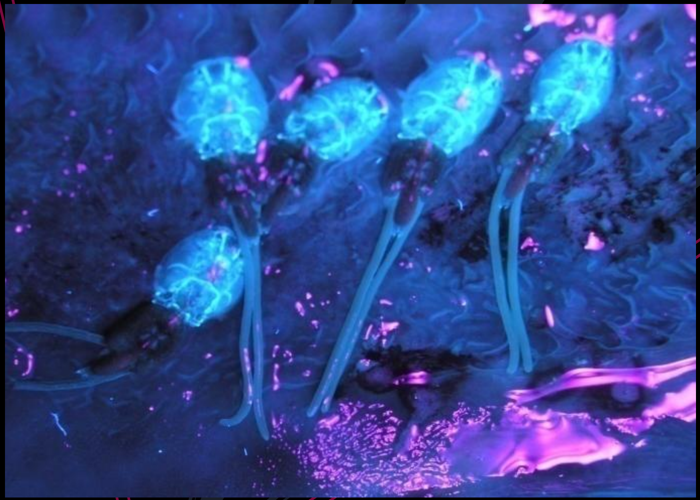
Key point

"… in view of the diversity of life-history strategies and differential vulnerability of host species associated with sea lice in both the Pacific and Atlantic Oceans, as well as the geographic differences in the intensity of the industry and its regulation, it is not plausible to draw a single over-riding conclusion regarding the potential negative impacts of sea lice on all wild fish stocks world-wide… "

Key point (continued)

"Nevertheless, we believe that the weight of evidence is that sea lice of farm origin can present, in some locations and for some host species populations, a significant threat. Hence, a concerted precautionary approach both to sea lice control throughout the aquaculture industry and to the management of farm interactions with wild salmonids is expedient."

1. Sea lice as disease



"Parasites can be considered pathogens, or organisms capable of causing disease, if the behaviour or physiology (and ultimately the health and/or survivorship) of the host organism is altered or compromised to an exceptional extent."

Sea lice – some basics

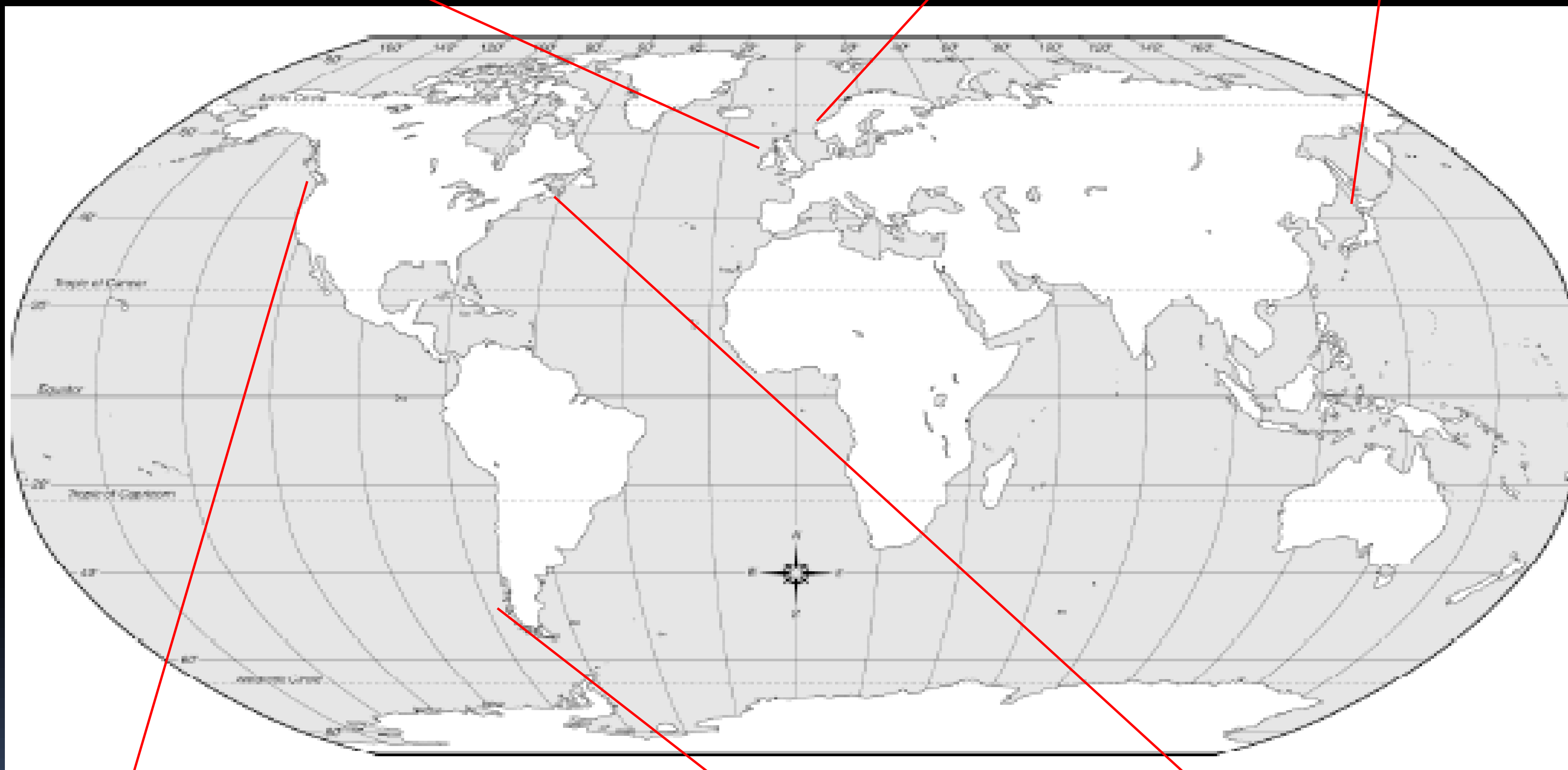
- Colloquial term for range of copepod crustaceans of the family Caligidae
- Vary by host species and geography
    - *L. salmonis* (host specialist – of major concern)
    - *Caligus spp* (host generalist – of concern in certain contexts: e.g. *C. rogercresseyi* in Chile)
- Some debate as to whether the species are in fact the same in Atlantic and Pacific oceans

Distribution

Scotland and Ireland:
L. salmonis and C. elongatus

Norway:
L. salmonis

Japan (NE Asia):
C. orientalis

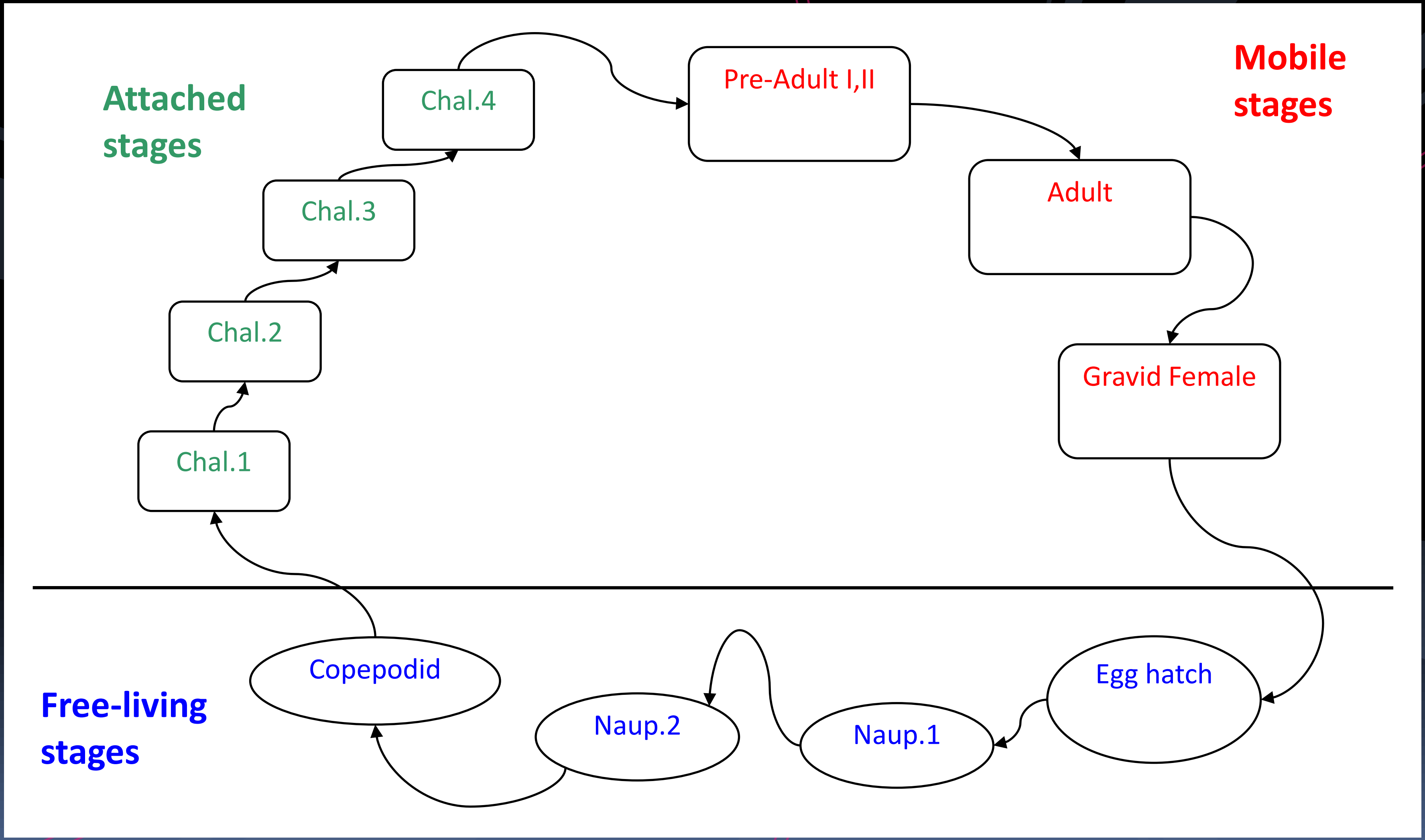


North America (Pacific):
L. salmonis and *C. clemensi*

Chile:
C. *rogercressyi*

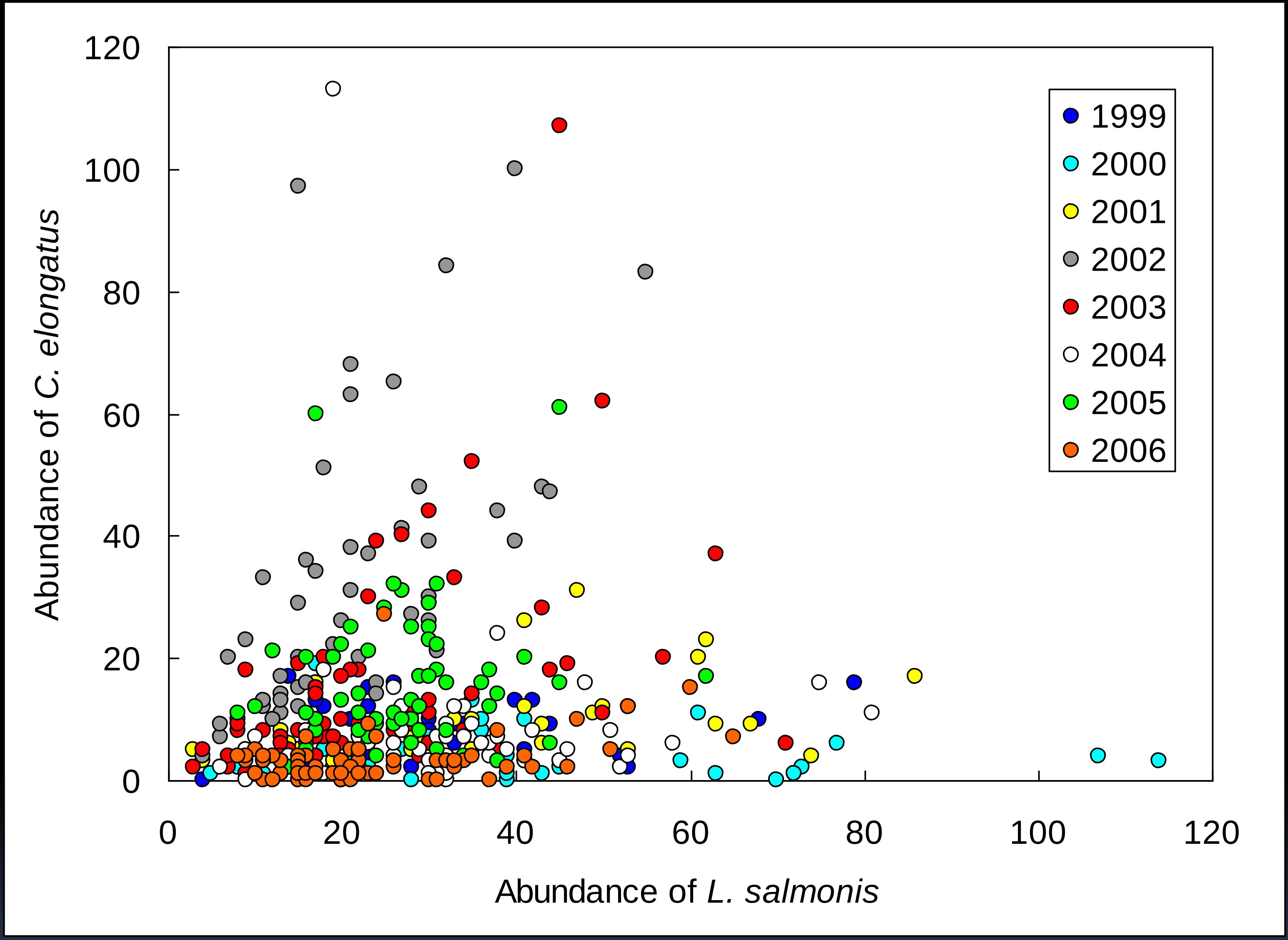
North America (Atlantic):
L. salmonis

Life cycle


Attached stages
Chal.4
Pre-Adult I,II
Mobile stages
Chal.3
Adult
Chal.2
Gravid Female
Chal.1
Copepodid
Free-living stages
Naup.2
Naup.1
Egg hatch

Sea lice – a disease?

- Naturally occurring parasite
- Seen in certain contexts as a sign of a 'fresh' and healthy fish
- Present on almost all salmon
  - *L. salmonis* (100% prevalence over 10 yrs in Scotland)
  - *C. elongatus* (90-100% in same survey)
- Can occur in large numbers on wild adult salmon with no evidence of compromised health or condition



Abundance of sea lice (*Lepeophtheirus salmonis*, *Caligus elongatus*) on individual wild, one sea-winter, adult Atlantic salmon (Salmo salar) (n = 430; length, weight ranges: 49-77.5 cm, 1.1-4.6 kg) captured in fully marine seawater at Strathy Point, N Scotland 1999-2006.

Sea lice – a disease?

Not really a problem for adult salmon

Evidence of detrimental effects on smolts

- 90 chalimi / 50 mobiles on 60g salmon (Bjorn ‘ 97)
- more than 30 chalimi on 40g salmon (Finstad ‘ 00)
- led to Norway ‘standard’ of 11 chalimi on 15g smolt

BUT then there is the case of juvenile pinks

- as low as 1-3 mobiles on 1g pink (Morton & Routledge ‘05)

2. Can sea lice be avoided?

When salmon are farmed:

- infection of hosts by lice from wild fish will occur;
- they become part a dynamic host-parasite system in which they can produce a large number of larvae in restricted spatial area;
- any fish which escape are likely to cause even more widespread dispersion of the parasite.

It is practically impossible to avoid initial infection of farmed fish or to subsequently avoid infection of wild fish found in the vicinity of fish farms

Can disease be avoided? (Farm)

Farmed salmon will typically be infected, but:

- this is rarely likely to be so severe as to damage health

Even at high levels of infection it may be that indirect effects are more serious, particularly susceptibility to concurrent disease (e.g. ISA - Chile/Shetland; SRS - Chile; PD - Ireland/Norway?)

Can disease be avoided? (Wild)

For wild salmon even low levels of infection can be much more of a problem

Direct :

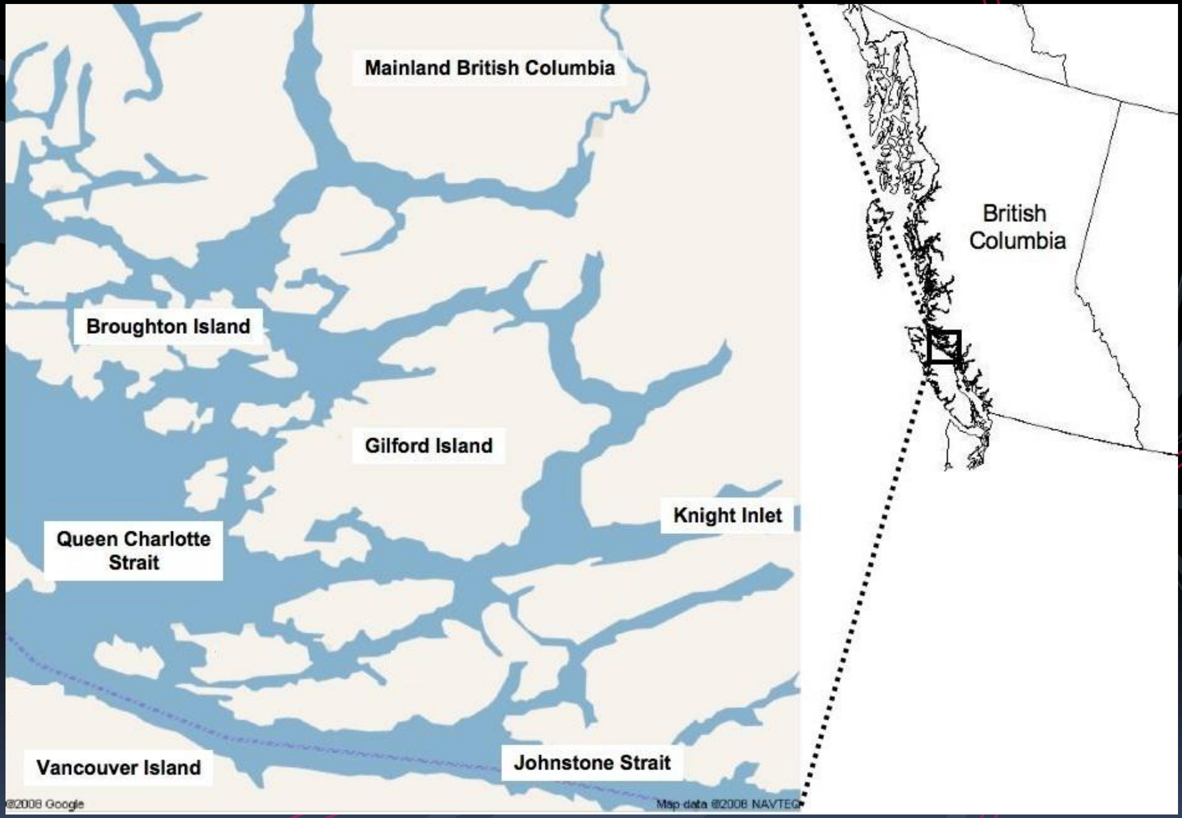
- vulnerability of smolts
- newly exposed to osmoregulating challenge in saline waters
- have yet to acquire innate ‘immunity’ (pink ~<0.7g; Jones’08)

Indirect :

- metabolic demand leading to reduced growth
- slower swimming speed or taking greater risks to find food can both lead to a higher chance of predation

Can disease be avoided? (Wild)

Perhaps most studied in the Broughton, BC



Can disease be avoided? (Wild)

Perhaps most studied in the Broughton, BC

- particular concern with juvenile pink salmon

Sea trout (*Salmo trutta*) have raised similar concerns for wild stocks in Ireland and Scotland

Some concern with Arctic charr in Norway

Recent concern in Scotland that recovery of wild stocks (salmon) is less marked given '2nd' year class farms

Little is known of impacts on (non salmonid) wild populations in Chile

Avoid disease on local wild hosts?

Closed containment may provide complete 'avoidance'

- not yet technically/economically feasible
- no guarantee as to when it may be practicable
- alternative avoidance scenarios must continue

Avoid disease on local wild hosts?

Closed containment may provide complete ‘avoidance’

- but infection is not synonymous with disease

Other avoidance scenarios

- proper siting of farms / area management
- create ‘farm free’ zones
  - extended fallow (e.g. NB bays, CAMP in BC)
  - total exclusion (Norwegian Salmon Fjords)
- individual immunity (may be an option for farmed)
- ‘prophylactic’ use of drugs (not without problems)

3. Can we prevent disease?

We assume exposure is inevitable (i.e. it is not practical to avoid infestation)

Tools that might prevent ‘disease’ developing:

- vaccination (limited, experimental, success to date)
- dietary nucleotides / immune modulators
- risk factor modification (see Section 4)
- genetics (some evidence of innate resistance across species, but also between families / ‘stocks’); using this to enable successful selective breeding is non-trivial
- siting of cages (may lead to conflicting objectives – e.g. moves to deeper water <-> lower salinity)

Discussion points from Chapter 1-3

No single over-riding conclusion possible

Concerted precautionary approach is expedient

Species differences are important

Laboratory findings versus field effects

- single pulse infections rather than on-going exposure
- temperature, salinity and other effects

Can we define what is meant by "disease" in a given context (host / parasite / geography / practice)?

4. Reducing disease impact

Monitoring sea lice in salmon farms

- fair degree of similarity in protocols

Sampling regimes of farms

	Canada (E)	Canada (W)	Chile	Ireland	Norway	Scotland
No. of cages	2 – 6	2 – 4	2	2	2 – 3	4 – 8
No. of fish/cage	5 to 20	20	10	30	20	5 to 10
Frequency	Bi-weekly	Bi-weekly	Bi-weekly	Bi-weekly or monthly	Bi-weekly	Weekly
Source	Westcott et al (2004)	BCMAL (2005)	http://www.sernapesca.cl	O'Donohoe et al (2005)	http://www.mattilsynet.no	SSPO (2006)

4. Reducing disease impact

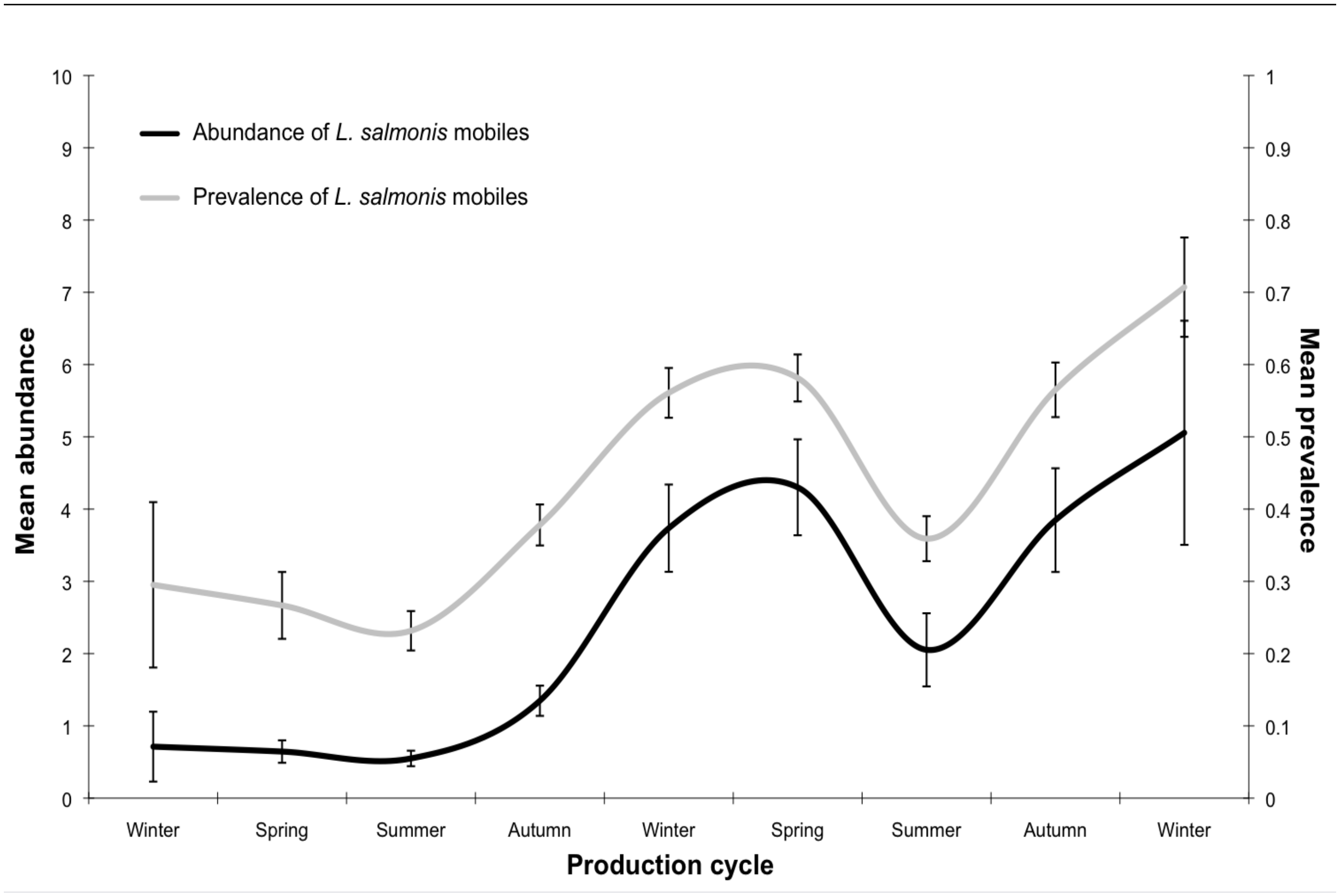
Monitoring sea lice in salmon farms

- fair degree of similarity in protocols

What is being monitored?

- a variety of different stages / species
- site (or at best cage) averages are commonly reported
- most often abundance (rather than prevalence)

Prevalence and Abundance



The prevalence and abundance profile, with associated 95% confidence intervals, for *Lepeophtheirus salmonis* mobile sea lice over two-year production cycles on Scottish farms between 2002 and 2006. [From Figure 6 in Baillie et al. (2009)]

4. Reducing disease impact

Strategies that exist within aquaculture

- non chemical control strategies

Strategies for reducing sea lice infestation on salmon farms which do not involve the use of chemical treatments (1/2)

Control Strategy	Description	Approximate adoption dates
Single year class stocking	The practice of having only one year class of stock present in a site at any one time (in contrast to multiple year classes – ages of fish – being present in different cage groups at the same time on a given site). This is much more of an imposition on small operations which may have only a few farms but still wish to have a range of fish sizes available to send to market. For larger operations it is much more straightforward and in most countries these producers have adopted this approach.	(1991); (1994); (1995); E. Canada (2001); W. Canada (2002); (2006) [N.B. These dates are by no means exact and within each country there were 'early adopters' as well as some – mostly smaller – producers who have yet to use this practice.]
Fallowing periods	The decision to leave sites free of fish for a period leads to the practice of "fallowing". In many cases this period will be around 4-8 weeks, though in a few cases it is more analogous to "fallowing" in the agricultural sense of leaving a field unplanted for a year (or at least growing season). For example, in British Columbia (BC) some sites were left empty for a full wild salmon running season while in New Brunswick (NB) a 'rotation' plan is in plans which should result in areas being fallowed every third year.	Because of the interlinked nature of this practice with the use of single year class stocks the dates will be very similar to those noted above. (i.e. It is unlikely that all fish will be removed from a site when multiple age classes are present and so fallowing is not really an option.) The BC experiment happened in 2003, while the NB rotation plan was introduced in 2006.
Synchronised production	In many ways this is a natural extension to the two practices noted above – the major difference being that a number of sites are involved. Once sites were stocking with only one year class and practicing fallowing (essentially to break the cycle of 'self infestation') it made sense to coordinate this with neighbouring sites (as these were the next most likely sources of cross infestation in the absence of significant challenge from wild, as is largely the case in E Canada, Ireland and Scotland). It has also increasingly involved synchronised treatment interventions (see below).	This was introduced from around the mid-1990s in and as part of their respective Area Management Agreement and Co-ordinated Local Aquaculture Management System processes,. In , and elsewhere, it has also greatly increased with the consolidation of production (i.e. it is much easier to coordinate when one owns all of the sites involved). The trend is more recent and more limited in (e.g. Hardangerfjord from 2003), while the first recorded attempt at such an approach in was not documented until 2007.

Strategies for reducing sea lice infestation on salmon farms which do not involve the use of chemical treatments (2/2)

Control Strategy	Description	Approximate adoption dates
Biological control	The only successful 'natural' control measure so be used to date on a commercial scale is the use of cleaner fish. These are discussed below but have been largely restricted to the north east Atlantic countries – partly because of the more ready availability of the relevant wild species. A number of alternative biological control measures have been suggested but so far with no evidence of effectiveness. These include the use of pumping fresh water into cages (Stone et al. 2002) and even the use of garlic in feed (Boxaspen and Holm 1992).	All of , and made reasonably extensive use of cleaner fish in the mid 1990s. However since 1998 the only place where significant and regular use has been made is . (Even here they are typically only used when salmon are in their first year of production. Nor have they been used extensively in northern due to low water temperatures and the short summer season.)
Site location	As noted in the discussion below there are a number of aspects of site location that are likely to affect lice levels on farms. For example, locating a farm in a position with fast flowing water or with swift water exchange in the surrounding area is likely to lead to lower lice infestation. Sites located in areas of lower salinity are also likely to be associated with reduced sea lice infestation pressure.	While each country has planning requirements that must be satisfied before salmon farms become active, the authors know of no formal requirement to consider likely effects of location on sea lice levels as part of this planning process.
Production/Design	There have been a number of cage design or production initiatives that have been suggested as being valuable in reducing sea lice infestations. These include the use of light traps (Pahl et al. 1999), automated feeding systems (Lyndon and Toovey 2000), and even a device which emits electromagnetic waves (http://aquafind.com/info/bioemitter2.php).	While a number of these production designs have been taken up by the industry for other reasons (e.g. automated feeders) the authors know of no evidence to support claims that they reduce sea lice infestation.

4. Reducing disease impact

Strategies that exist within aquaculture

- non chemical control strategies

- drug-based control strategies

Treatments that have been, or are being, used to reduce sea lice infestation on salmon farms

Active compound	Trade-name	Chemical class / Mode of action	Notes on availability / use
Dichlorvos	*Aquagard*	Organophosphate / Blocks acetylcholinesterase	Effective against “mobile” pre-adult and adult lice only. Discontinued in most countries.
Azamethiphos	*Salmosan*	as above	Drug brought back to the market with approved in the UK (2008).
Hydrogen peroxide	*Paramove; Salartect*	Reactive oxidizer / Oxygen bubbles form within sea lice and disrupts.	Used in the past when access to appropriate therapeutants was limited. Recent use in Chile and Norway as a potential rotation.
Cypermethrin	*Excis*	Synthetic pyrethroid / Blocking of sodium channel…	Used since the late 1990s these bath options still are a part of the core rotation strategy in areas which are not restricted to in-feed options. *ALPHA MAX* was recently approved for use in (2007) and is available under the ‘cascade’/EDR use in .
Cis-Cypermethrin	*Betamax*	as above	
Deltamethrin	*ALPHA MAX*	as above	
Teflubenzuron	*Calicide; Ektobann*	Insect growth regulator (IGR) / Disrupts ecdysis	Inhibits production of chitin and halts louse development - thus effective only against chalimus and preadults. Not available in most national markets since around 2003.
Diflubenzuron	*Lepsidon*	as above	This preparation was used to a limited extent in from 1996 to 2000.
Emamectin benzoate	*SLICE*	Avermectin / Disruption of chloride ion movement within nerve cells.	This has been the most widely used treatment intervention since around 2000.

4. Reducing disease impact

Strategies that exist within aquaculture

- non chemical control strategies
- drug-based control strategies

Use of ‘treatment triggers’ in various countries

Treatment trigger levels which exist in various salmon-producing countries

Country	During wild smolt migration	Other times of year	Notes
Canada (E)	not known	not known	
Canada (W)	> 3 total mobiles	> 3 total mobiles	Reduced from 6 mobiles at “other” times in 2006.
Chile	not applicable (no wild salmonids)	> 6 mobiles, (including gravid females)	The application of this trigger is relatively recent (2008?)
Ireland	> 0.3-0.5 gravid females	> 2 gravid females	No reason stated as to why a range is given during smolt migration.
Norway	> 0.5 adult females, or, > 5 total mobiles	> 2 adult females, or, > 10 total mobiles	Reducing to 0.5 females or 3 mobiles at all times (2008/09)
Scotland	> 0.5 adult females	> 1 adult female	

In some cases these are legislative requirements while in others they are guidelines adopted by industry. The exact timing of the “smolt migration” period will vary from country to country, and even within countries – e.g. Finnmark in Norway.

4. Reducing disease impact

Strategies that exist within aquaculture

- non chemical control strategies
- drug-based control strategies

Use of ‘treatment triggers’ in various countries

Optimal use of treatments:

- rotation between products
- appropriate timing of treatments

4. Reducing disease impact

Strategies that exist within aquaculture

- non chemical control strategies
- drug-based control strategies

Use of ‘treatment triggers’ in various countries

Optimal use of treatments:

- rotation between products
- appropriate timing of treatments
- may be at odds with treating at a trigger level

4. Measuring effects/reduction

Often only adequate when we bring together

- *in vitro* (lab studies can give us some evidence)
- *in vivo* (epidemiological / field data)
- *in silico* (modeling for scenarios / sensitivity)

The case of tolerance to treatments

- *in vitro* (bioassays)
- *in vivo* (empirical evidence from use on farm)
- *in silico* (modeling to predict likely impacts)

4. Reducing disease impact

Strategies for reduction in the wild are more complex

Setting up appropriate monitoring / surveillance

- expected (or accepted) levels affect sampling strategy
- lethal versus non-lethal sampling
- various capture methods introduce different biases

Using triggers based on wild fish to treat farmed

- desirable? / possible? / auditable?
- effective?

4. Reducing disease impact

Is individual-based monitoring of value when looking at population-levels effects in the wild?

- yes, but limited
- more difficult to target locations for sampling effort
- sampling by definition will almost always be 'survivors'
- parasite load may not be indicative of population effect
- but population effect are multi-factorial

4. Reducing disease impact

Prophylactic treatment of <u>wild</u> populations

- EX experiment in Norway
- limited evidence of positive effect
- unlikely to be practical given scale of intervention required

Setting up appropriate monitoring / surveillance

- expected (or accepted) levels affect sampling strategy
- lethal versus non-lethal sampling
- various capture methods introduce different biases

5. Disease management systems

Arguably the most studied aquatic pathogen in terms of management and modeling

Integrated Pest Management (IPM) approaches have been applied

- fallow, coordinate stocking and treatment
- biological and 'environmental' controls
- rotation and timing strategies for intervention

Use of models

Use of models

"Much of the current controversy over sea lice in the Broughton comes from using different mathematical models on different portions of the available data. Each model has its proponents, who feed their models with different data. Hence all the conclusions that flow from the models - farms contribute most of the sea lice, farms are a minor contributor, and everything in between - are equally 'right'."

(Harvey 2008: p.8)

Use of models

"All models are wrong but some are useful"

for:

- making assumptions explicit
- exploring associations/mechanism (limits)
- sensitivity of model to changes across variables

Types of model

Risk factors modeling

Time series models

'Spreadsheet' models

'Conceptual' (probabilistic) modeling

Population dynamics

Hydrodynamic and physical models

Integrations of one/more of the above

What are you trying to achieve?

Critical unknowns

Better understanding of wild-farm ‘connect’

- modeling larval output from lice on farmed fish
- improved methods (incl. genetic) to monitor lice on wild host populations and in plankton sampled
- impacts of new species (e.g. cod)

Impact of varying exposure to wild hosts

- what are impacts of sub-lethal loadings?

Range as a determinant of impact

- loch/fjord/archipelago-level management

Models for resistance to lice treatments

Performance-based indicators

Agreement on monitoring protocols

- largely comparable for farmed fish
- need to be able to compare meaningfully for the case of wild counts

Implementable / Auditable trigger levels

- on farmed fish these can be meaningless
- even more difficult if ‘targets’ are set for wild fish

Optimal use of treatments

- timing, synchronisation and rotation
- monitoring of efficacy and any emerging tolerance