Sea Lice Research Development Workshop

REPORT

January 21st and 22nd, 2010

Fairmont Algonquin

St. Andrews, NB

Acknowledgements:
DFO Aquaculture Collaborative Research and Development Program (ACRDP)

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Introduction

Sea lice are a parasite which can have an enormous impact on the salmon aquaculture industry worldwide. SLICE® (emamectin benzoate) has been the only treatment option in Canada for a number of years and the continued reliance on this one product has lead to a reduction in its effectiveness, as seen in number of geographic areas. In 2009 NB DAA, in support of the aquaculture industry, applied to the Pest Management Regulatory Agency (PMRA) for the Emergency Registration (ER) of two bath treatments, ALPHA MAX® and Salmosan®, as alternatives to SLICE® for sea lice treatment. Skretting also supported the industry by working with the Veterinary Drug Directorate (VDD) to enable growers to access Calicide® through an Emergency Drug Release (EDR) while the application for full registration was in process. With three news treatment options available to the industry and the need to make progress toward the development of an Integrated Pest Management strategy (IPM) the NBSGA held a workshop in December 2009.

This workshop was the first step toward engaging the industry on the various components of an effective IPM strategy, and enabled discussions about how it could function based on the products available and the experience of those who have worked with them. 120 attended the workshop and included representation from the pharmaceutical companies, veterinarians, regulators, researchers and industry from across Canada. As discussed at the workshop, an effective IPM has many components, only one of which focuses on the need for access to, and effective use of, chemotherapeutant. The components of an IPM also involve monitoring and control of sea lice through other methods such as farm management techniques, biological control, vaccines, and possibly mechanical removal. In discussing the possible control methods, the speakers at the December workshop began to identify knowledge gaps in regard to sea lice dynamics and environmental factors affecting sea lice transmission in Atlantic Canada.

As a result of this workshop and industry discussions, the NBSGA organized a second workshop for January 21st and 22nd to address specific knowledge gaps and research needs of the East Coast salmon farming industry that would support enhanced sea lice management.

The Sea Lice Research Development Workshop brought together 39 invited individuals representing federal and provincial regulators and researchers, academia, veterinarians and the aquaculture industry from Atlantic Canada. The two day meeting was designed to review knowledge gained through the research and scientific monitoring conducted in 2009 as part of the conditions for use for ALPHA MAX® and Salmosan® bath products, and identify and prioritize current and future research needs.

Discussion at the workshop was focused on developing research projects that would:

- provide the information necessary to support access to and eventual licensing of alternative products for sea lice treatment that will enable use throughout all bay management areas
- provide the information necessary to ensure that product treatments achieve optimal results and avoid tolerance from developing to these products
- provide an improved understanding of sea lice dynamics in the Bay of Fundy to support eco-management strategies
- test novel approaches to sea lice management

The research program developed as a result contains projects that address the following key result/topic areas:

1. Regulatory Research
2. Environmental Dynamics
3. Management Practices
4. Novel Treatments / Green Technology
5. Modeling

Acknowledgements

The NBSGA wishes to acknowledge the support of:

Aquaculture Collaborative Research and Development Program (ACRDP) for this workshop.

In addition, the participation by all of the speakers at this workshop is greatly appreciated by the NBSGA.

Unless otherwise noted research synopsis were prepared by the NBSGA.

SEA LICE RESEARCH DEVELOPMENT WORKSHOP

Fairmont Algonquin Hotel – St. Andrews, NB

January 21, 2010

8:30 a.m. *Coffee / Check-In*

9:00 Welcome / Workshop Overview – *Pamela Parker / Bev Bacon*

9:15 Experience in NB in 2009 with AlphaMax and Salmosan – *Larry Hammell*

10:15 Environmental Results to support policy decisions in the use of bath treatments – *Mike Beattie*

10:45 *Coffee Break*

11:00 Sea Lice dynamic modeling – data to support decision making – *Crawford Revie*

11:45 Sea Lice movement/ hydrological – influences on treatment decisions – *Fred Page*

12:15 *LUNCH*

1:00 Plenary Discussion - What we know and what knowledge gaps persist?

1:45 Breakout Group Sessions (*Breakout groups will discuss research questions that will address the identified area; group is also asked to indentify immediate, short and long term research option)*

1. Treatment Options: what information/documentation is required to support treatment strategies
2. Improved Management Methods for Sea Lice: identify opportunities, including novel treatment options for improved farm management; consider potential interaction with other diseases
3. Modeling Sea Lice Dynamics: what information is required to support farm management decisions, including discussion about risk factors for high lice burdens

3:45 Report out from Breakout Groups

4:30-5:00 Summary & Prioritization of Knowledge Gaps

6:30 p.m. *Dinner*

January 22, 2010

8:30 a.m. *Coffee*

9:00 Review and Refine Identified Research Opportunities & Prioritize

- Identify specific project hypothesis
- Identify collaborative research teams and potential project leaders
- Discuss funding opportunities and mechanisms for access
- Communication strategy for plan and results of work, and also interaction with international groups doing similar plans

11:45 Closing Comments / Adjournment

Presentation Synopsis and Speaker Biographies

Monitoring Field Efficacy of Treatments for Sea Lice (L. Salmonis) in New Brunswick during 2009 – presented by Larry Hammell

Hammell made his presentation on behalf of himself and his colleagues, Crawford Revie, Bernita Giffin at the Centre for Aquatic Health Sciences, Atlantic Veterinary College, University of PEI

Sea lice (*Lepeophtheirus salmonis*) infestations are a severe challenge to the salmon farming industry in New Brunswick due to the emergence of resistance to Emamectin Benzoate (EMB, Slice®). Starting in July, 2009, deltamethrin (DM, Alphamax®) treatments at NB sites were monitored by selecting 10 cages at each site and counting all lice stages on 10 fish per cage. This was done prior to treatment (maximum of 7 days prior) and then repeated 4-7 days after treatment and again 8-14 days after treatment. A similar approach was taken to monitoring the treatment effects with azimethiphos (AZ, Salmosan®) which started in October, 2009. Due to the late start of AZ treatments, only 2 sites were completed for all pre- and post-treatment counts. Post-treatment numbers were compared to pre-treatment counts at a cage-level for measuring the response to treatment. Overall, there was a relatively poor reduction (17%) in average adult female lice stages with DM and a relatively strong removal (86%) on one of the AZ treatments (but the other treatment had only 5% reduction). Most (89%) of the pre-adult lice (includes all adult males also) were removed with DM while AZ removed a smaller proportion (51-67%). Chalimus stages were generally reduced (mean decrease of 33%) with DM but were not affected by AZ (increased by 250%). The interpretation of impacts of treatment on sea lice counts is complicated by the influx of copepodid stages which can add substantial numbers of chalimus to the fish between counts even if the treatment had a profound effect. This dynamic also affects the numbers of pre-adult and adult lice since chalimus can become pre-adults and pre-adults can molt into adults between counts. Overall conclusion is that effect of DM or AZ are often suboptimal, highly variable, and require refinement of treatment methods and more frequent monitoring to better characterize post-treatment changes. (Synopsis prepared by L. Hammell)

Larry Hammell

K. Larry Hammell is coordinator of Fish Health at the Atlantic Veterinary College and an associate professor in the Department of Health Management. He is studying the epidemiology of sea lice infection of farmed Atlantic salmon and development of resistance to chemotherapeutants. He is also integrally involved in another project on the epidemiology of infectious salmon anaemia in farmed Atlantic salmon.

Environmental Results to support policy decisions in the use of bath treatments – presented by Mike Beattie

The presentation began with an overview of the work that had been completed in compliance with Emergency Release terms and conditions of use received from PRMA for the ALPHA MAX and Salmosan products. The ALPHA MAX trials included water and sediment sampling, as well as monitoring of sentinel species, lobster and plankton. The

Salmosan trials included waster and sediment sampling. Drifters were used to track the flow of both products after the release of the treatment skirt. The activities were described as pictures were shown of various points in the treatment / monitoring process.

Specific ALPHA MAX treatment data was presented in graphs, and included the pre and post lice counts for cage treated. The average deltamethrin concentration within the cage and per quadrant location was presented over time for multiple bath treatments. During the 40 minute treatment, the deltamethrin concentration began to decrease 20 minutes after delivery, with water samples from quadrant B always showing the lowest concentration. The intended dosage of 0.3ppb was not attained in any treatment situation and therefore the question was presented: where is the active deltamethrin? Several options were discussed along with an experiment to be completed at Huntsman Marine Science Center to help answer this question.

The results from 1 cage treated with Salmosan were presented in graphs to show Salmosan concentration inside the cage, outside the cage and average over the 30 minute treatment. The maximum concentration was not reached in the center of the cage until 15 minutes into the treatment and a small amount (.016ppb) was detected slipping out from under the skirt in one location. The target dose of 0.3 ppm was not reached.

The remainder of the presentation revolved around the work that still needs to be completed for the industry to move toward a comprehensive integrated pest management strategy (IPM). The R&D work required fell into two major areas: research needed to answer regulatory / risk assessment questions, and research needed to maximize efficacy and minimize tolerance for the treatment options available. Under each of these major headings the research needs were again subdivided. Activities identified that will be needed for an effective IPM included education and standard operating procedures for counting sea lice and delivery of product, bioassay work to monitor for tolerance, maintenance a database to track data collected, evaluation of wild reservoirs for sea lice and "eco-controls". Longer term R&D activities identified should include vaccine development and other "green" options.

Please see attached presentation

<u>Michael Beattie</u>

Michael Beattie received a BSc, (hon.) and MSc. in marine biology from the University of New Brunswick, a DVM degree from the AVC and a Marketing certification from the Norwegian School of Bus. In. 1997 he became a member of the Royal College of Veterinary Surgeons. Since 2003 he has served as the Chief Veterinarian for Aquaculture in the New Brunswick Department of Agriculture and Aquaculture. Prior to joining the Provincial government Mike was the North American Product Manager for the world's largest integrated aquaculture company, Nutreco. He was involved in uncovering new research, carrying out field trials and marketing new products.

Data to Support Decision Making: Sea Lice Modeling – presented by Crawford Revie

The data required for sea lice models was broken down into four major components:

- Data on sea lice infestations levels
- Biological parameters

- Environmental variables
- Clinical data on treatment interventions

Questions presented under the topic of sea lice level estimation included: do numbers vary greatly from site to site or BMA to BMA? What are the changes seen through the seasons and over years? Can we see these trends? Revie suggested that it will take significant amounts of data over large periods of time to see trends, but they can be seen. He presented work completed in Norway that showed trends in the sea lice numbers were affected by the smolt stocking pattern. The smolts stocked in the fall had less sea lice pressure than those smolts stocked in the spring of that same year. One piece of information that needs investigation is how water temperature affects sea lice abundance and settling patterns. In Norway there is little temperature change so it was not useful in the modeling done there but the environment is very different here in Atlantic Canada. The tides and water movements of the Bay of Fundy may also have a big influence on how sea lice disperse. Data from treatments in the field need to be collected to allow assessments of treatment efficacy. Different life stages of the sea louse may be affected differently by the different products used, and so these stages must be counted correctly post treatment. When this post treatment count happens is also important as some of the in-feed products take time to show effect. The eventual tolerance to any pesticide must be considered and therefore changes in efficacy must be monitored.

Modeling work has to be validated by field data and so another question will be how to integrate the lab and field data. A range of types of computer models were presented – time series models, hydrodynamic and physical models, and population dynamics models. The type of model that is most appropriate for use, and how to decide which model works best will be a challenge. The example was given that there may be a particular life stage that requires modeling.

Please see attached presentation

<u>Crawford Review</u>

Crawford Revie is a professor within the Department of Health Management at the Atlantic Veterinary College which is part of the University of PEI in Charlottetown, Canada. Prior to this he was based at the University of Strathclyde in Glasgow, Scotland. A major focus of his research over the past five years has been the application of data-driven models to disease control within the veterinary domain; in particular to gain a better understanding of host-parasite dynamics in aquatic settings and to build tools to allow for the investigation of alternative intervention strategies. Crawford is involved in sea lice related research on both coasts of Canada as well as in Norway, Chile and Ireland. Areas of expertise include: Epi-informatics (the application of informatics techniques to epidemiology), Population dynamics and modelling of sea lice on salmon farms, Risk factor and multiple variable analysis, and Decision support tools

Sea lice movement / hydrographics: Influences on treatment decisions – presented by Fred Page

The presentation began with conceptual diagrams of lice and therapeutant dispersal from fish farms. Several scenarios were pictured including the ideal scenario of having no lice in the system, and the scenarios where a farm has lice that are under control and uncontrolled. The role of oceanography was discussed relating the discipline to areas where the information provided could assist with the control of sea lice and the products used to treat for the parasite. Areas identified included estimating the spread of sea lice to help in evaluating control measures and the IPM, and estimating transport and dispersal of control products which is necessary for regulators.

Under the heading "What do we know" several slides were shown depicting the spread of a dye patch from a "treated" cage and the vertical profile of the dye from work done in 1997. It was noted that the vertical mixing rate varied with location vertical stratification, current speed and bottom depth. Graphs were shown giving dye patch scale versus time and horizontal eddy diffusion rates in southwest New Brunswick. Using this data, several representations showing the implications for therapeutant use were presented including the area of patch and area swept by patch over time. The estimates of area swept with the distance between farms leads to the possibility that over 30% of farms within proximity of a treated cage could be exposed within 6 hours. It was noted that the impact would depend the toxicology of the product and that there would be 2-3 orders of magnitude dilution within a 3 to 5 hour time frame. With maps provided showing the modeling of 6 and 12.5 hour exposure zones throughout the current ABMA system, it was suggested that the model built for ISA needs to be modified for therapeutant transport and dispersal.

Current meter and drifter results from a 2009 ALPHA MAX treatment was presented along with a summary of the issues presented. The final slides listed potential research areas and research needs with rationale and action items. In addition to the hydrographic information required for the necessary suite of models, other work identified included the characterization of sea lice sources, the distribution and abundance of pelagic and settled sea lice stages and the characterization of sea lice biology.

Please see attached presentation

Fred Page

FRED PAGE (PhD) is a research scientist, the Responsibility Center Manager for the Ocean Coastal Ocean Sciences Section of the Department of Fisheries and Oceans located at the Biological Station in St. Andrews, and is the Director of the DFO virtual national Center of Integrated Aquaculture Science (CIAS). Dr. Page is a member of the DFO-NBDAFA Memorandum of Understanding Aquaculture Environmental Coordinating Committee (AECC) and a frequent scientific advisor to the salmon industry and government regulatory bodies (NBDAA, NBDENV, DFO Habitat) on oceanography in the area and aquaculture interactions. He is a bio-physical oceanographer specializing in the investigation of linkages between the physical characteristics and processes of the coastal and shelf seas and their living resources. He has been actively involved in the development of aspects of the environmental monitoring program for the salmon industry in SWNB and is presently evaluating the DEPOMOD model for its usefulness in indicating sulphide levels in the vicinity of some salmon farms in SWNB.

Breakout Group Discussions

Based on the number of individuals attending the workshop, four smaller groups were formed to facilitate more detailed discussions. Each group was assigned a specific area of potential research and categorizes the work into short, medium and long term options. The four areas for discussion were:

1. Research to support access to products / regulatory requirements
2. Research to support optimizing treatments and farm management strategies
3. Novel treatment / green technology options
4. Modeling sea lice dynamics and the information required

Group leaders and reporters were assigned.

Group 1 - Research to support access to products / regulatory requirements

Mike Beattie presented the results of the discussion held around the regulatory requirements for the continued access to alternative products as determined with representatives of Environment Canada and PMRA. In the short term there is a requirement for research activities to take place around the topic of environmental impact. This would include dye dispersion studies conducted both in the lab and on multiple sites to further ensure the efficiency of in-field treatments and determine product fate in the environment. Product fate would include analysis of water, sediment, organics and non-target species that could be exposed to treatment products. Lab based toxicity studies for non-target organisms were also identified as an immediate priority to establish exposure thresholds based on the concept of pulse dosing as could potentially occur with multiple cage treatments over a short period of time. Additional work on product fate in the sediment was considered as a medium term project which would look at sediment toxicity in the lab, its potential affect on non-target species and sediment decomposition. Chemical and solid accumulation and resistance management research were also placed in this category.

Group 2 - Research to support optimizing treatments and farm management strategies

The report from this group, given by Chris Bridger, identified the development of standard operating procedures (SOPs) for treatment mechanics and data collection as their first priority. This was agreed to as the highest priority activities identified, such as the dye dispersion study, are covered off in other areas. The group did however stress the importance of the dye study being completed within cages using both skirts and tarps so these methods are fully evaluated sand this information can be part of the treatment mechanics SOPs. The group also suggested the idea of "pest management areas" be evaluated as it relates to synchronized treatments with boundaries possibly adjusted seasonally. This would be an idea that would be more fully addressed through the modeling work to be conducted. Other short to long research activities identified centered on assessing current husbandry practices, alternative containment options and the identification of possible wild reservoirs for sea lice. Additional ideas mentioned included the need for the evaluation of a gel to neutralizing product, and cage side test kits to determine organic load / ensure proper treatment dosage is achieved.

Group 3 - Novel treatment / green technology options

During the reporting out from the breakout session Ian Bricknell and John Burka, who were invited to the workshop to provide an external perspective presented potential options under the topic of treatment options / novel treatments and related some personal knowledge about previous trials. Short term projects presented included stationary or movable "cleaning stations", coating that impede sea lice respiration, and screening harvest boat waste water. The upwelling of fresh water within the cages was discussed as copepodids prefer salinities above 26ppt, and the possibility of lowering of cages was mentioned as copepodids do not infect fish below 4 meters depth. The potential ability of mussels to act as a biofilter for sea lice nauplii was suggested with the idea that 17 mussel strings could filter 5 meters of water in 24 hours. Another short term option presented was the assessment of hydrogen peroxide as an alternative treatment, and recommended discussions with the manufacturer and PMRA as to determine the potential of having the product registered for use as a pesticide in the marine environment.

Medium term research projects presented included research into wild reservoirs for sea lice, potential cleaner fish, and possible repellants or masking compounds that could be put in the salmon diets. Immunostimulants have been used in fish feed in other countries as a pulse treatment just prior to sea lice settlement. It was suggested that this could be an option but the modeling information would be required to determine when it would need to be used. Lice traps was an option discussed as many methods have been used in the past such as light and pheromones. The caution from Bricknell was that in previous trials the trap had become overwhelmed with lice and therefore shortly became ineffective. A review of the methods previously use to identify the most promising for use in the Bay of Fundy would have to be completed along with an evaluation of the mechanics of any potential trap from an engineering viewpoint.

The potential long terms projects suggested included research into fish genetics and breeding to develop lice resistant families, identification of potential pathogens of sea lice that could be used as a biological control, and the development of time-release drugs to increase the length of time the salmon are protected. Lice depress the salmon's immune response and so research into compounds that prevent the settlement of the lice onto the salmon is an option that should be evaluated. Vaccines would be the optimal control measure and research into one that would affect chalimus stages 1 to 4 was suggested to be the best direction.

Ian Bricknell

Ian Bricknell went to the University of Reading, graduating with first class honors from there in 1986. From Reading University, Ian moved to Lancaster University gaining his Ph.D. in 1990. In 1989 Dr Bricknell was offered the position of Higher Scientist at Fisheries Research Services (FRS) in Aberdeen in the fish immunology group where he worked in the field of fish health developing fish vaccines and new and improved diagnostic methods for the detection of disease in wild and farmed fish. In 1993 Dr Bricknell was promoted to Senior Scientist and in 1999 to Principal Scientist, becoming head of the Immunodiagnostics Department. In 2007 Dr Bricknell accepted the post of *Libra* Professor of Aquaculture Biology at the University of Maine and in 2009 was appointed as the first Director of the Aquaculture Research Institute. Since arriving in the USA he has established a new aquatic animal disease research group.

John Burka

John F. Burka is a professor in the Department of Biomedical Sciences at the Atlantic Veterinary College of UPEI. He has been responsible for the physiological aspects of the experiments involving sea lice challenge. He has also been actively pursuing collaborations with other groups, particularly those in Norway and UK. John was on sabbatical leave in Norway (June - Dec., 2000), studying the sea lice resistance to therapeutics, and the molecular techniques for establishing a parallel program in North America.

Group 4 - Modeling sea lice dynamics and the information required

The first short term activity identified by this group lead by Crawford Revie, was the development of SOPs for the counting of sea lice as presented by another group. Revie added to the basic idea by saying that there should be some formal training involved as well as possibly a certification process. Other suggested priority research projects were on sea lice dynamics and bioassay work on stock prior to treatment. Medium term priority work included a risk factor study, work on treatment efficacy and research work on the larval dispersal of sea lice. Long term work included the use of alternative models, and research into sea lice resistance mechanism, and sea lice population genetics.

Day 2

Review of Identified Research Priorities

The second day of the workshop started with a review of the list of potential research projects identified under the major headings. These headings were adjusted to include:

1. Research to support access to products / regulatory requirements
2. Optimizing treatments
3. Farm management
4. Novel treatment / green technology
5. Modeling

This review concentrated on ensuring the group reached consensus on the top three ranking projects within each main research area. With the consensus confirmed, the process of identifying project leads and collaborators began.

Next Steps

A summary of the potential research ideas in each of the five categories was developed (see Appendix 1) sent to workshop attendees, identifying the priority work that arose from the group discussions. This summary was sent within 5 days of the research workshop.

Those identified as project leads for the various research initiatives were asked to discuss the project with the identified collaborators who agreed to participate, and develop a Letter of Intent (LOI) for the project. It was agreed that these LOIs be submitted to the NBSGA by February 19th and the Association would then develop a research program for presentation to funding agencies at a single meeting. The intent would be to gain funding support through these agencies for the program as whole. Alternatively the appropriate program within in agency or department would be identified for each project. This meeting was tentatively scheduled for March 5th with the anticipation that some work may proceed as early as April 2010.

In Conclusion

Feedback from this meeting and process followed by the NBSGA in engaging industry and collaborative researchers and other stakeholders has been positive.

Direct feedback included:

> Thank you, Betty. It was a pleasure participating and I learned quite a bit. It was good to meet you as well. Cheers, John F. Burka, Ph.D.
>
> Enjoyed the meeting and was very pleased with how well it all went and finished up - lots of homework for everyone! Well done to you Bev, Betty and Sybil!

Cheers, Ben (Forward)

Thanks also for allowing me to participate in the research workshop. The workshops were great. Hopefully, they will help everyone resolve some of the issues quicker. Thanks again, Take care, Amber (Garber)

Since the workshop, a comprehensive, Collaborative Sea Lice Research Program has been developed that contains over 14 projects in the five key topic areas with a value of over $1 million. The NBSGA is currently securing funding for the various projects through a variety of potential partners.

Participants

Name		Organization
Backman	Steve	Skretting
Bacon	Bev	RDI Strategies
Beattie	Mike	NB DAA
Blackier	Chris	Open Ocean Systems
Bricknell	Ian	U Maine
Bridger	Chris	AEG
Burka	John	UPEI
Burridge	Les	DFO - SABS
Doe	Ken	EC
Donkin	Alan	NNI
Forward	Ben	RPC
Garber	Amber	Huntsman
Griffin	Bernita	UPEI
Hammell	Larry	U PEI
Hawkins	Leighanne	Cooke Aquaculture
House	Nancy	DFO - AMD
House	Betty	NBSGA
Jones	Patti	AVC
Kearney	Evan	Admiral
Kesselring	Mark	Northern Harvest
Lalonde	Benoit	EC
MacKinnon	Allison	Novartis
McGladdery	Sharon	DFO - SABS
McPhee	Dan	Maritime Vet
Morton	Sean	Open Ocean Systems
O'Brien	Nicole	NL DFA
Page	Fred	DFO - SABS
Parker	Pamela	NBSGA
Pee Ang	Keng	Cooke
Pendleton	Jack	Admiral

Revie	Crawford	U PEI
Robinson	Shawn	DFO - SABS
Smith	Amanda	SimCorp
Smith	Sybil	NBSGA
Stanley	Trevor	Skretting
Straight	Howard	Admiral
Szemerda	Mike	Cooke
Taylor	Tom	NNI / CFI
Wickens	Kevin	PMRA

APPENDIX 1

Sea Lice Research and Development Workshop

Summary and Prioritization of Research Projects

NEW BRUNSWICK SALMON GROWERS ASSOCIATION

SEA LICE RESEARCH DEVELOPMENT WORKSHOP

January 21 & 22, 2010

SUMMARY & PRIORITIZATION OF RESEARCH PROJECTS

A. RESEARCH TO SUPPORT ACCESS TO PRODUCTS - REGULATORY REQUIREMENTS

1. Environment Impact Study – **(A)**

Dispersion Study (dye)

- Tank **(by March 2010)**
- Field sites (3?) **(A)**
- To assist in ground-truth hydrological modeling
- Answers exposure
  - Treatment limitations
  - Informs BMAs for IPM
  - Sediment
  - Persistence/bioaccumulation
  - Tarps vs. skirts
- Informs efficacy study – why we can't achieve target dose

Environmental fate (pen/release)

- Concentration of product at release
- Fate – Fish? Organics? Active?

2. Lab Study **(B - 2010)**
   - Threshold/dose/time/response
   - Supports study of chemical on non-targets using pulse doses informed by field trials

Research project to be let by Les Burridge (DFO) and Ken Doe (EC)

3. Product Fate **(B)**
   a. Chemical and solids on non-target species
      - Sediment toxicity (lab)
      - Sediment/non-targets
      - Sediment decomposition

   b. Chemical and solid accumulation
      - Spatial/temporal

c. Resistance management
   - Monitoring – bioassays, clinical efficacy, mode of action
   - Prevention – rotate chemical families, containment

4. Non-Target **(B)**
   - Reproductive effects

5. Monitoring **(moved to Farm Management and Modeling)**
   - Environmental fate
   - Efficacy

6. Green Technology **(moved to Novel treatments)**

Unless otherwise identified, research projects will be developed as a collaboration between NBDAA, NBSGA, DFO/SABS, AVC and informed by PMRA

Project development lead – Mike Beattie with Fred Page, Jack Pendleton, Sean Morton

B. OPTIMIZING TREATMENTS

Research identified as priorities in this area included:

1. Dye Study – in net pens **– to be included in dispersion study under A1**
   - Tarp versus skirts
   - Mixing/organic loading
   - Escape of product

2. Organic loading – treatment reaction **– to be covered in research included in A1-3**
   - Efficacy re: absorption
   - Toxicity post treatment

3. Monitoring **– to be covered under Regulatory, Farm Management and Modeling**
   - Sensitivity for treatment efficiency
   - Monitor synergy between treatment options
   - Sensitivity monitoring - resistance avoidance
   - Bioassay
   - Single vs. multi-treatments

Consensus was that these items were all critical but would be covered under the research being conducted under the Regulatory, Monitoring and Farm Management.

C. FARM MANAGEMENT

1. Standard Operating Practices – Farm Management **(A)**

- Delivery of treatment (dye study in tank and field)
- Monitoring
- Data collection – effective data collection of lice counts and life stages; water temps, etc.
- Efficacy of treatment
- Synchronization of treatments between farms

  NBSGA will lead on the development of SOPs in consultation with industry stakeholders in New Brunswick, BC and Norway. Crawford Revie will inform process, AVC to provide the training necessary.

2. Factors affecting infection/settlement **(B)**
   - Wild reservoirs
   - Seasonality of lice abundance
   - Husbandry practices
     - Avoidance
     - Net cleaning
     - Water depth
     - Feeding times
     - Smolt entry
   - Economic cost/benefit analysis

3. Define BMA's for IPM (**ongoing beginning in 2010 – see Modeling #2)**
   - Synchronization
   - Seasonal factors
   - Hydrological

Other options not ranked:
- Explore gel pack to neutralize treatments
- Cage side testing kits to determine organics/appropriate treatment dose
- Containment options

D. NOVEL TREATMENTS/GREEN TECHNOLOGY

1. Screen wastewater from harvest boats (**A)**

   NBSGA coordinating with Cooke and working with industry for test in 2010

2. Mussel lines to filter planktonic lice **(B)**

   Shawn Robinson to lead in project proposal for test summer 2010

3. Hydrogen peroxide – to optimize treatments (resistance?) **(A)**

   Mike Beattie to lead in project proposal

4. Lice traps **(B)**
   - Pheromones
   - Light

- Engineering solutions

Literature review identified as first step to be led by Shawn Robinson, Ian Bricknell and Keng

5. Immunostimulants **(C)**
   - Pulse treatments (β glucans)
   - Up-regulate macrophages to prevent sea lice settlement
   - Marine bacteria versions of β glucans

   Lead for work on immunostimulants – Ian Bricknell and Mark Fast
   Lead for work on marine bacteria – Ben Forward
   Lead on feed (Target Fast) – Trevor Stanley and Alan Donkin

6. Alternative hosts **(C)**
   - Cleaner fish

   Conducting a local survey of potential cleaner fish and a literature review identified as first steps to be undertaken by Ben Forward and Amber Garber

7. Vaccine Development at appropriate target stage (long term)

8. Disease resistance families (on-going internal industry work underway)

Other options not ranked:

- Rubbing post with trap to prevent reattachment)
- Upwelling
- Fresh water dilution
- Repellent in diet to prevent copepodid from attachment
- Dropping nets to lower depths

E. MODELLING

1. SOPs – Lice Counting **(A)**
   - Frequency
   - #s of fish
   - Cage #, random vs. targeted
   - Stages

   Training with possible certification

2. Sea Lice Dynamics **(B)**
   - On farm, between farm
   - Off farm pressures/reservoirs
   - Importance of temperature

3. Regulatory Bioassay Work **(B)**
   - Each new stock entry/before treatment

4. Risk Factor Study **(B)**

- Farm management
- Environment

5. Treatment Efficacy **(B)**
   - Realism
   - How treatments work

6. Larval Dispersal **(B)**
   - Model from between farm and off-farm work

7. Lice population genetics **(B)**

8. Resistance Mechanism **(C)**
   - At population level

9. Alternative modeling approaches (ongoing)

   Lead for modeling projects will be undertaken by Crawford Revie and Fred Page. It is understood that some work (i.e. identification of wild reservoirs) will take time; however, a start will be attempted in the near future.

RESOURCES:

There are a variety of programs where funding could be sought for this work (see list below). However, it was suggested that this research is critical in enabling industry and government to respond to a critical issue and therefore a more strategic approach should be explored. The suggestion was that a single meeting could be held with all potential federal and provincial research collaborators (i.e. DFO, NBDAA, ACOA, NRC, etc.) in attendance to review the research strategy and the various project components. A special purpose fund could be established that could receive funding from a variety of sources (governments, industry drug companies, etc.). This fund would then be used to support the research and could be audited annually to ensure that funds were being directed under agree-upon parameters.

This will be further explored by Sharon McGladdery, Mike Beattie and Pamela Parker.

Funding programs are available through:
ACRDP
DFO – environmental and regulatory science
IRAP/NRC
NSERC Strategic Partnerships
Novartis
Huntsman (lab space)
RPC
AVC
NBDAA – TDF
Industry
ACOA

Industry Update on Pesticide Usage

Dr. Michael J. Beattie
Kathy Brewer-Dalton
NBDAA Staff
NBSGA 2009

Outline

- Alphamax
  - Update on Trials
  - R & D
- Salmosan
  - Update on Trials
- Integrated Pest Management Program 2010
  - Database variables
- Required R & D
  - Long Term, Mid Term and Short Term

Alphamax

- Ring Testing
- Sampling Protocols
    - Water samples
    - Sediment samples
    - Sentinel Species
    - Lobster
    - Plankton
    - Drifters
- Results
- What Next

Salmosan

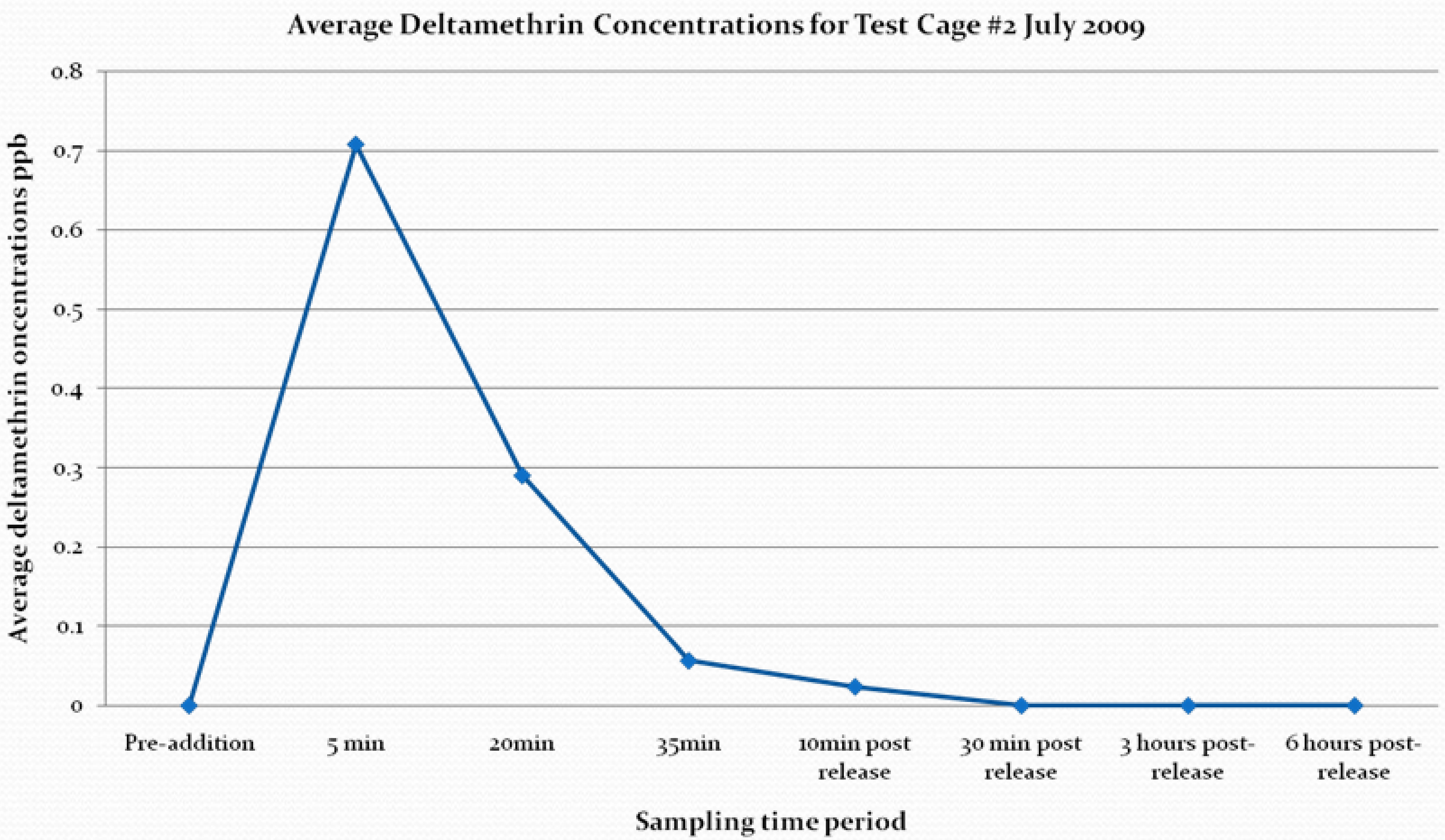
- Sampling Protocols
  - Water samples
  - Sediment samples

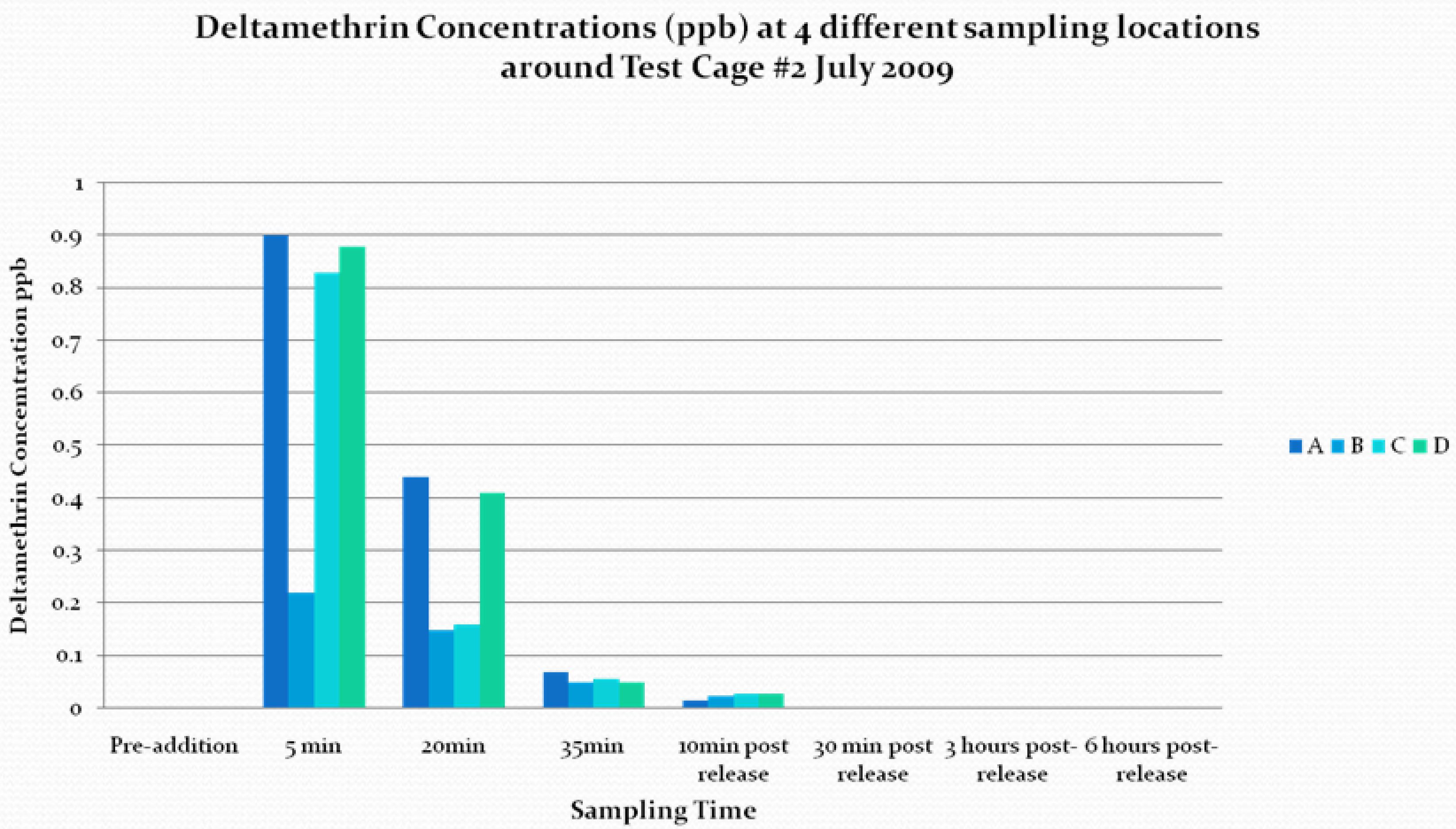
- Completion of testing

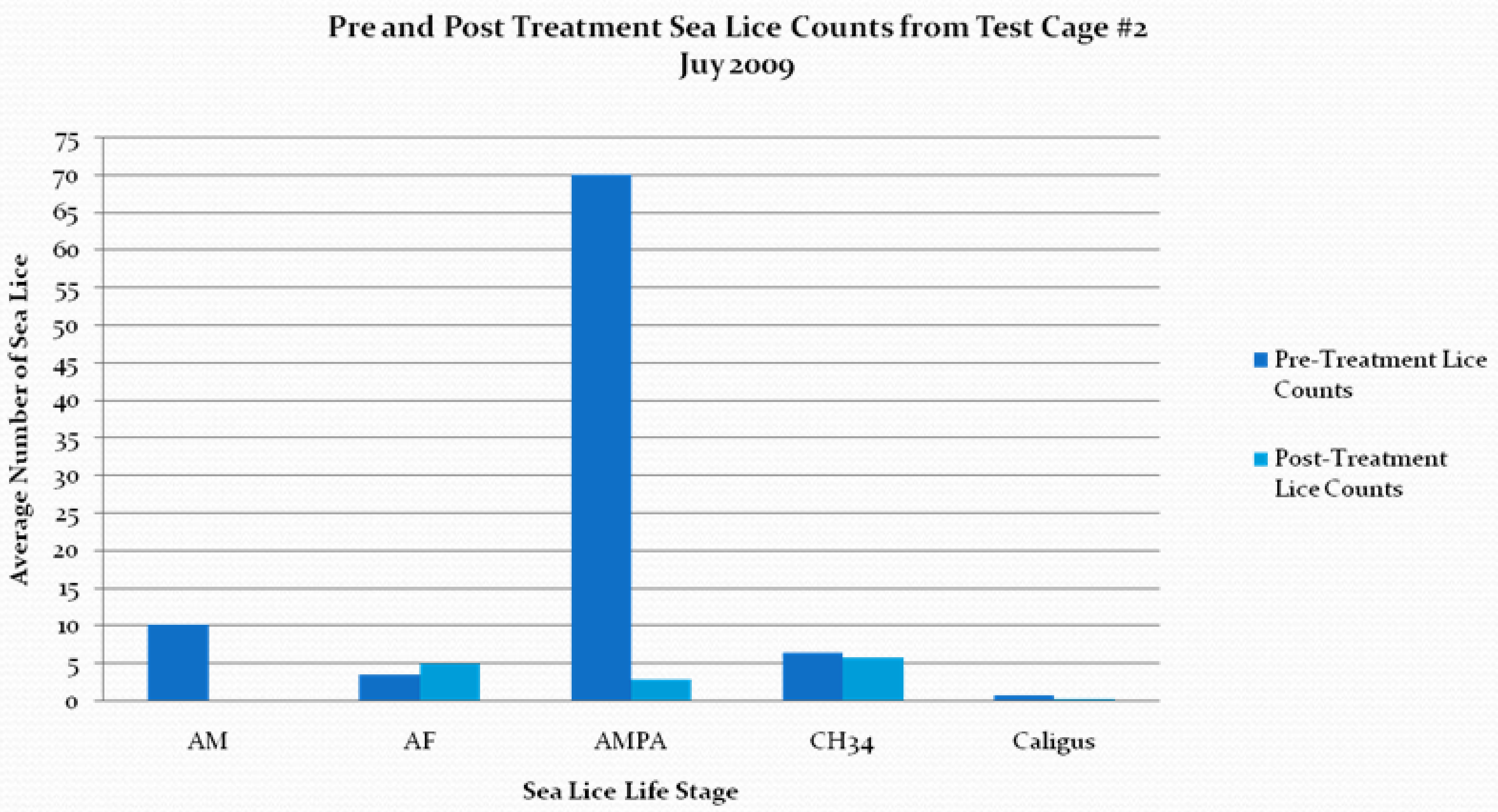
- Finalization of Reports

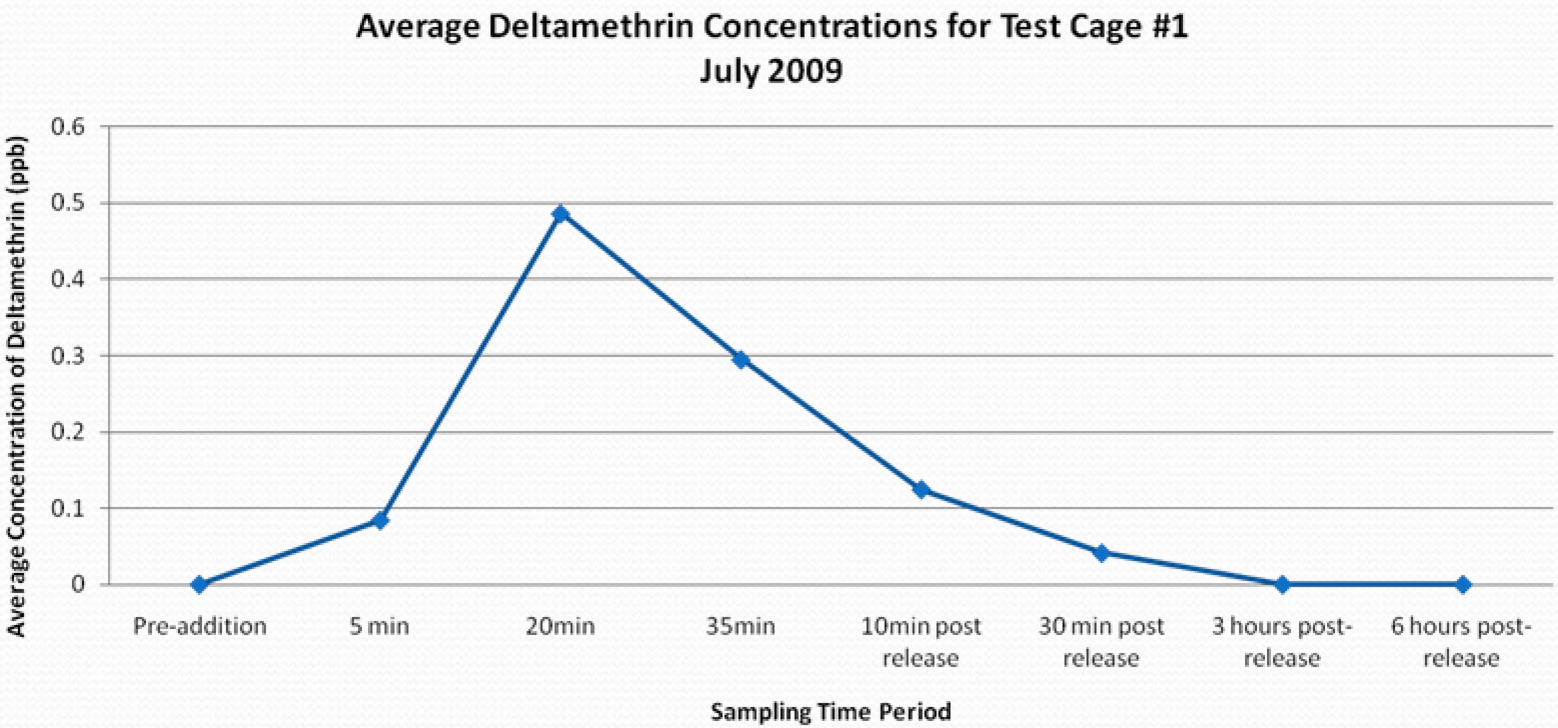

VERTICAL
MIXING
Piramal Glass

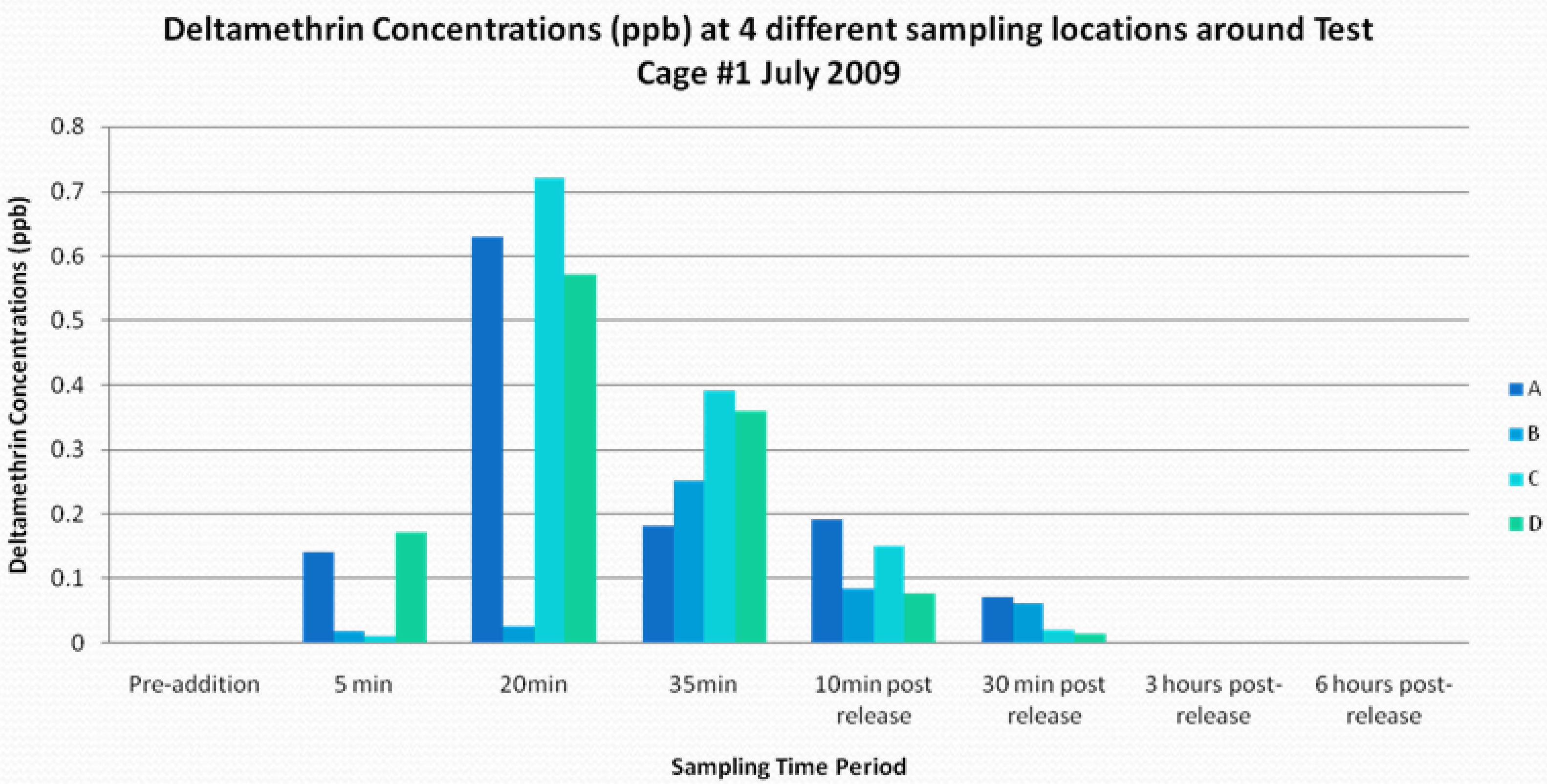

12 PC.
AMBER
32 OZ.
B/R

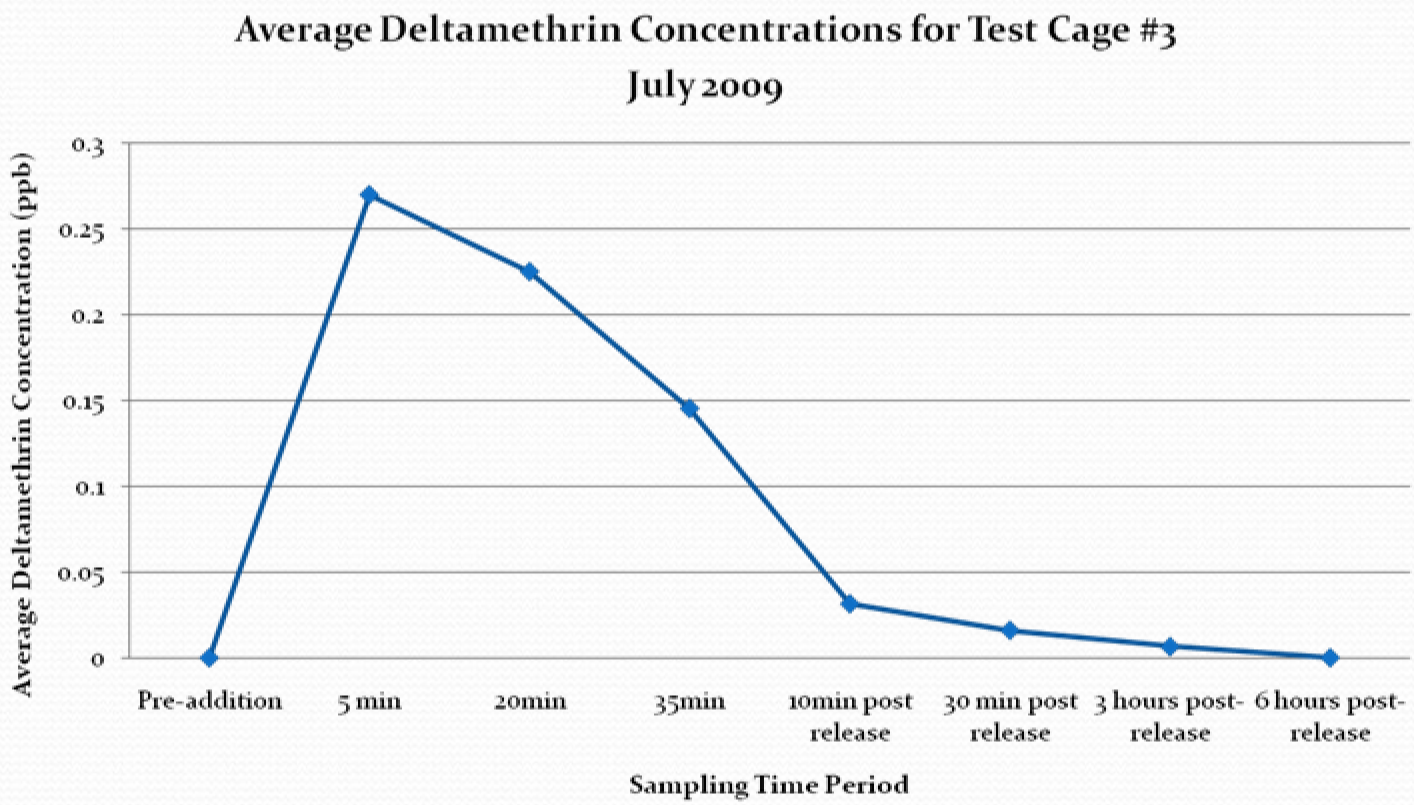

Average Deltamethrin Concentrations for Test Cage #2 July 2009
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Average deltamethrin oncentrations ppb
Pre-addition
5 min
20min
35min
10min post release
30 min post release
3 hours post-release
6 hours post-release
Sampling time period

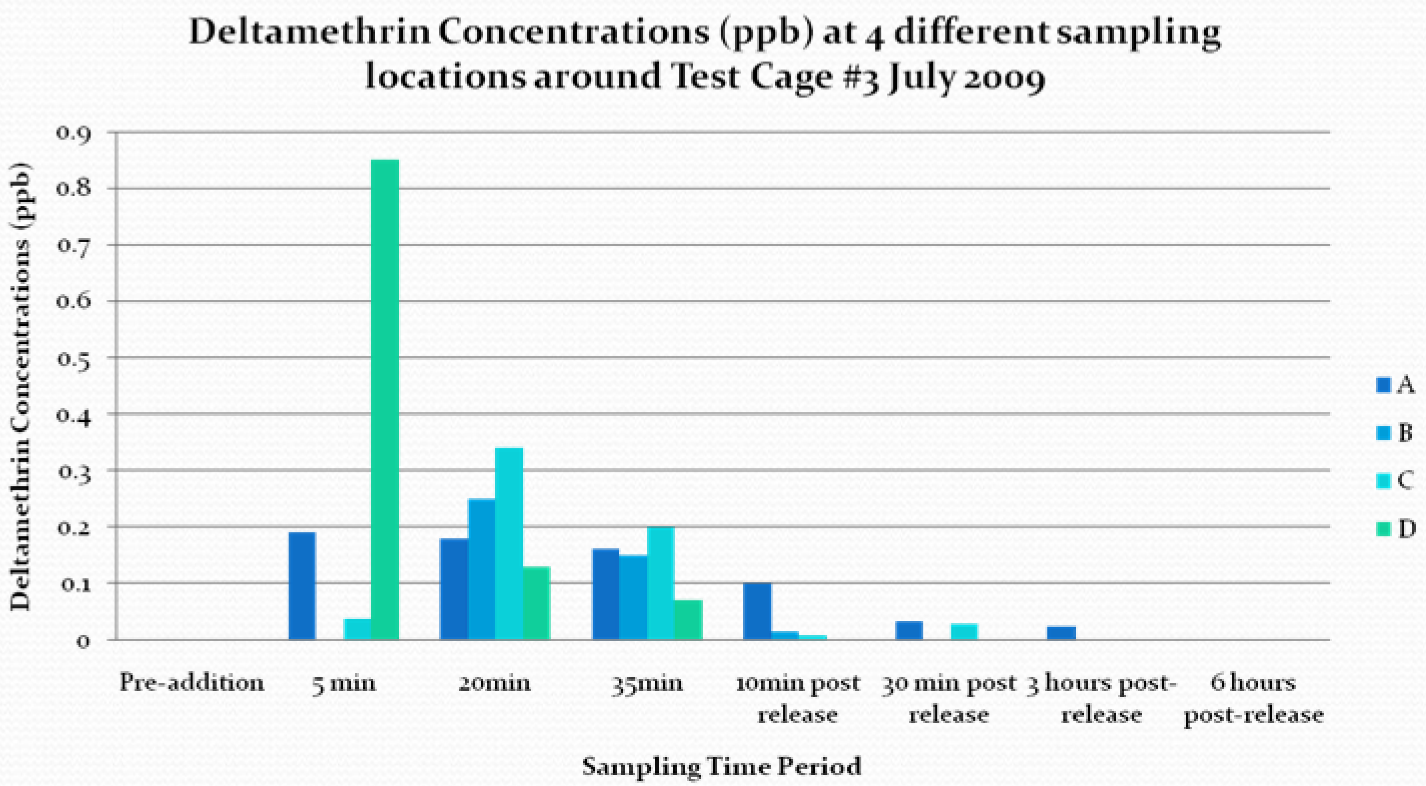

Deltamethrin Concentrations (ppb) at 4 different sampling locations around Test Cage #2 July 2009
Deltamethrin Concentration ppb
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pre-addition
5 min
20min
35min
10min post release
30 min post release
3 hours post-release
6 hours post-release
Sampling Time
A
B
C
D


Pre and Post Treatment Sea Lice Counts from Test Cage #2
Juy 2009
Average Number of Sea Lice
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
AM
AF
AMPA
CH34
Caligus
Sea Lice Life Stage
Pre-Treatment Lice Counts
Post-Treatment Lice Counts


Average Deltamethrin Concentrations for Test Cage #1
July 2009
Average Concentration of Deltamethrin (ppb)
0.6
0.5
0.4
0.3
0.2
0.1
0
Pre-addition
5 min
20min
35min
10min post release
30 min post release
3 hours post-release
6 hours post-release
Sampling Time Period


Deltamethrin Concentrations (ppb) at 4 different sampling locations around Test Cage #1 July 2009
Deltamethrin Concentrations (ppb)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pre-addition
5 min
20min
35min
10min post release
30 min post release
3 hours post-release
6 hours post-release
Sampling Time Period
A
B
C
D


Average Deltamethrin Concentrations for Test Cage #3
July 2009
Average Deltamethrin Concentration (ppb)
0.3
0.25
0.2
0.15
0.1
0.05
0
Pre-addition
5 min
20min
35min
10min post release
30 min post release
3 hours post-release
6 hours post-release
Sampling Time Period


Deltamethrin Concentrations (ppb) at 4 different sampling locations around Test Cage #3 July 2009
Deltamethrin Concentrations (ppb)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pre-addition
5 min
20min
35min
10min post release
30 min post release
3 hours post-release
6 hours post-release
Sampling Time Period
A
B
C
D


6C-4629
Brunswick

Where is the Active Deltamethrin?

- Hydrographics
  - Central vortices
  - Slipping below the tarp
- Bound to Organics
  - Net effect ....fouling organisms
  - Mucous from stressed fish
  - Fish uptake
  - TOC dissolved in Fundy waters

HUNTSMAN

Staggered Start
Pre and Post Sealice Counts
Spaghetti Tags
MS-222
20 Fish/Tank (600 g) - .4 m^3 water = 24 Kg/m^3
440 Fish

Tanks
2 @ 9 ppb no fish
4 @ 3ppb
6 @ 3ppb + 3 ppb after 20 min
6 @ 6ppb
6 @ 9ppb

Tx
20 Min
40 Min
} 72 Bottles

People
1 handling
1 MS-222
4 counting sealice
1 tagging
1 putting fish in tanks
1 recording

Product
3ppb in 16 tanks x .12 ml = 1.92 ml
6ppb in 6 tanks x .24 ml = 1.44 ml
9ppb in 8 tanks x .36 ml = 2.88 ml

Need
Flat Bed
X-actics
O_2

UNITED

Center vs cage edge effect

Dirty vs clean nets

Influence on neighboring cages

Slice vs Alphamax Cage 1

3ppb + 3 ppb Cage 9 → Cage 6, Cage 12

6ppb x 2 cages (1) clean → Cage 5

(1) dirty → Cage 11 → Cage 8, Cage 14

H_2O Samples x 3 Cages

TOC
3 Cages Pre & Post
@ 4 sites
Bio - 10 bottles
↓
DFO Manitoba

BOD
O_2- 10 bottles
SABS
↓
NBDAA Lab

Suspended Solids
10 hematocrit
or blood tubes
↓
NBDAA Lab

Deltamethrin
4 on perimeter/5 min = 32
1 in center/2 min = 20
X 3 cages = 156 samples
↓
RPC

MAN O WAR

Center vs cage edge effect

IMTA

3ppb + 3 ppb

6ppb

Influence on Downstream Cage

H_2O Samples

TOC
2 Cages Pre & Post
@ 4 sites
Bio - 8 bottles
↓
DFO Manitoba

BOD
O_2- 8 bottles
SABS
↓
NBDAA Lab

Suspended Solids
hematocrit
or blood tubes
↓
NBDAA Lab

Deltamethrin
4 on perimeter/5 min = 32
1 in center/2 min = 20
X 2 cages = 104 samples
↓
RPC

WATER COLLECTION ON EBBING TIDE

Deer Island
- Lords Cove
- Stewartown Wharf
- Leonardville
- Deer Island Pt.
- Fairhaven
- Northern Harbour - Lobster Pound

Upshore
- Saint John – Irving Park
- Lorneville
- Dipper Harbour
- Chance Harbour
- Boyne's Cove

Other
- Limekiln
- Reserve Cove
- St Andrews Wharf
- Bayside Wharf
- L'Etete Wharf

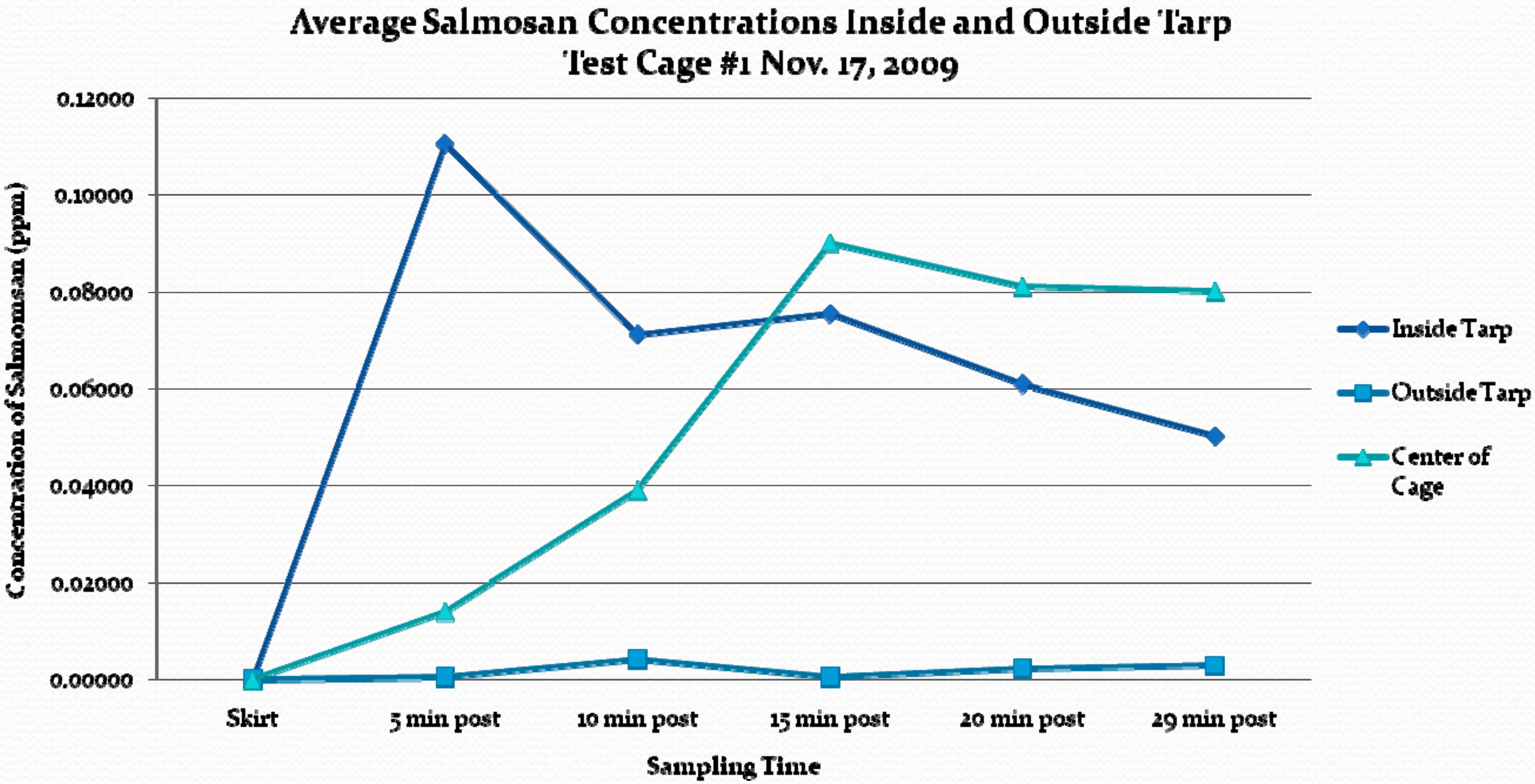
Collect 2 Liters of water per location

↓

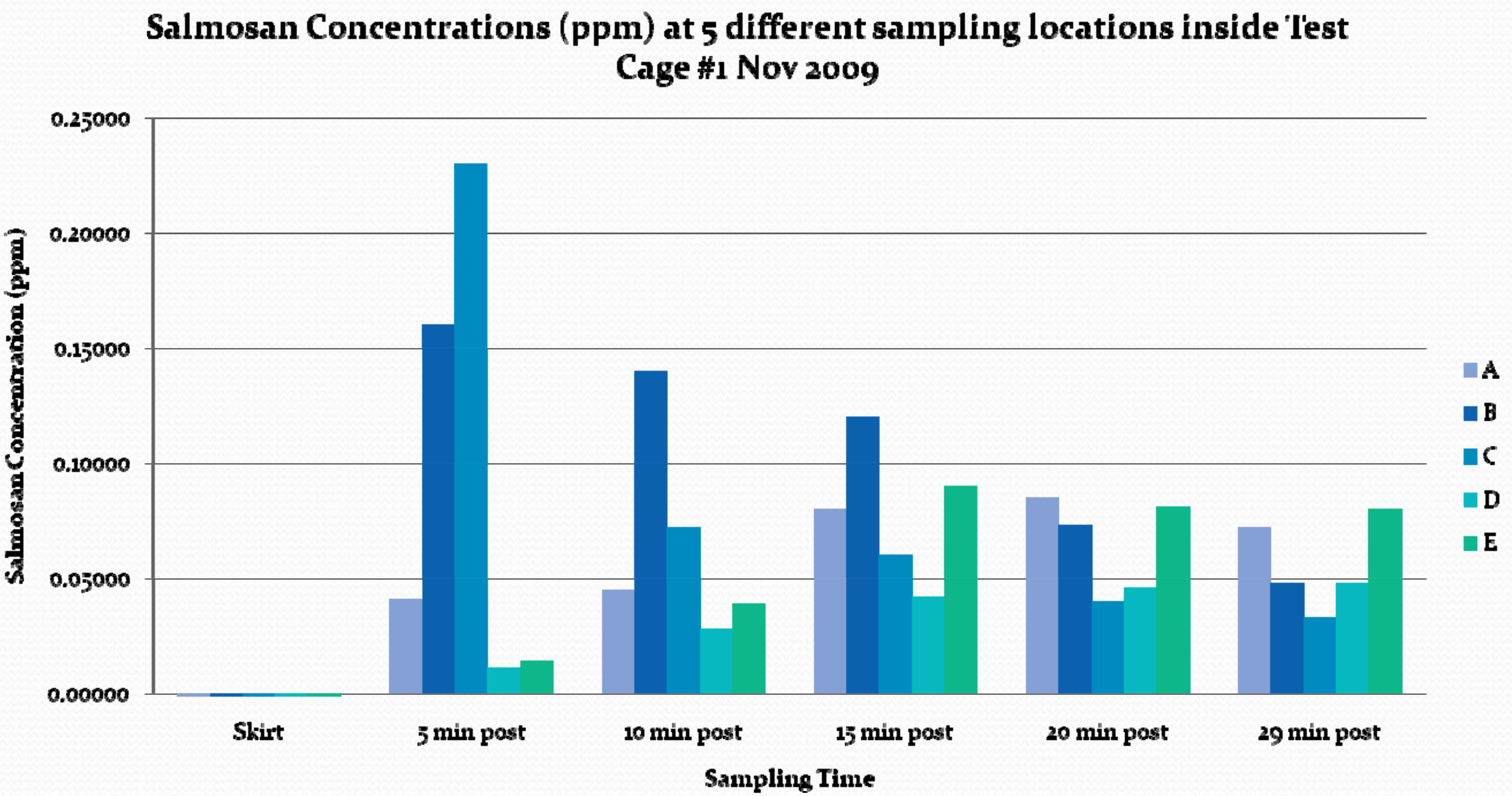
1 Liter – 6ppb Deltamethrin
500 ml – BOD
40 ml – TOC
250 ml – suspended solids

Bulk Turbidity

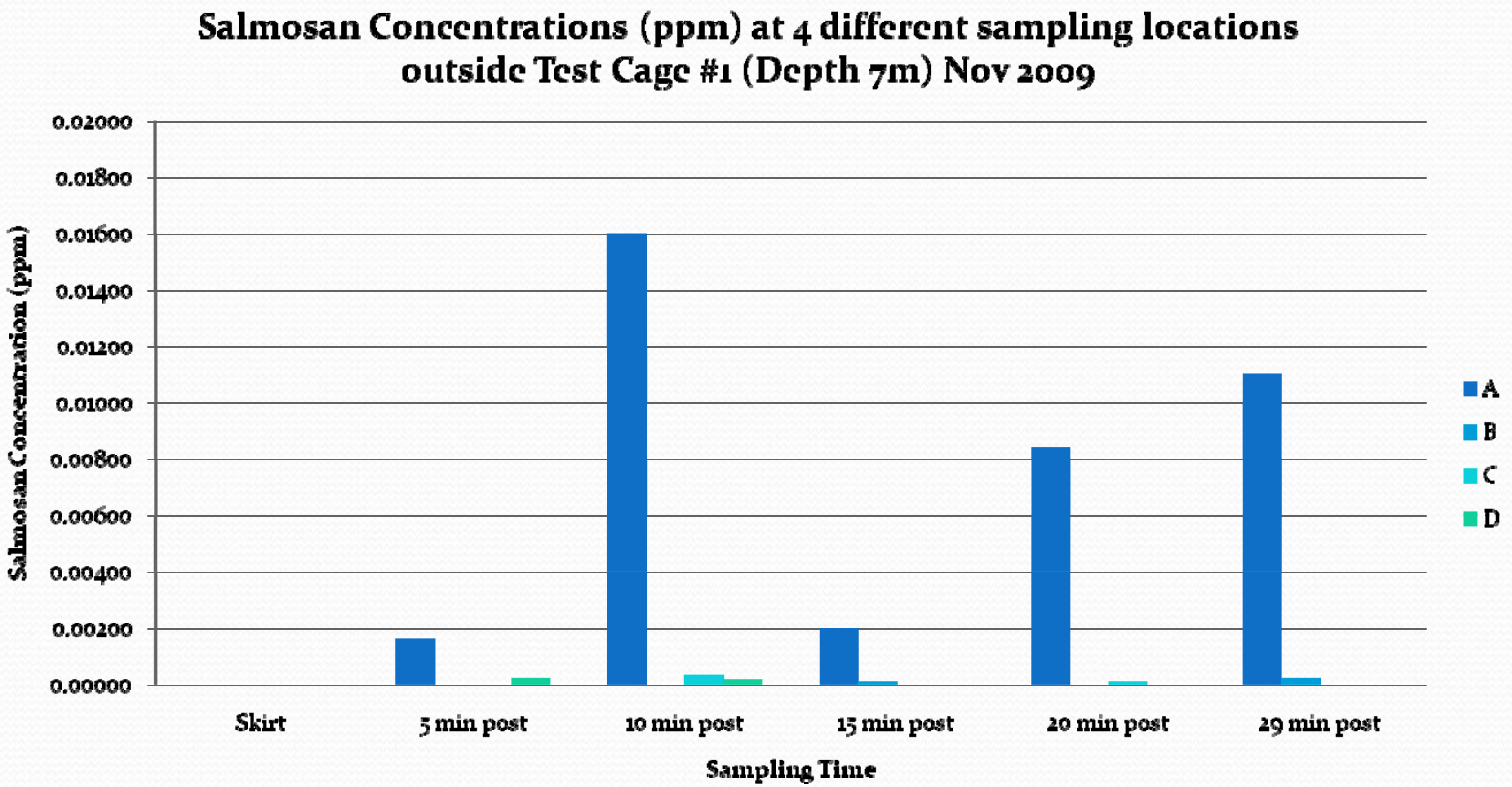
Salmosan Trial



Salmosan Trial



Salmosan Trial



R & D Requirements

- Regulatory / Risk Assessment
  - Fate post exposure
    - Dispersion
    - Dilution
    - Bio-concentration
    - Decomposition
  - Non-target organisms
    - Exposure
    - Duration
    - Effects
  - Occupational Exposure
- Max. efficacy & Min. Tolerance
  - Application
    - Tarp vs. skirt vs. well boat
    - Time to achieve target dose
    - Distribution within cage
  - Env. Factors
    - Water quality vs. efficacy
    - Non-target life cycles
    - hydrographics
  - Product Rotation

Integrated Pest Management

- Database ; required to track and redefine best mngt practices (SOP's for maximizing tx efficacy)
- Eco-Control
  - Monitor wild fisheries movement (reservoir)
  - Record length of fallow
    - Per Cage / Per site
    - Per BMA
  - Previous yr. clean-up? Lice counts
    - Success rate / Fish densities
    - Lice numbers going into winter
    - Water temps.

Integrated Pest Management

- Database ; required to track and redefine best mngt practices (SOP's for maximizing tx efficacy)
  - Product being used and its relative efficacy
    - Sea lice phase being targeted
    - Seasonality (high TOC levels)
    - Water temperature
    - Synergistic effects of tx in series (what product next? when?)
  - Delivery time for product
    - Pump size
    - Diameter of hose / number of perforations
    - Area covered during disperal

Integrated Pest Management

- Depth of seined fish
- Depth of skirts
- Size of cage
  - 15m, 70m pc, 100 pc, 150m pc
  - Tarped vs. skirt treatments

- Location of cage within grid
  - Hydrographic characteristics
  - Downstream effects ? (good or bad)
- Duration of treatment
  - 30 min – 60 min

Integrated Pest Management

- Feeding vs. non feeding of fish during tx
- Environmental conditions
  - Skirt movement
  - Oxygen levels
    - Water temp.
    - Plankton blooms
  - Lobster breeding grounds (juveniles) / fishing season
- IMTA
  - Mussel and algae harvest

Integrated Pest Management

- Sea Lice Counts
  - Education and Training to same level
  - SOP's for standardization
    - # of cages (random vs. pre-designed)
    - # of fish per cage
    - Frequency
- Bio-assays / Random Tx Analysis / Product Usage
  - Monitor for trends towards tolerance
  - Monitor for target dosage
  - Monitor for successful trends in series usage

Where do we go from here !

- Must engage all federal partners (EC Science)
  - Dedicated R&D funds with fewer strings ($'s spent)
- Must have tools in order to implement IPM Program
  - Salmosan, Excis
  - Alphamax at target dose
  - Calicide and other in feed treatments
- Must move towards "Green"
  - Containment
    - Tasmania
    - Swimming Pool

  Outside the box

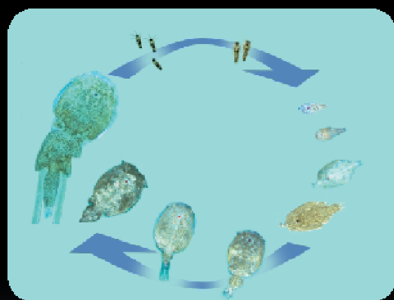
  Oxygen

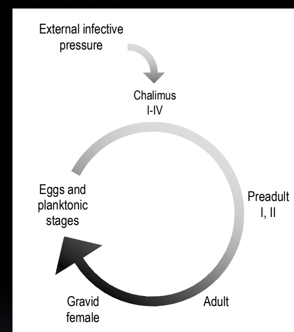
  Bio-Control (Bt)
- Vaccine Development

Partners

- AVC
  - Sea Lice Counts — Advice and guidance
  - Bio-Assays
- DFO SABS
  - Hydrographics — Cage Center Sampling
  - Sentinel Species — Advice and guidance
  - Lobster
- Health Canada
  - PMRA — 2 way communication
- EC Regional Science
- Industry

DATA TO SUPPORT DECISION MAKING: SEA LICE MODELLING





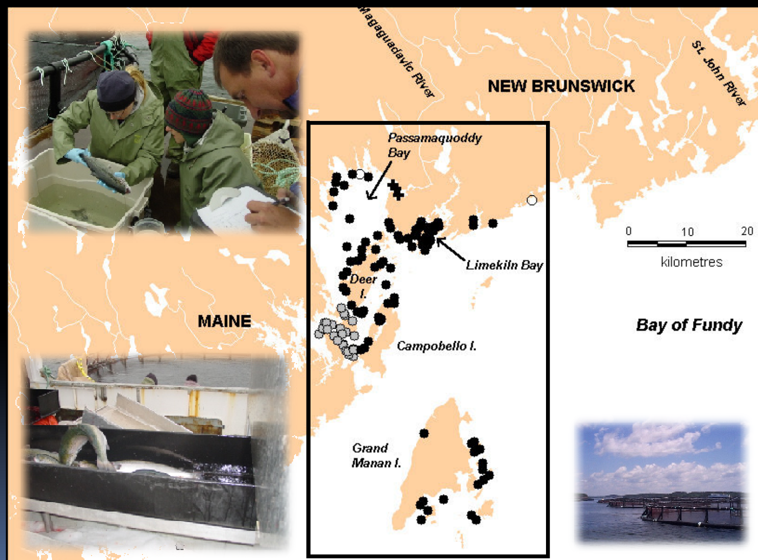
Crawford Revie
(Larry Hammell , Bernita Giffin, Chris Robbins & George Gettinby)

Centre for Aquatic Health Sciences (CAHS)
Atlantic Veterinary College
University of Prince Edward Island

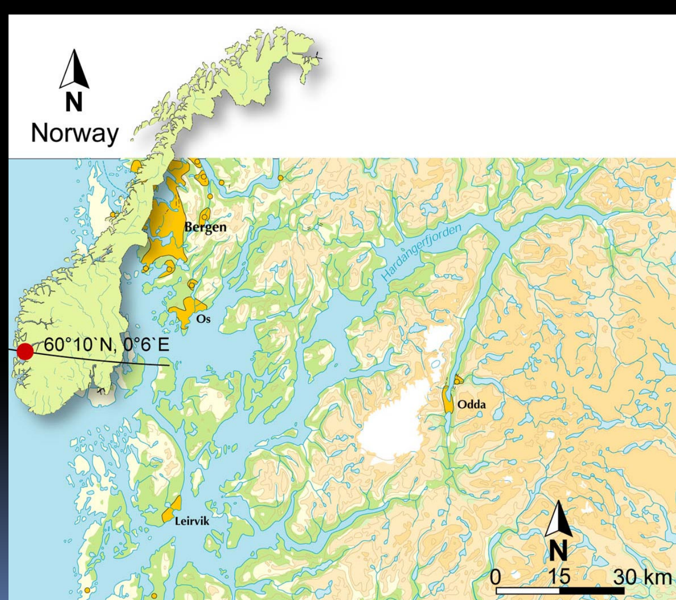
Data required for models

- Data on sea lice infestation levels
- Biological parameters (life stages / growth / etc)
- Environmental variables for importance
- Clinical data on treatment interventions
- A case study on ‘technology transfer’
  - Scottish sea lice model moved to Norwegian context

Sea lice infestation levels



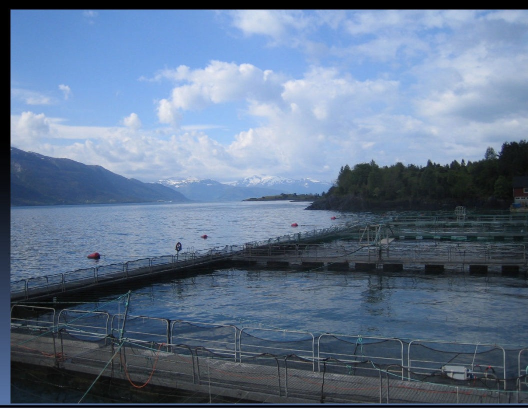
Sea lice infestation levels



Hardangerfjord

Around 150 km long, between 2-7 km wide

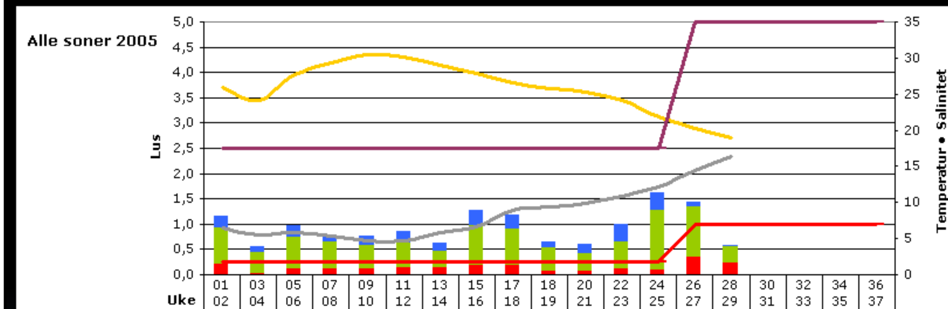
High salmon production for many years:
over 40 sites
c. 60,000 t/yr
c. 12 M fish stocked



Sea lice level estimation

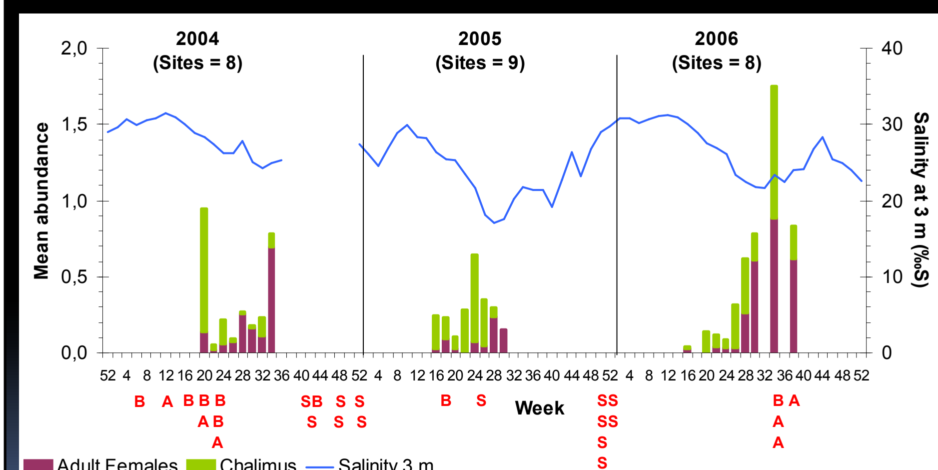
- Don't things vary greatly from site to site?
- What about changes thru time (seasons/years)?
- Can we really see trends / impacts?

Sea lice level estimation

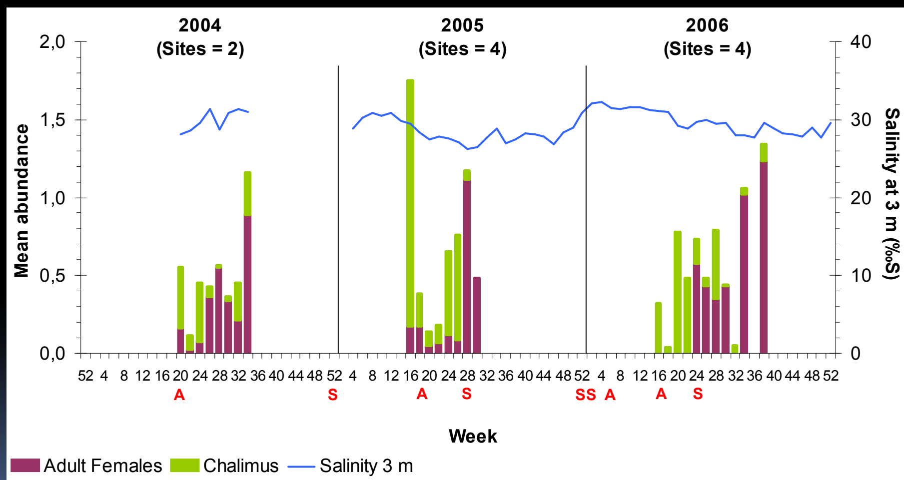


Uke	01 02	03 04	05 06	07 08	09 10	11 12	13 14	15 16	17 18	18 19	20 21	22 23	24 25	26 27	28 29	30 31	32 33	34 35	36 37
Fastsittende	0,22	0,11	0,23	0,13	0,18	0,21	0,16	0,29	0,28	0,11	0,17	0,36	0,37	0,08	0,03				
Bevegelige	0,73	0,42	0,62	0,52	0,46	0,50	0,33	0,79	0,70	0,47	0,36	0,53	1,17	1,00	0,33				
Voksne hoer	0,20	0,02	0,13	0,12	0,12	0,13	0,13	0,19	0,19	0,07	0,06	0,11	0,10	0,35	0,23				
Antall fisk undersøkt	880	620	1080	840	940	600	920	1120	960	1280	1260	1260	1240	1160	1120				
Salinitet (3m)	26,0	24,1	27,7	29,3	30,4	30,2	29,0	27,9	26,6	25,8	25,4	24,1	21,9	20,2	18,9				
Temperatur (3m)	6,5	5,5	5,9	5,4	4,6	4,7	5,8	6,7	8,8	9,5	9,9	10,9	12,1	14,5	16,3				
HFN grense tot.lus	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	5	5	5	5	5	5
HFN grense V. holus	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	1	1	1	1	1	1

Sea lice level estimation (Zone C)



Sea lice level estimation (Zone E)



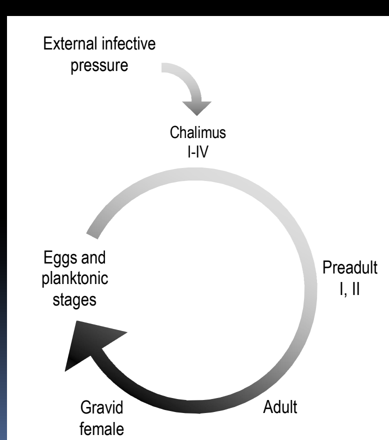
Sea lice level estimation

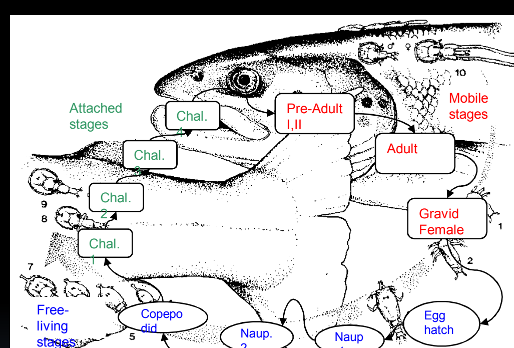
- ❑ Don't things vary greatly from site to site?
- ❑ What about changes thru time (seasons/years)?
- ❑ Can we really see trends / impacts?
  - ❑ YES – but you need to take care…
  - ❑ Key finding: the time (season) when fish were introduced to a site had a major impact on the subsequent pattern of lice infestation

Data required for models

- Data on sea lice infestation levels
- Biological parameters (life stages / growth / etc)
- Environmental variables for importance
- Clinical data on treatment interventions

Biological parameters





Parameters in models (an example)

$$\frac{dn_1(t)}{dt} = R_1(t) - R_1(t-\tau_1)e^{-b_1\tau_1} - b_1(t)n_1(t)$$

$$\frac{dn_2(t)}{dt} = \eta R_1(t-\tau_1)e^{-b_1\tau_1} - \eta R_1(t-\tau_1-\tau_2)e^{-b_1\tau_1-b_2\tau_2} - b_2(t)n_2(t)$$

$$\frac{dn_3(t)}{dt} = \eta R_1(t-\tau_1-\tau_2)e^{-b_1\tau_1-b_2\tau_2} - \eta R_1(t-\tau_1-\tau_2-\tau_3)e^{-b_1\tau_1-b_2\tau_2-b_3\tau_3} - b_3(t)n_3(t)$$

$$\frac{dn_4(t)}{dt} = \eta R_1(t-\tau_1-\tau_2-\tau_3)e^{-b_1\tau_1-b_2\tau_2-b_3\tau_3} - b_4(t)n_4(t)$$

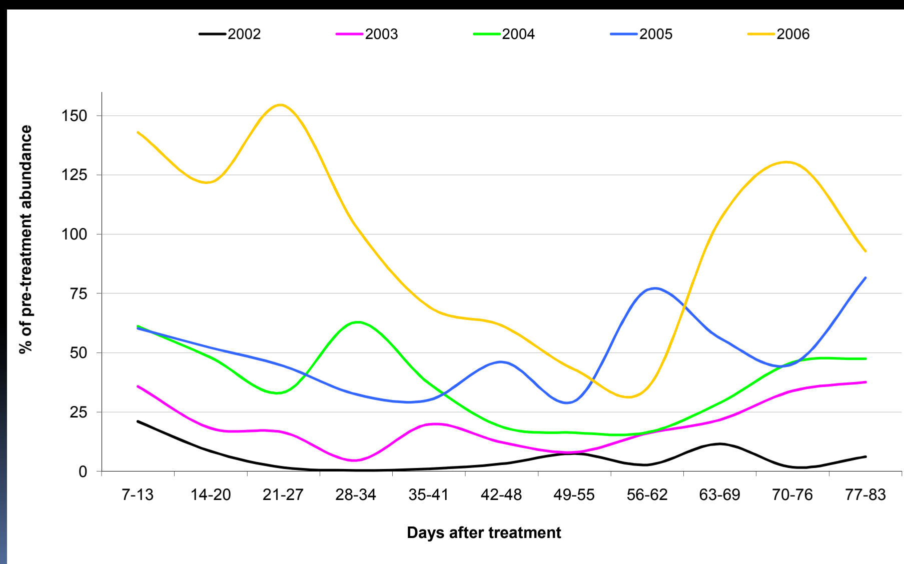
Stage	Time in Stage (days)	Description
Chalimus	15	
Pre-Adult 1,2	20	
Adult	10	
Gravid Female*	12	This represents the time taken for half the gravid females to die. An exponential reduction in population is assumed
Egg to Chalimus incubation time	20	

*Female fraction assumed to be 0.5

Clinical data for treatment efficacy

- Bath treatments: simple % knock-down (differs by stage?)
- In-feeds: not an instantaneous effect
- What about changes in efficacy?

Changes in SLICE™ efficacy (Scotland)



Using computer models

"All models are wrong but some are useful"

for:

- dealing with complexity and uncertainty
- making assumptions explicit
- exploring associations/mechanism (limits)
- sensitivity of model to changes across variables

Range of computer models

Sea lice represent one of the most well developed areas of modeling within aquaculture

- simple 'spreadsheet' models (e.g. Heuch & Mo, 2001)
- time series models (e.g. McKenzie et al, 2004)
- explore sampling implications (Revie et al, 2005)
- hydrodynamic and physical models (Asplin; Gillibrand, Amundrud, et al; Krkošek, Stucci, Foreman, et al)
- population dynamics (Norman; Stein, et al; Revie et al)

Data and Decisions

- Required for sea lice infestation patterns
- Needed to assess clinical efficacy
- How do we integrate lab and field data?
- What models are appropriate and where?
- Move away from 'database' to DSS
  - Data + Models + Knowledge (users)
  - capture/storage vs use/application
  - we plan to lead the way in NB

Thank you

Fisheries and Oceans Canada   Pêches et Océans Canada

Sea Lice movement/Hydrographics:

Influences on treatment decisions

Prepared by

F. Page, B. Chang, R. Losier, P. McCurdy
Fisheries and Oceans Canada, Biological Station, St. Andrews, NB

Help with B. Ernst, K. Doe et al. for past work
Environment Canada

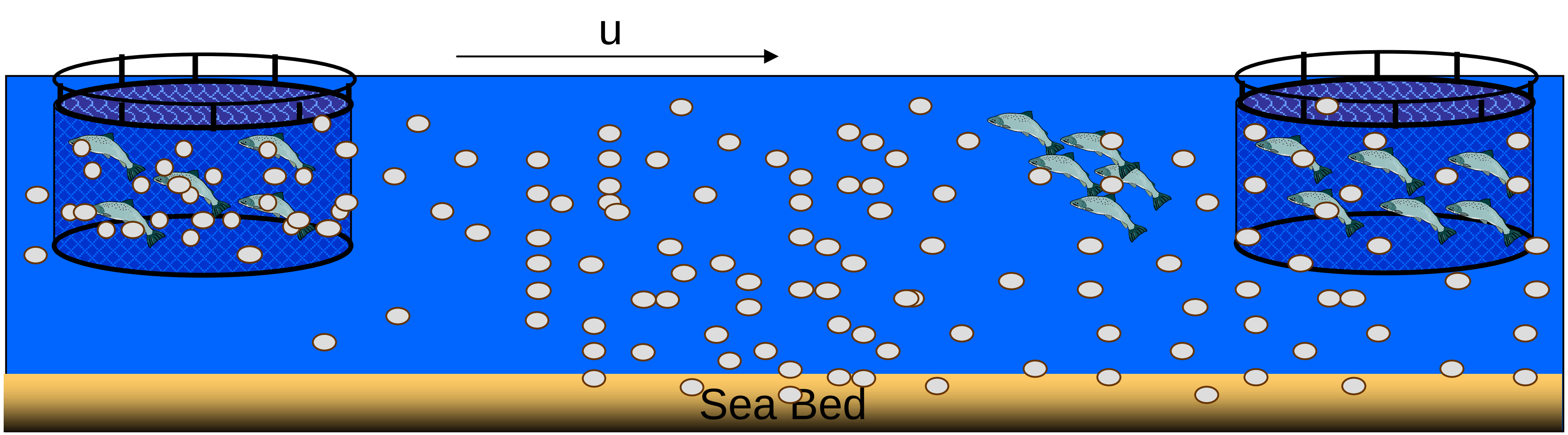
For

NBSGA's Sea Lice Research Development Workshop
St. Andrews, N.B., January 21, 2010

Canada

A Conceptualization of Lice and Theraputant Dispersal

Lice and/or Theraputant in Farm → Free-living Lice or Theraputant Dispersal → Interaction with other farms, Habitat and Wild Organisms

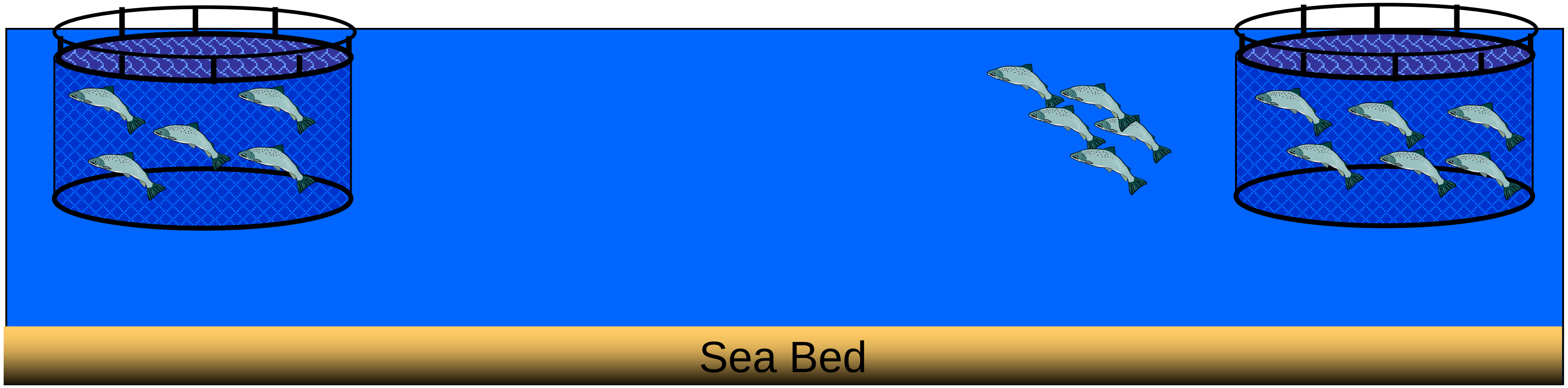


Release → Exposure → Consequence

Scenario: No Lice

<u>Ideal</u>: no lice on farms, no need for controls
no lice are released,
no substances are released,
no habitat is altered

NO RELEASE → ~~Exposure~~ → ~~Consequence~~

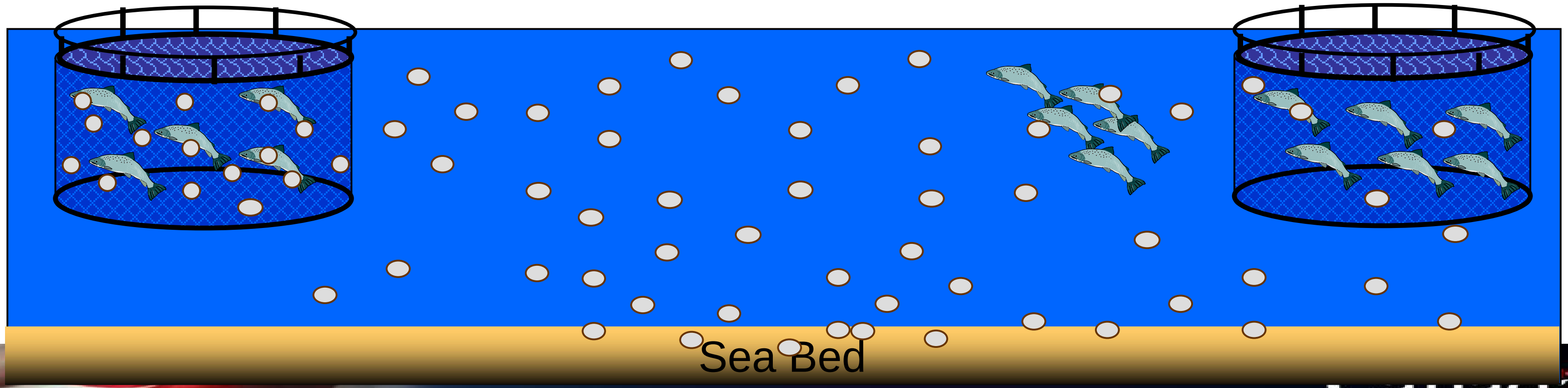


Scenario: Lice on Farms and Controlled

Realistic: lice on farms, abundance is controlled/managed
limited numbers of lice are released,
limited amounts of substances are released,
limited numbers of farms, organisms and habitats are exposed
limited consequence occur

Limited RELEASE → Limited Exposure → Limited Consequence

Lice
Control substances → **Transport, Dispersal**
Mortality, Decay → **Infection of other farms**
Negative Influence on non-targets

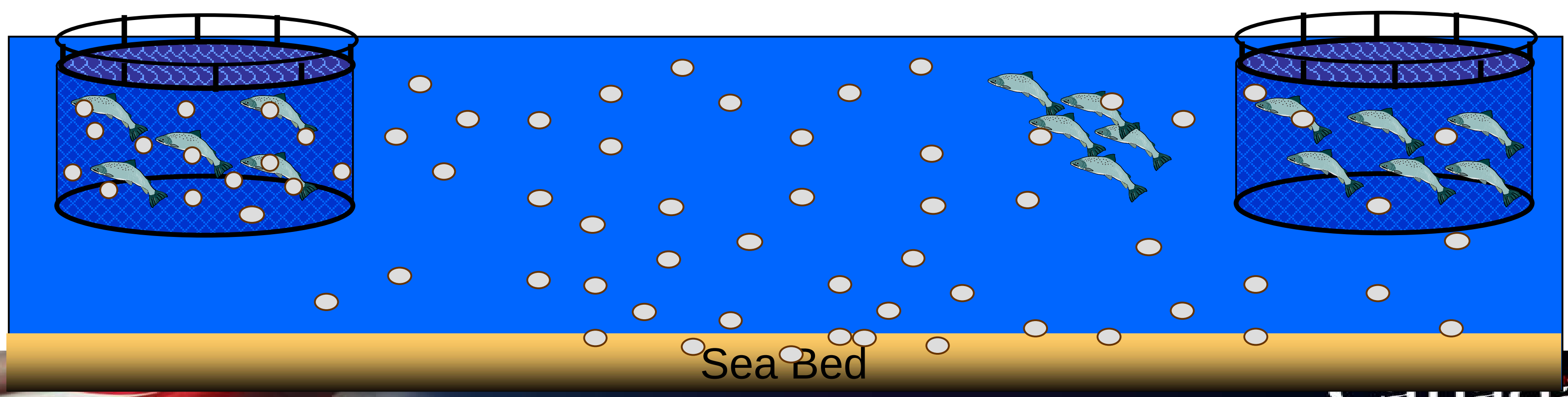


Scenario: Lice on Farms Uncontrolled

Crisis: lice abundance is uncontrolled/managed
large numbers of lice are released,
potential amounts of substances are released,
increased potential for exposure of farms, organisms and habitats
increased potential for consequences to occur

High RELEASE → Significant Exposures → Significant Consequences

Lice
Control substances → **Transport, Dispersal**
Mortality, Decay → **Infection of other farms**
Negative Influence on non-targets



Role of Oceanography

- Help estimate spread of lice
  - Useful for evaluating potential for primary controls to limit exposure of other farms to lice
    - Primary controls e.g. theraputants, lice traps, biological controls (e.g. mussel filtration)
    - Thermal conditions in relation to lice reproduction rates
  - Useful for helping to evaluate potential effectiveness of IPMP
    - E.g.treatment sequencing i.e. which farms treat first
  - Useful for evaluating secondary control sceanrios such as site operation (harvesting, stocking) and siting decisions (lice BMAs)

- Help estimate transport and dispersal of control products
  - Useful/Necessary for regulatory evaluations of control products
    - E.g.
      - PMRA ERs and full registration of pesticides
      - VDD and associated agencies EDRs and registration of drugs

Some Fundamental Questions:

How many lice are released to the environment?
How much control product are released?
Where and when do releases occur?

Sources and Releases

Where do the lice come from? Wild reservoir? Within farm?

Where do the free swimming lice stages go?
Where does the released control product go?
Can these be measured and modelled (i.e. predicted)?

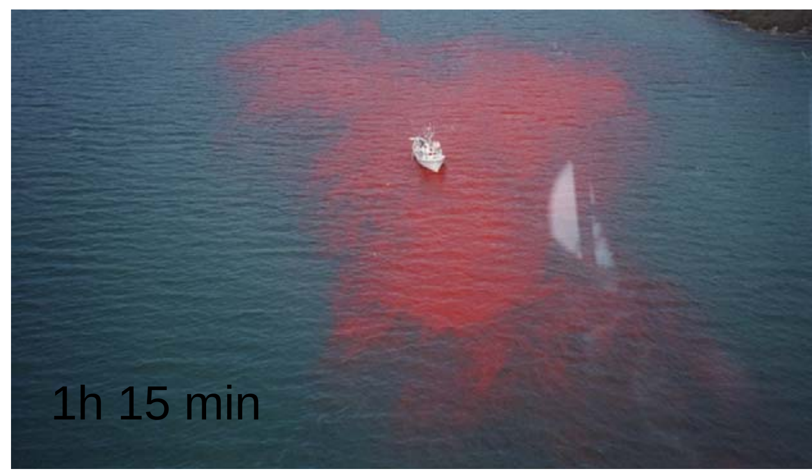
Exposures

Are source farms re-infected?
Are neighbour farms infected?
Are wild organisms affected? (e.g.wild salmon)
What are the consequence thresholds?
i.e. Are the consequences tolerable or acceptable?
economically?, socially?, legally?

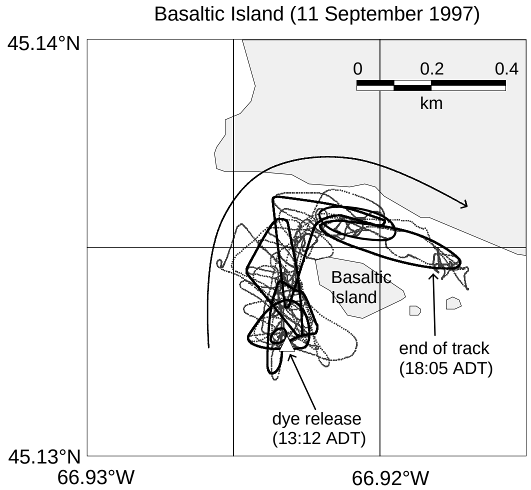
Consequences

What Do we Know?

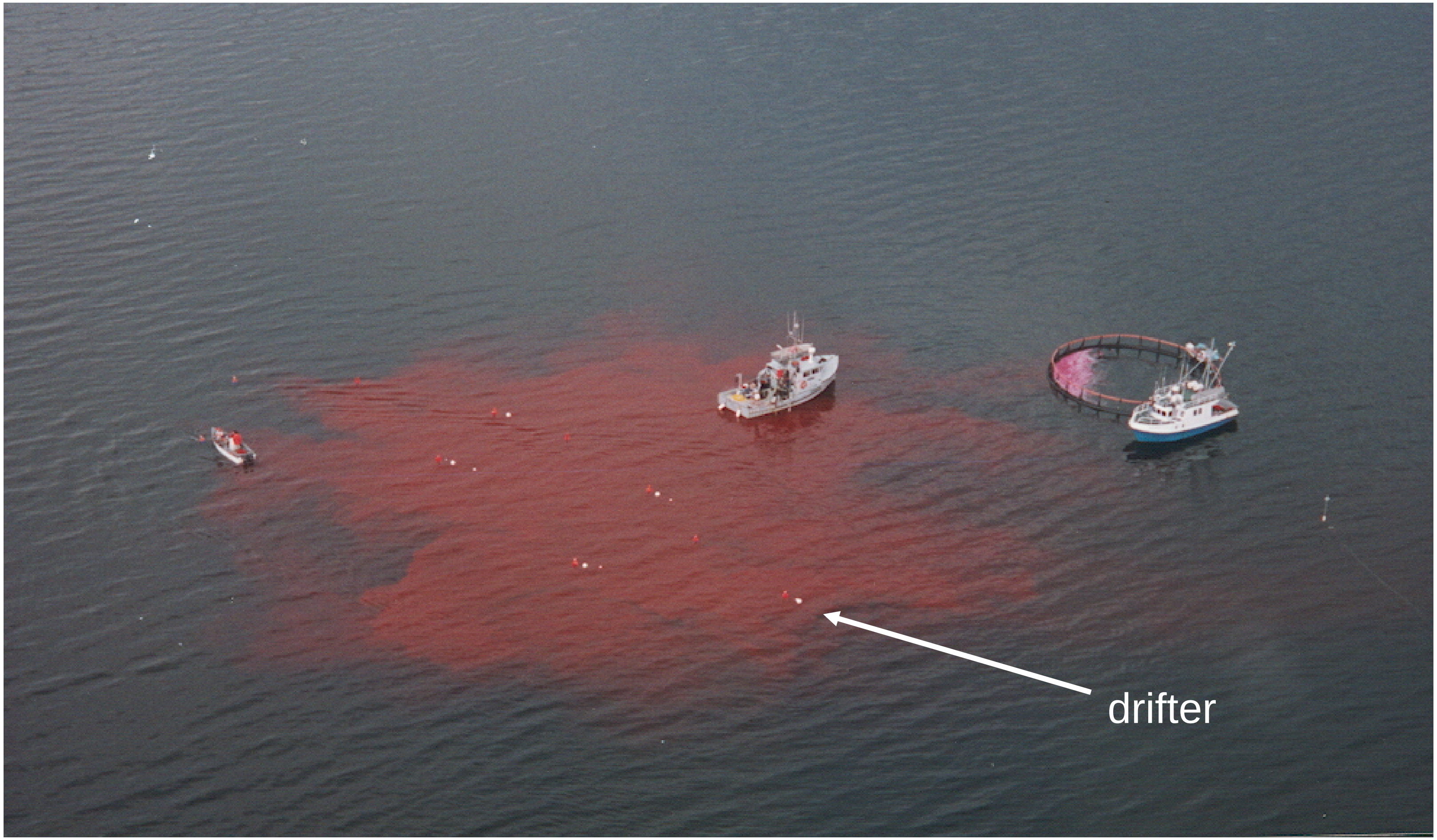
Spread of A Patch: A look from above



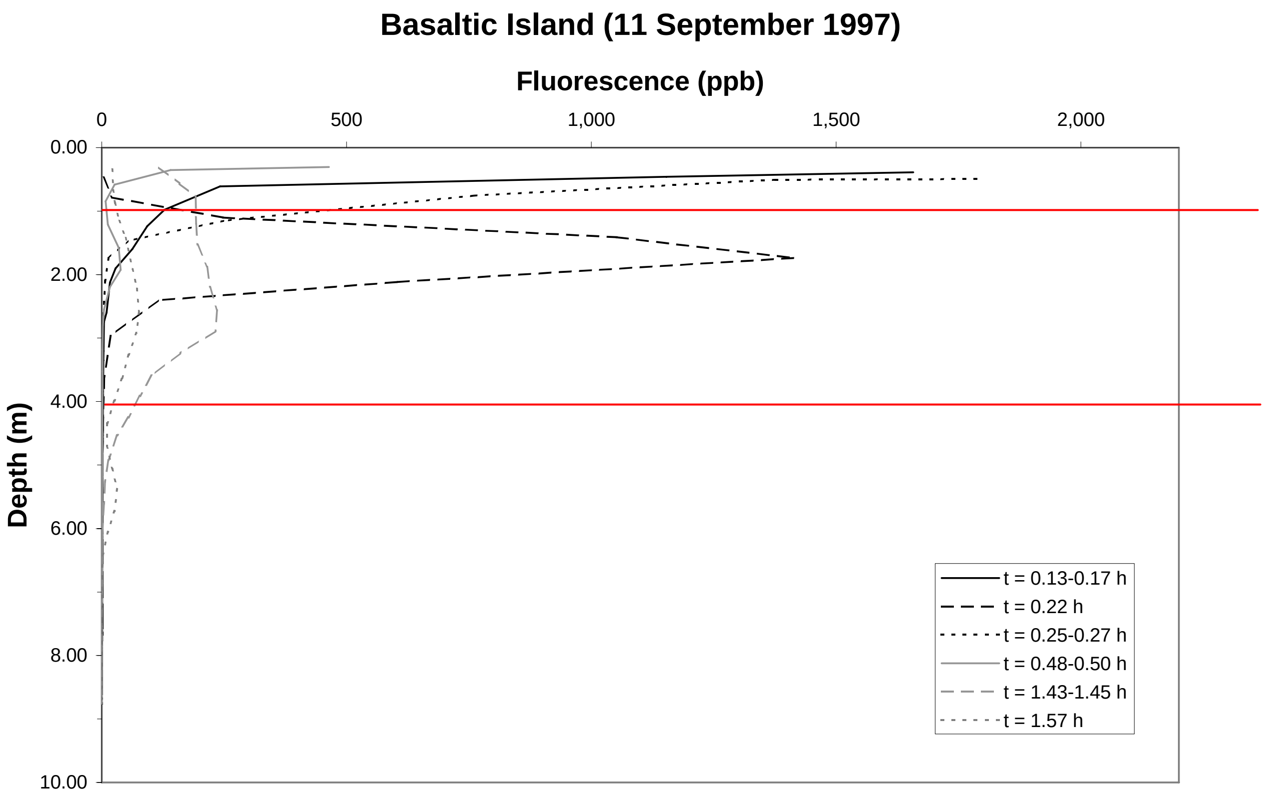
Spread of Patch: A look from above



Spread of Patch: follow with dye and drifters

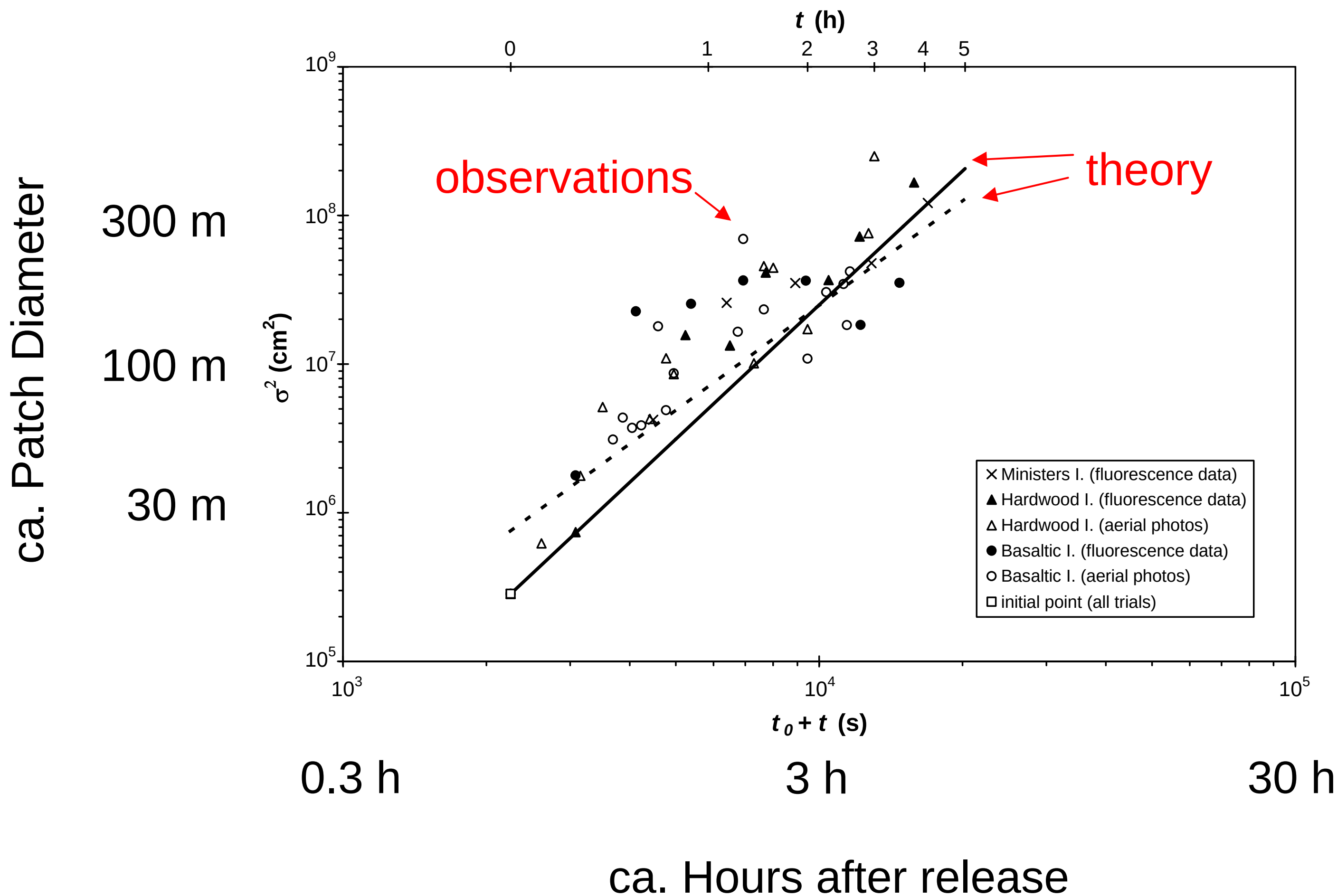


Dye Dispersal: Vertical Profiles



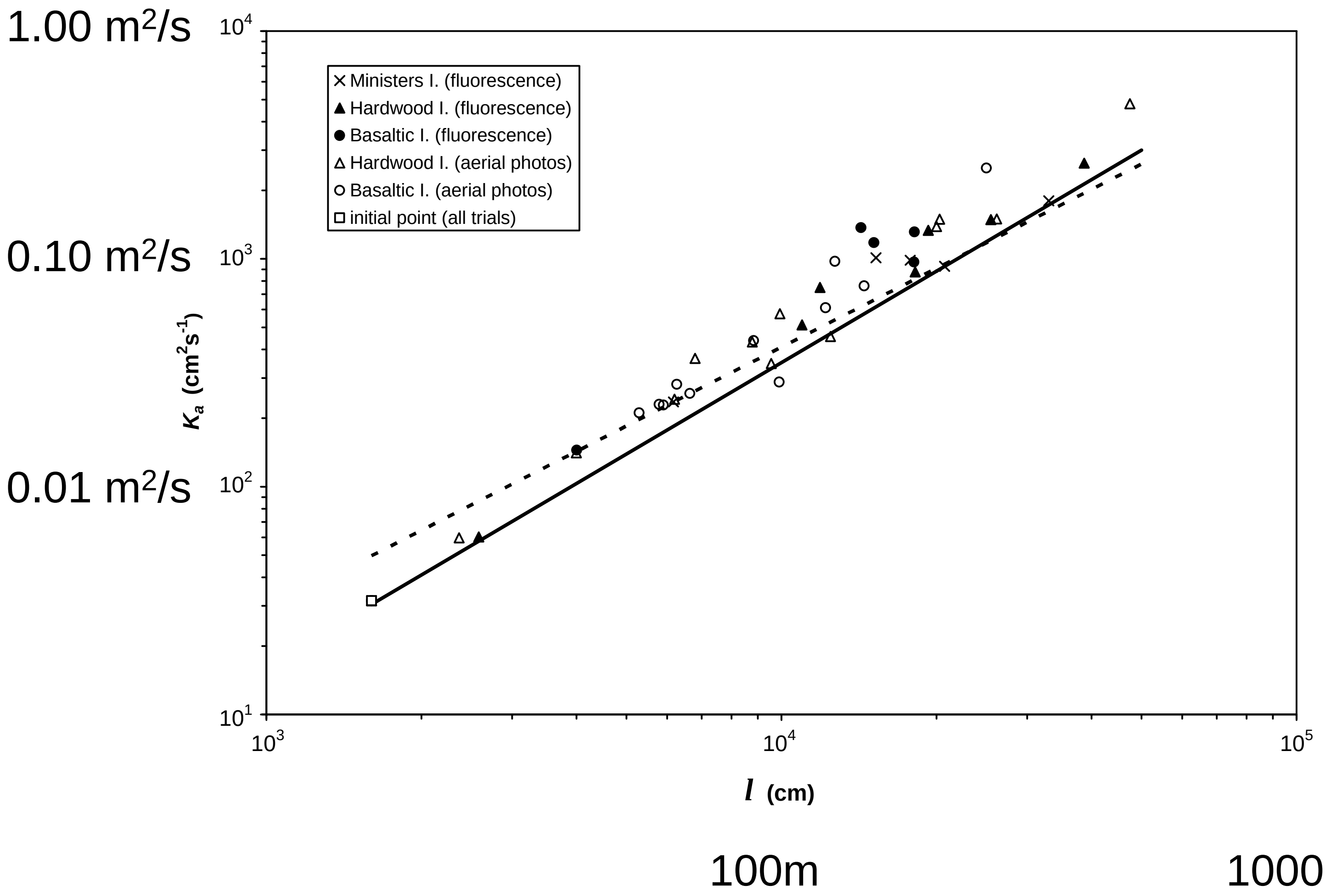
- dye initially in upper 1m initially
- dye mixed to 4m within 1.5 h
- mixing rate varies with location, degree of vertical stratification, current speed and bottom depth

Dye Patch Scale vs time in SWNB



- observations in general agreement with the Okubo theory
- considerable variation in observations at any one time

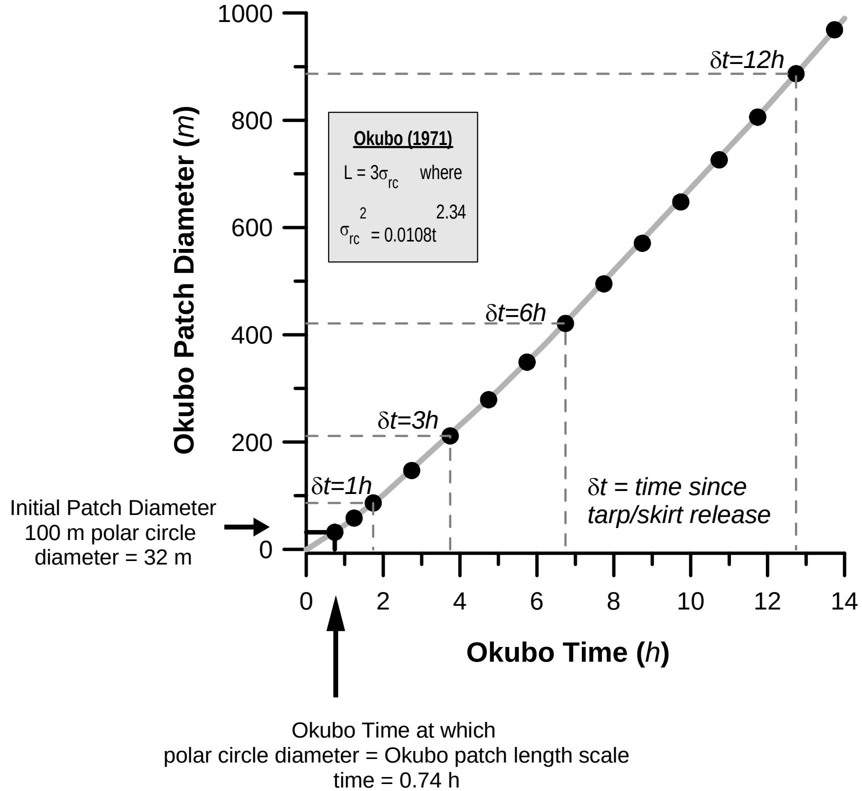
Horizontal Eddy Diffusion Rates in SWNB



- Data from dye release studies
- dye patches followed for about 6h
- Note K at any length scale can vary by almost a factor of 10

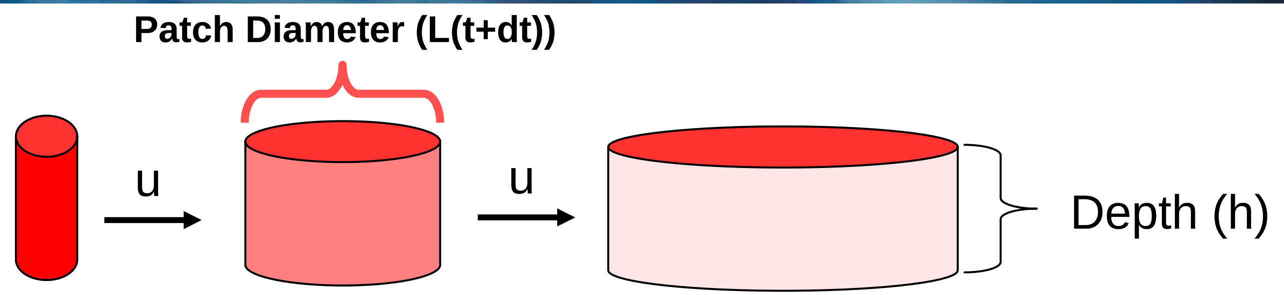
What can we Infer with some Back of the Envelope Calculations

Application to Sea Lice and Theraputants: Patch Diameter

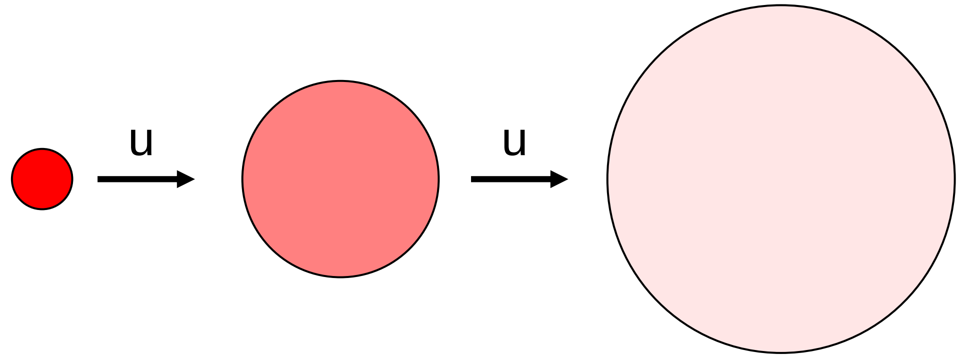


Area of Patch increases with time

Simple representation of patch drift and dispersal



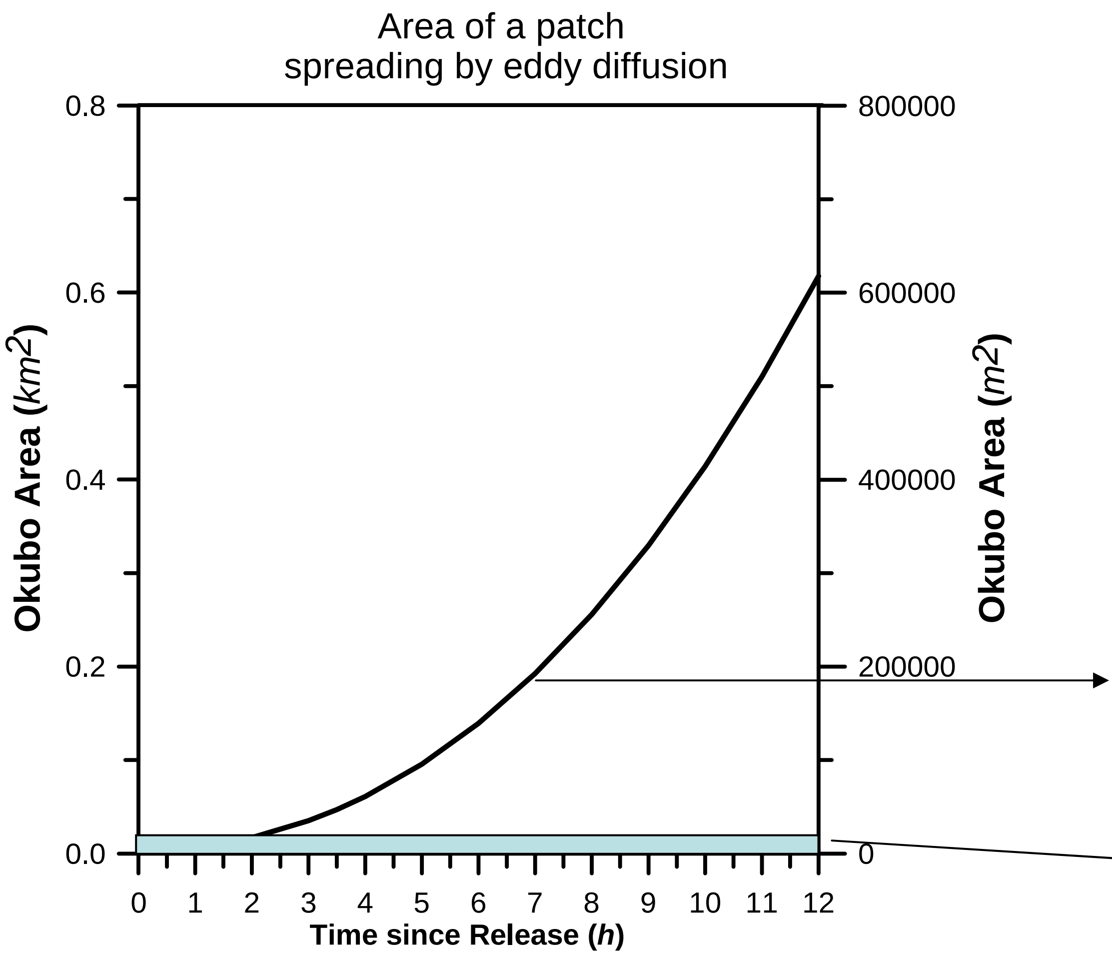
Patch Area



Area of patch

$$A = 3.14*(0.5L_{Okubo}(t+dt))^2$$

Area of Patch increases with time



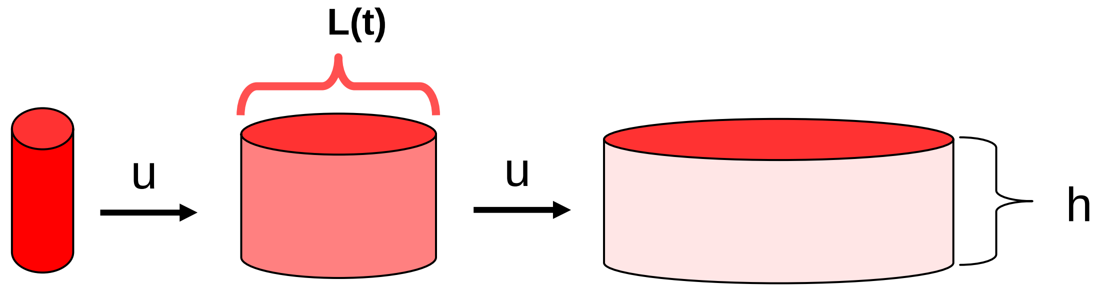
- area of a Passamaquoddy Bay ~10km^2
- area of 10 patches after 5 h of dispersing is similar to the area of St. Andrews harbour, Lime kiln Bay or Beaver harbour ~ 1-2 km^2

- ~ area of a Katy's Cove

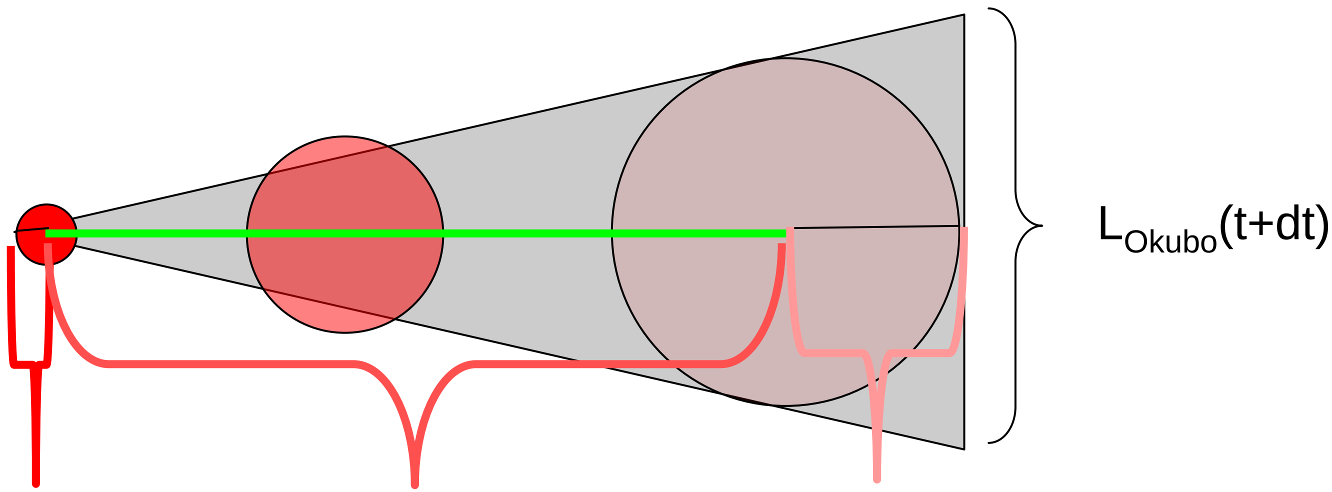
- area of a 100m polar circle cage is ~800 m^2
- area of a farm 20 cages is 16000 m^2

Application: Area Swept or Area Exposed

Simple representation of patch drift and dispersal



Swept Area or Area exposed



$0.5L_{cage}$ at t_o + $L_{adv} = u \times t$ + $0.5L_{Okubo}(t_o + dt)$ = L_T

Area Swept by patch from time t to t+dt is approximately

$A_{swept} = 0.5\ L_T \times L_{Okubo}(t+dt)$

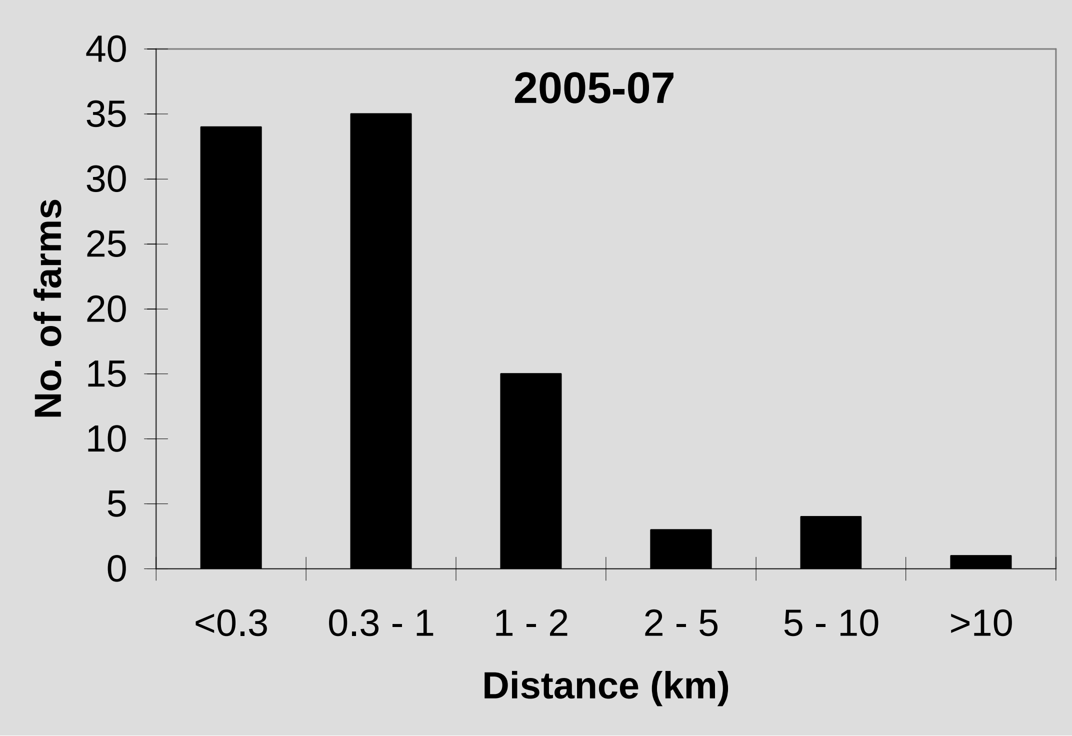
Estimations of Area Swept or Area Exposed

Cage Radius (m)	Water Velocity (m/s)	Time at Large (h)	Advection Length Scale (m)	Patch Diameter at Time dt (m)	Swept Area by Time dt (m^2 (km^2))
DIFFUSION ONLY - NO ADVECTION					
15	0	1	0	86	5,866 (0.01)
15	0	6	0	421	139,257 (0.14)
15	0	12.5	0	927	675,848 (0.68)
DIFFUSION and ADVECTION					
15	0.1	1	360	86	18,000 (0.02)
15	0.1	6	2160	421	500,000 (0.5)
15	0.1	12.5	4500	927	2,300,000 (2.31)

- **the swept area of 5 patches after 1 tidal cycle similar to the area of Passamaquoddy Bay ~10km^2**
- **the area of 1 patch after 12h or 2 patches after 6 h is similar to the area of St. Andrews harbour, Lime kiln Bay or Beaver harbour ~ 1-2 km^2**

Advection length scale vs farm separation

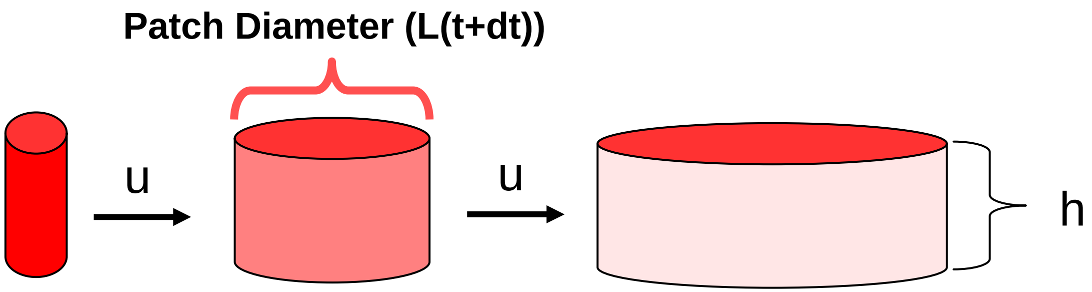
Water Velocity (m/s)	Time at Large (h)	Advection Length Scale (m)	Patch Diameter at Time dt (m)
DIFFUSION ONLY - NO ADVECTION			
0	1	0	86
0	6	0	421
0	12.5	0	927
DIFFUSION and ADVECTION			
0.1	1	360	86
0.1	6	2160	421
0.1	12.5	4500	927



- > 30% of farms within 6 h eddy diffusion length scale
- > 65% of farms within a 6 h advection length scale
- > 90% of farms within 12.5 h advection length scale

Okubo based Dilution Rate

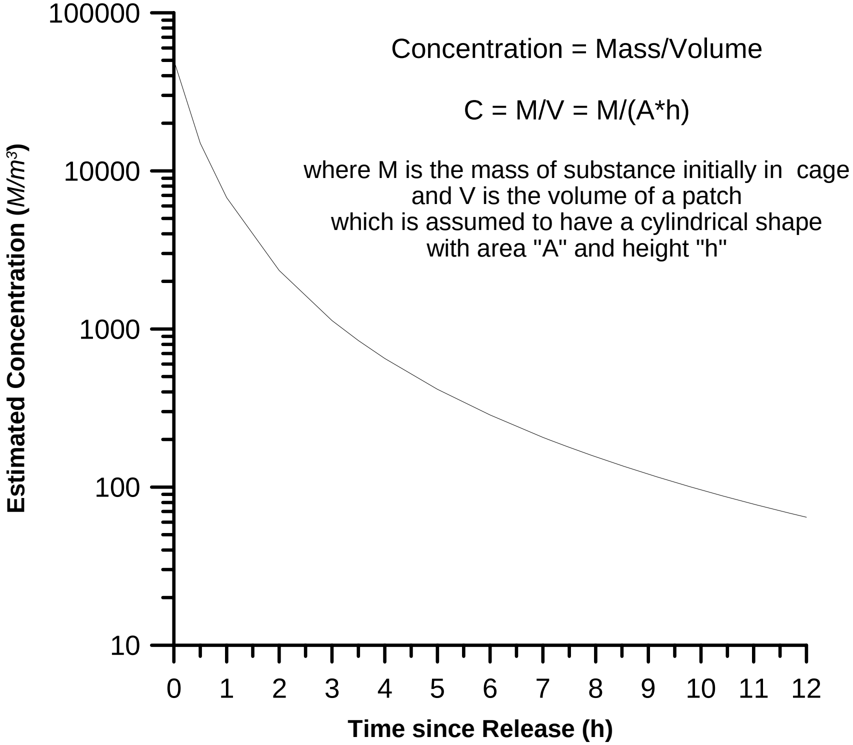
Simple representation of patch drift and dispersal

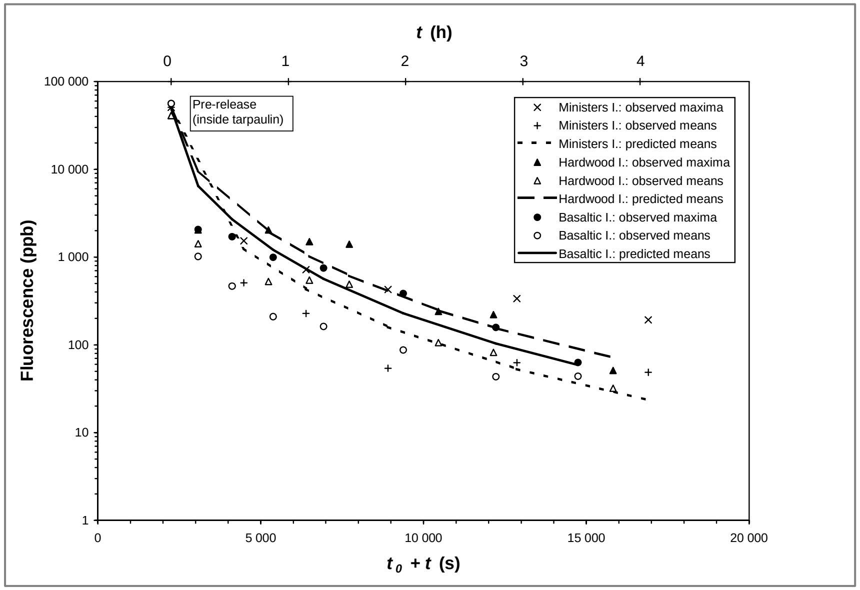


Concentration (t) = Mass at t0 / Volume(t)

where Volume = Patch Area*Patch depth

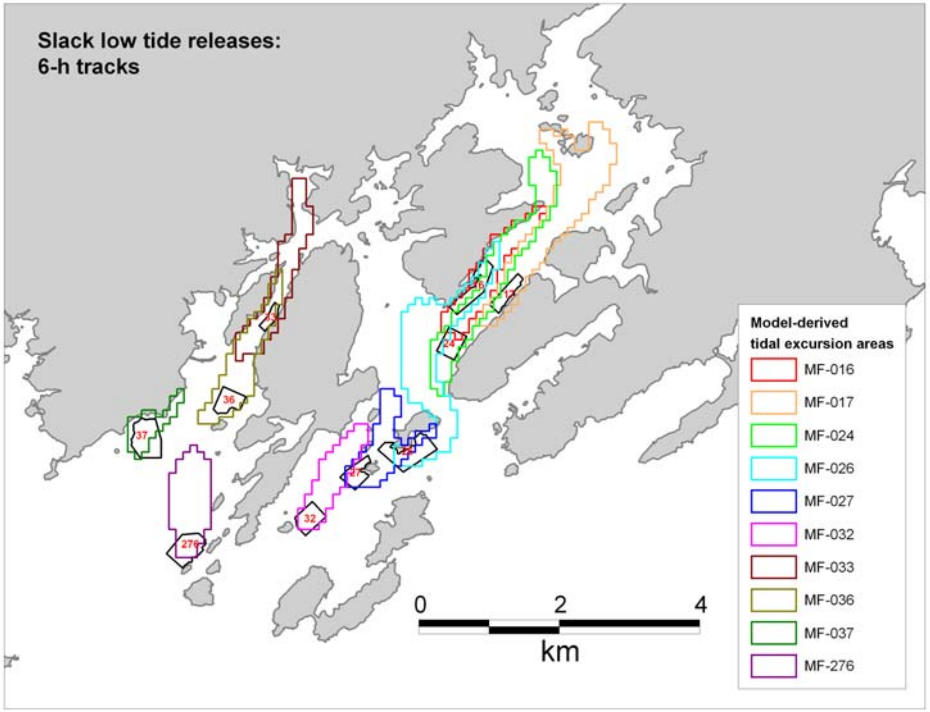
Okubo based Dilution Rate



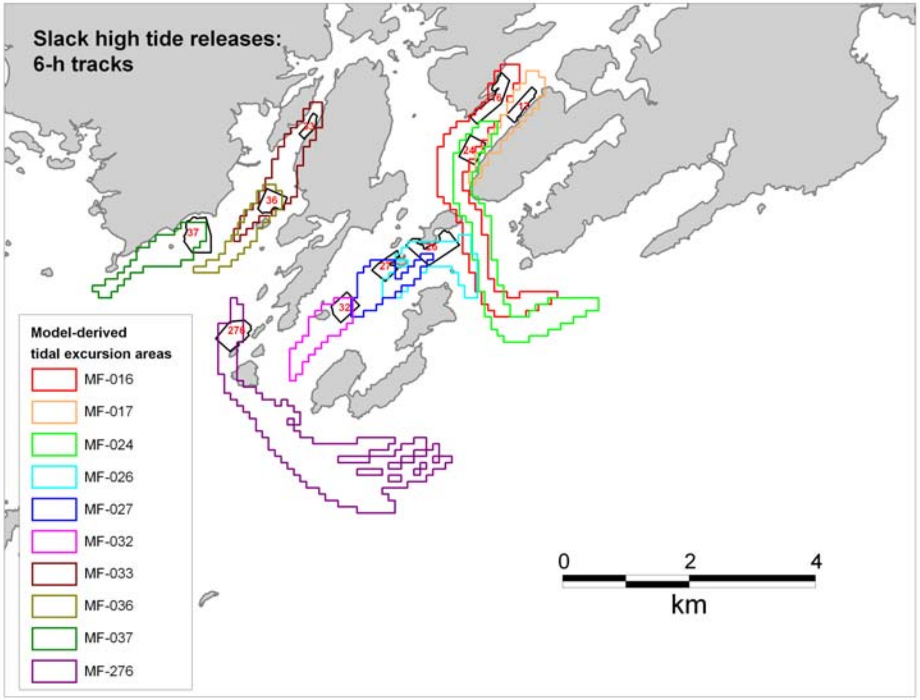


- 2-3 orders of magnitude dilution in ~3-5 h
- impact depends on the toxicology

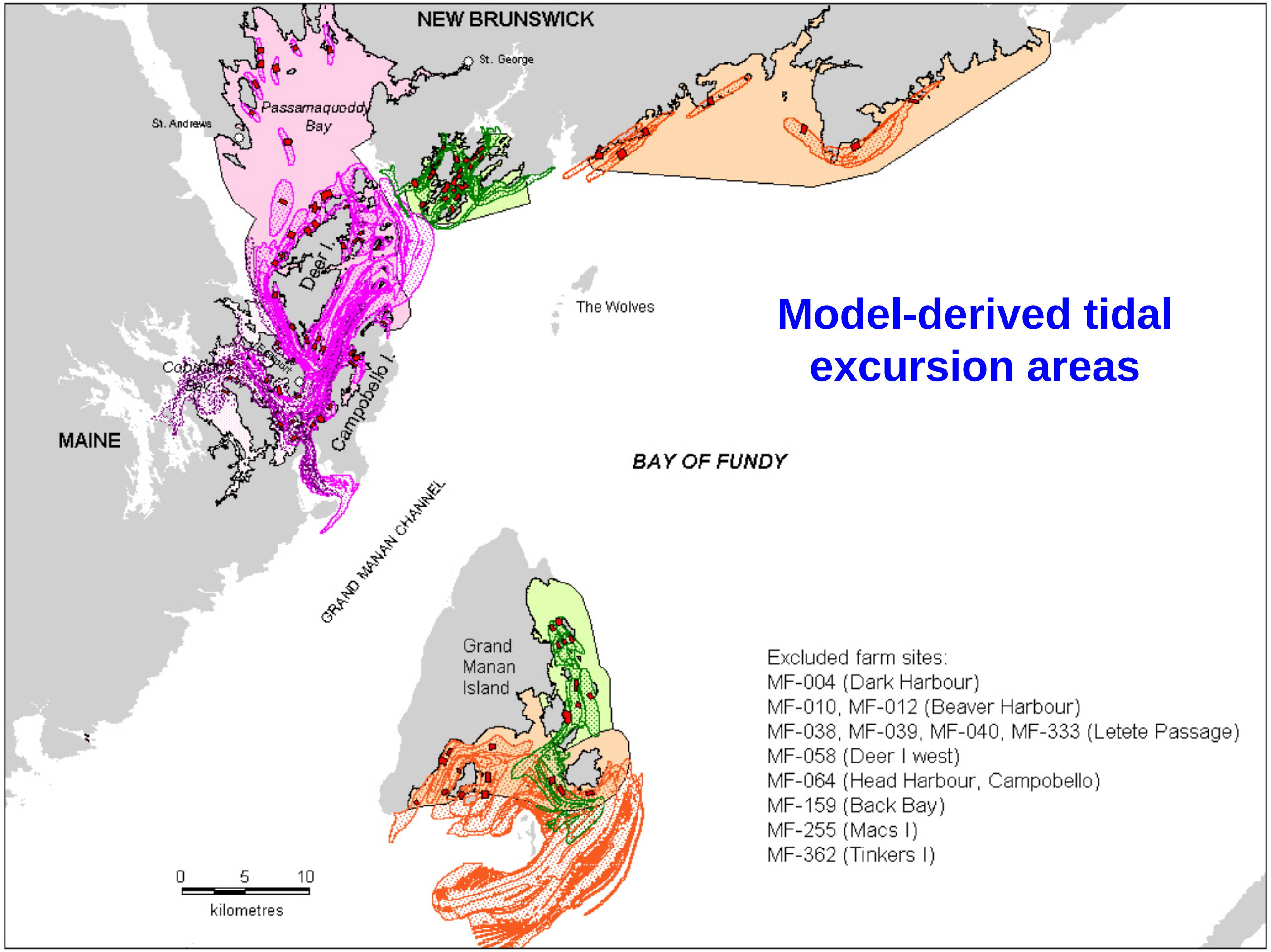
Modelling: 6 h exposure zones



- model suggests length scales of advection on scale of km



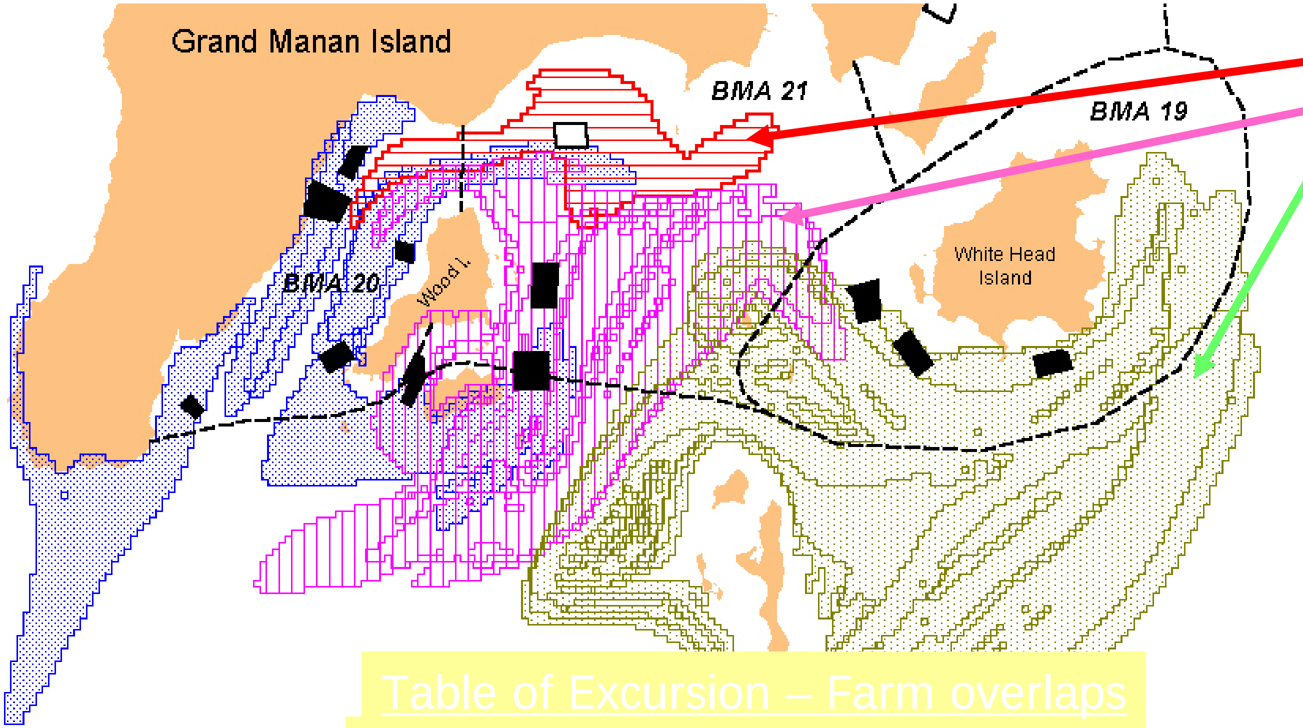
Modelling: 12.5 h exposure zones



- existing Model for ISAv
- can modify for sea lice dispersal as done in BC
- can modify for therapeutant transport and dispersal

Fisheries and Oceans Canada   Pêches et Océans Canada

Modelling: exposure contacts



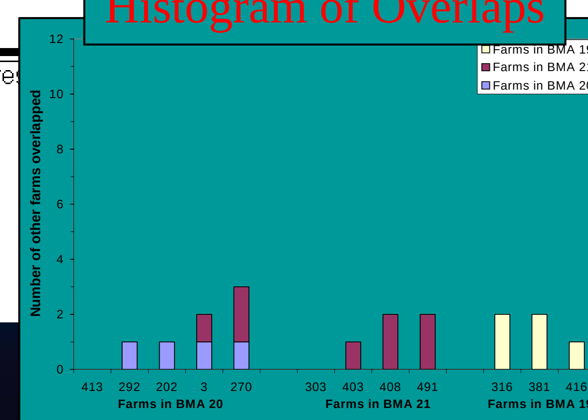
Excursion Plumes

- one per farm
- colours indicate farms within designated BMAs
- obvious overlaps between individual plumes and farms and farms in difference BMAs; therefore BMAs not effective
- new BMA boundaries have been established

Table of Excursion – Farm overlaps

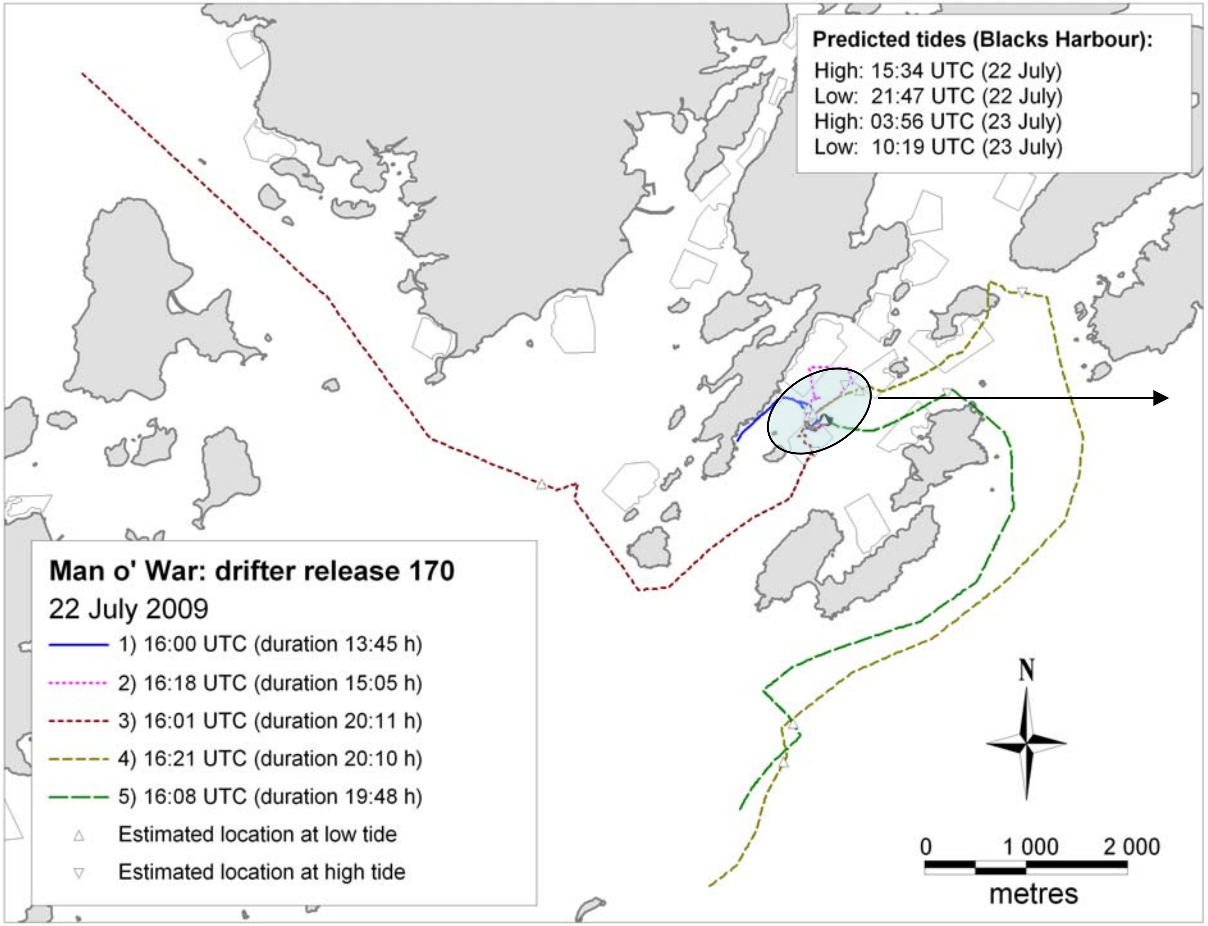
Overlaps for farms operating in 2001		Originating farm of tidal excursion area										
		202	292	003	270	413	303	403	408	491	316	381
Receiving farm site	202	●	●									
	292	●	●									
	003			●	●							
	270			●	●							
	413					●						
	303						●					
	403							●	●	●		
	408				●			●	●	●		
	491				●					●		
	316										●	●
	381										●	●

Histogram of Overlaps



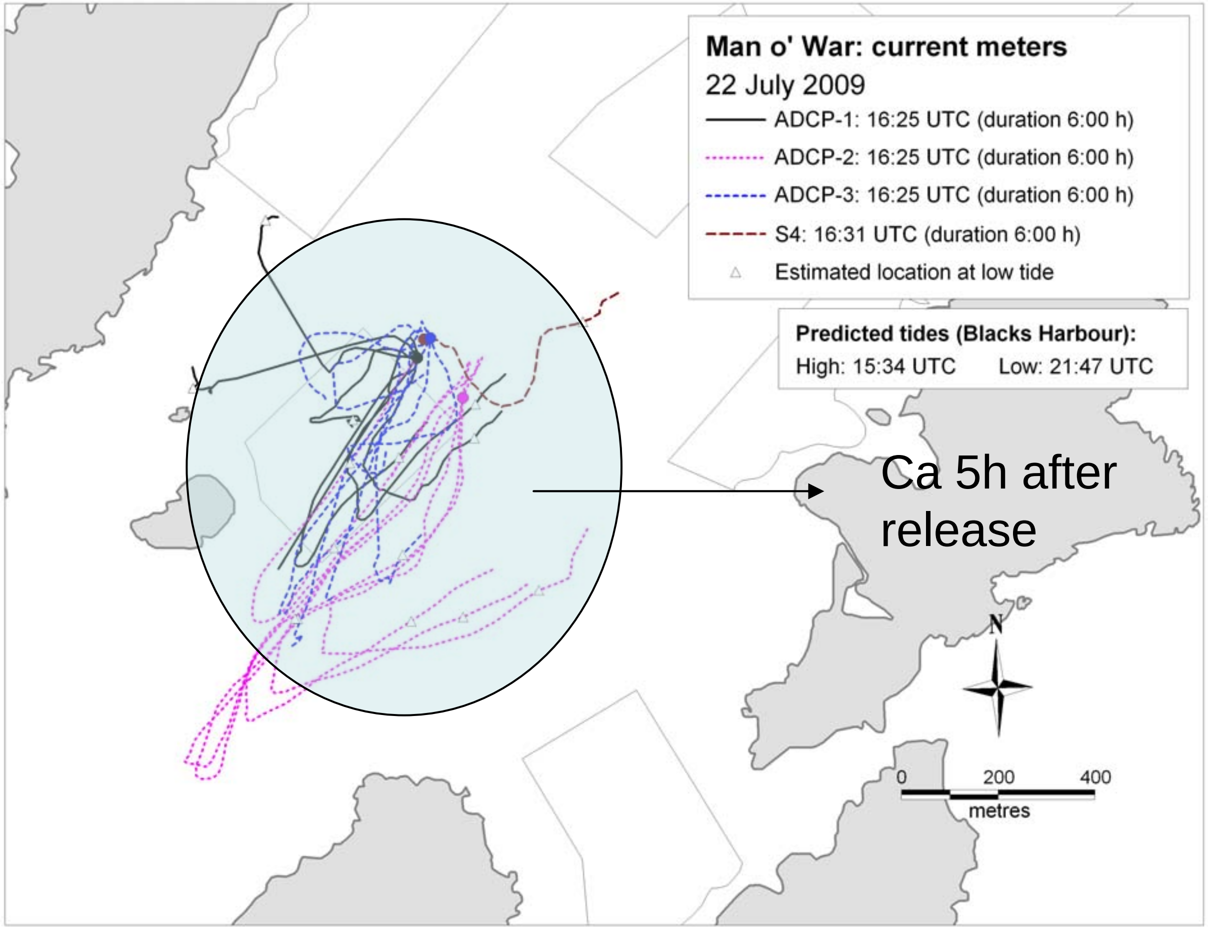
Recent Work
i.e. summer – fall 2010
alphamax treatments

Drifter results summer 2009



Ca 5h after release

Drifter results summer 2009



- magnitude of dispersal similar between drifters and CMs
- directionality different

Summary of the Issue

- We have governing equations
- We have some empirical tools and methods to estimate drift and dispersal
- Drifters and dye give similar results
- There is some variation in directionality between current meter and dye/drifter observations – probably due to small scale spatial variation in currents
- We have analytical mathematical solutions or models to simple situations
- We have numerical methods and models for solving more complex situations
  - these need to be customized to the lice and theraputant issues
  - they need to be customized the solutions to local conditions and circumstances
  - The circulation models should encorporate a wider range of flow conditions
    - Tides, spring-neaps, winds, etc.
- The models are relatively simple
- The models and observations are similar in terms of scale of transport and dispersal
- We need to utilize the solutions in ways that are practically useful to development of lice control strategies and day-to-day lice management control practices

Summary

- there is a suggestion of a strong potential for exchange of pelagic free swimming lice stages between farms
    - hence, it may be beneficial for IPMP to take exchange potentials into consideration when deciding which farms should be treated and when

- there is a suggestion of a strong potential for relatively large areas (1-10s km^2) to be exposed to bath treatment theraputant patches within a few hours after release
    - concentration of the theraputants is likely to be diluted by 100-1000x within a few hours after release
        - dilution rates at specific times and places vary considerably

- should work on improving understanding of near field current regime

Some Research Themes

Potential Research Areas

- **Develop transport and dispersal models for lice and theraputants**
  - **Rationale**: movement of the pelagic stages of lice and chemicals released into the water controlled to a greater or lesser extent by water movements, current patterns vary on small spatial scales (10-100sm) and it is not practical to simultaneously measure the currents over a broad geographic areas; models enable transport and dispersal scenarios to be evaluated; PMRA needs for regulatory evaluations.
  - Actions:
    - Develop a suite of models that range from simple (BOTECs, analytical, spatially homogeneous; e.g. DEPOMOD like) to complex (numerical, spatial and temporally variable; eg.FVCOM)
  - **Characterization of horizontal and vertical dispersion rates**
    - **Rationale**: these rates are fundamental to estimating the dilution rate of chemicals released into the water
    - **Actions**:
      - release and monitor the temporal evolution of the locations of drifters
      - measure the level of water turbulence
      - release and monitor the spatial and temporal evolution of patches of dye or chemicals
  - **Improve characterization of near field (i.e. within and near farm) flow fields**
- **Flushing rates and time scales for specific geographic areas?**
    - **Rationale**: these rates are fundamental to estimating the accumulation of chemicals and lice in areas
    - **Actions**: Run models

Potential Research Areas

- **Characterization of sea lice sources**
  - **Rationale**: parameterizes the location, abundance and duration of lice releases into the water
  - **Action**:
    - Time series of counts of gravid females and their eggs from fish farms
    - Identification of natural lice reservoirs

- **Empirical Characterization of the distribution and abundance of pelagic and settled sea lice stages**
  - **Rationale**: Useful for assessing model accuracy
  - **Action**:
    - plankton surveys

- **Characterization of lice biology (e.g. stage durations and settlement preferences)**
  - **Rationale**: assessment of lice transport and dispersal requires definition of the duration of the pelagic life stages and the behaviour of the pelagic lice i.e. are they passive or active and if active does this over ride the physics influences on movement
  - **Action**:
    - Literature searches and experimental work

Potential Research Needs:

- **Characterization of chemical exposure scenarios swept areas, frequency and duration of exposures**
  - **Rationale**: essential for regulatory assessment of environmental impacts
  - **Action**:
    - develop specific model outputs and conduct specific model calculations and runs
    - summarize results in terms of maps and contact tables; similar to ISAv work
    - Make results available to risk assessment teams

- **Identify the research products that contribute to decision making!**
  - **What level of sophistication is needed?**
  - **What specific outputs are useful?**
    - **Eg. exchange potentials, theraputant concentgration-time profiles**
    - **For evaluaiton or development of IPM strategies**